SYSTEM DYNAMICS MODELLING FOR HUMAN RESOURCE PLANNING

By

Izidean Musbah Aburawi

A thesis submitted in partial fulfilment of the requirements of
Sheffield Hallam University
For the degree of Doctor of Philosophy

November 2005

STATEMEMENT OF AUTHENTICATION

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not presented this material, either in whole or in part, for a degree at this or any other institution.

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ABSTRACT

The research undertaken in this thesis concerns the application of system dynamics to the field of Human Resource Planning (HRP). Human resource planning has been defined as the process whereby a company develops and deploys the right staff at the right places, at the right times to fulfil both organization and individual objectives. In this process staff are recruited and trained before they can contribute to an organisation's goals. Recruitment and training of new staff needs to be carefully planned to prevent staff shortages or staff surpluses.

Such planning, in turn, very often makes use of models, and the aim of this research is to show that the application of system dynamics can be used to produce effective models for use in human resource planning. The models developed build on the Inventory and Order Based Production Control Systems (IOBPCS) work of Towill (1982) and extend the work of Hafeez (2000), who applied these IOBPCS ideas to skill pool modelling in human resource management. The models developed in this thesis provide companies with the means of producing optimum HRP strategies. In total four new models are developed: SKPM (basic Skill Pool Model), APSKPM (Automated Pipeline Skill Pool Model), APSKPM+(P+I), (Automated Pipeline Skill Pool Model plus Proportional and Integral controller), and a PPSKPM (Progression and Promotion Skill Pool Model).

In each case the models are developed in terms of control parameters that relate to aspects of the human resource planning process that can be controlled by the human resource manager or decision maker. Using computer simulation the dynamic behaviour of the human resource systems represented by the models is determined over time for any given set of control parameters. By varying the parameters in a systematic way optimal models are produced to aid the decision maker. Any set of parameters represents an HRP strategy and, by using simulation, system dynamics can be seen to furnish optimal human resource planning policies for the decision maker.

In the thesis the models are systematically tested with real data relating to the Libyan petrochemical industry. Data from two case companies are used in this testing. The case-company testing demonstrates that system dynamics can be used to create effective models for use in human resource planning and shows also the same relationship between control parameters that was found in the work of Towill and Hafeez.

ACKNOWLEDGMENTS

I am indebted to my supervisory team, Dr Khalid Hafeez and Professor Allan Norcliffe, for their enduring support, careful supervision and guidance throughout my candidature. Thank you for sharing your knowledge and skills without reservation. You have been the best teachers and role models I ever had.

I am particularly grateful to all staff members at Sheffield Hallam University for their valuable feedback, advice and editorial review of the thesis. Many thanks, also, to my father, my mother, and for all the people who have given me encouragement and support whilst conducting my research and writing up this thesis.

Finally my deepest thanks go to my wife, Aida, for the support she has provided me throughout. Thank you for your encouragement and the way you have assisted me in everyway possible to make this thesis a success.

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NOMENCLATURE

$1/T_i$	It is the proportional constant to deal with the discrepancy between target staff and actual staff level. The units are per month.
1/S	This represent the integration process whereby the actual staff level is accumulated over time through the recruitment and training development.
IOBPCS	Inventory and Order Based Production Control System
APIOBPCS	Automated Pipeline Inventory and Order Based Production Control System
APSKPM	Automated Pipeline Skill Pool Model
APSKPM+ (P+I)	Automated Pipeline Policy using Integral controller
ASL	Actual staff level
DRSIP	Target recruit staff in process
DSL	Desired staff level
FSLR	Forecast staff leaving rate
ITAE	Integral Time Absolute Error
MSE	Mean square error
PPAPSKPM	Progression and Promotion Automated Pipeline Skill Pool Model
PPSKPM	Progression and Promotion Skill Pool Model
PSLR	Present staff leaving rate
RCR	Recruitment completion rate
RDR	Recruitment demand rate

RSIP	recruit staff in process
RSIPA	recruit staff in process adjustment
SG	Staff gap
SKPM	Skill Pool Model SKPM.
Ta	Time over which staff leaving rate is averaged in months.
Tc	Estimated recruitment lead time
Ti	Time to reduce the staff gap to zero measured in months.
Tp	Promotion process delay measured in months
Tr	Recruitment process delay measured in months.
Tw	time to reduce recruit staff gap deficit to zero
X	mean value
X1	Duration of the staff level deficit
X2	Rise time
X3	Duration of overshoot
Y1	Initial drop of staff level
Y2	Peak staff level overshoot
Y3	Peak overshoot -
α_a	This is the multiplier used in simulation to take account of the time to average the staff leaving rate.
α_r	This is the multiplier used in simulation to take account of The recruitment process delay.

CHAPTER 1
INTRODUCTION

1.1 Chapter overview

This chapter is devoted to describing the research problem addressed in this thesis together with the research aims and objectives. A simple diagram of the structure of the thesis and research framework is included.

1.2 Background to the research

More than ever before, human resource planning (HRP) needs to be responsive to the needs of organizations and the staff they employ. Walker (1974) has suggested that, through HRP, management should be able to develop and deploy the right people at the right places at the right times to fulfill both organizational and individual objectives. Firms, therefore, should be linking their human resource planning to the organization's long-term business objectives and should be constantly looking for strategies that will help them to cope with competition and diversification. Organizations should also be predicting future human resource levels in order to forecast recruitment and training needs to ensure that sufficient experienced people are rising through the rank to fill vacancies at higher levels (Brian and Cain, 1996).

Interest in human resource planning has grown dramatically over the past few years. HRP is beginning to respond to a greater demand for new talent due to increased competition in the world market. This fact was pointed out by Walker (1980) some while back, but is still valid today. Executives are being forced to rethink the way in which they attract the staff they need and how they should train and employ their staff. Firms are constantly looking out for strategies that will help them cope with complexity and competition, and the previous lack of linkage between human resource planning and long term objectives. Firms are now realizing that skilled people are needed to coordinate the human capital and material resources required to accomplish objectives.

The dynamics of market forces and job opportunities are also becoming a challenge for many organizations as they seek to retain their core staff. Companies are losing critical business knowledge as employees walk out from their doors. Also, the recent transition from the industrial market to the knowledge economy dictates an immediate and wholesale retraining scenario for many organizations to remain at the cutting edge of technology. An efficient human resource or intellectual capital investment strategy demands a good understanding of the dynamics of recruitment and training issues (Hafeez, 2003).

Skill, knowledge and competence cannot be bought and delivered instantly. It takes a considerable amount of time to do this. Human resource planning therefore must also be concerned with improving staff morale and productivity and must seek to minimize staff turnover. HRP should help to facilitate companies make effective use of employee skills, provide training opportunities to enhance those skills, and boost employee satisfaction with their job and working conditions. Training should include employer-sponsored efforts to improve the skill and competences of employees through education, work-shadowing, and apprenticeship programmes for personal development. Additionally, human resource planning should involve forward looking analysis of current and future human resource development needs, analysis of the issues and challenges facing a particular occupation such as the supply and demand of skilled people, the impact of changing technology, the need for skills upgrading and the effectiveness of existing training.

The research undertaken in this thesis is concerned with human resource planning. Specifically it concerns how an organization can ensure in a timely way that it has the requisite people with the right skills needed to achieve its corporate objectives. The research uses system dynamics (Forrester 1961) and draws on ideas used in Inventory and Order Based Production Control Systems (IOBPCS) as developed by Coyle (1977) and Towill (1982). In this context system dynamics is used to ensure that the level of production required (order rate) matches the production completion rate, where the order rate is based upon the level of goods demanded, and to ensure that the level of sales equals the production rate. In the research described in this thesis the skill levels of staff in human resource planning are the analogue of inventory levels in production planning. The resulting system dynamics models are called Skill Pool Models (SKPM) for obvious reasons and were first derived by Hafeez (2000). The work in this thesis builds strongly on the work of Hafeez and Abdelmeguid (2003).

During this thesis we are going to extend Hafeez's work by validating SKPM models for various situations in industry. The models will be developed to provide companies with the means of producing optimum HRP strategies. They will enable the companies to best manage the actual level of the skill pool, through recruitment and training, to reach the desired levels needed to achieve organizational goals. Systems thinking will be used to develop causal loop diagrams that display all the major influences and feedback loops that exit between the variables in the models. Dynamic simulation will then be used to analyse the system behaviour and enable the decision maker to gain insight into the organization's HRP function.

System dynamics is typically defined as that part of management science that deals with the controllability of managed systems over time, usually in the face of external shocks (Sterman, 2001). In the HRP context a shock may well correspond to a change in the normal staff leaving rate, or in the level of production - thus necessitating the need for a change in the staff resources that may be needed - or a change in the environment in which the organization resides. System dynamics allows us to study and manage complex feedback systems by creating models representing real world systems, (Coyle 1977). In this thesis, computer simulation will be used to analyze the behaviour of complex dynamic HRP systems and will make use of the proprietary software package known as *ithink*.

1.3 Statement of the research problem

The aim of this research is to demonstrate that system dynamics can be used as a tool in human resource planning as an aid to decision making. Specifically this study is concerned with extending the Skill Pool Model of Hafeez (2003), and demonstrating its usefulness in devising optimum human resource strategies for real companies. The research work will be concerned with creating system dynamics models and studying their behaviour. This will facilitate an understanding of the relationship between the behaviour of the system over time and its underlying structure and decision rules, thus enabling the company to optimise its recruitment and training strategy to suit organizational needs.

1.4 Research Objectives

The specific objectives for this research work are the following: -

1. To establish the cause and effect relationships between changes in recruitment, training and actual staff level by using causal loop diagrams
2. To extend the Skill Pool Model and validate it for various cases where it is important to be able to optimise human resource planning strategies as identified by Hafeez and Abdelmeguid (2003)
3. To develop and validate system dynamic models to address progression and regarding issues in human resource planning and
4. To demonstrate that system dynamics can be used as an aid to decision making in Human Resource Planning.

1.5 Literature review

Human resource planning and modelling are the main topics of the literature review. The literature review has been carried out to enable the researcher to understand the concepts of using system dynamics in human resource planning. The literature review has also been useful in determining a suitable methodology for the research. Amaratunga and Baldry, (2001), state that:

> *"A literature review is useful in revealing the established and generally accepted facts regarding the situation being studied, and usually enables one to identify and understand the various theories or models, which have been used*

by previous researchers in the field. A literature review may also assist a researcher in identifying an unsolved problem in the field being studied and this may then itself become the main focus of the research study".

A literature review was undertaken so that as much relevant information could be obtained and evaluated in respect of the given topic. The literature review enabled the researcher to understand the current status of the topic and subsequently consolidate thinking about the topic, thus identifying the best way forward.

Carrying out a literature review, as stated by Holt (1997), will also help to:

- Understand the peripheral issues
- Reveal the extent to which research and current understanding has reached
- Identify the key variables impacting upon the topic
- Suggests routes to take with regard to advancing knowledge or understanding of the topic
- Suggests routes with regard to solving issues surrounding the topic
- Yield source data
- Help generate other ideas
- Compare ideas and thinking with respect to existing knowledge.

Carrying out the literature review, with these aspects in mind, has also enabled the researcher to understand the current status of the topic.

1.6 Research methodology

The methodology used for this research is an integrated system dynamics methodology as discussed by (Hafeez et al 1996), which is adapted for creating models for human resource planning, and studying their behaviour over time. The methodology will adopt four main features as shown in Figure 1.1:

1. Literature review, along the lines as described earlier.
2. Development and validation of conceptual (system dynamics) models.
3. Testing these models in the Libyan petrochemical sector by using real data
4. Using the models to determining optimum HRP policy parameters.

In addition to the above four stages, there will be a fifth stage, namely that necessary to validate the achievement of the overall research objective:

5. Developing key success factors in order to assess achievement of the main research objective.

This approach to the research will therefore test the applicability of the models in the petrochemical industrial sector. By showing later in Chapter 4 that this sector is typical of many where HRP is important, and therefore also test the suitability of using system dynamics in human resource planning more generally.

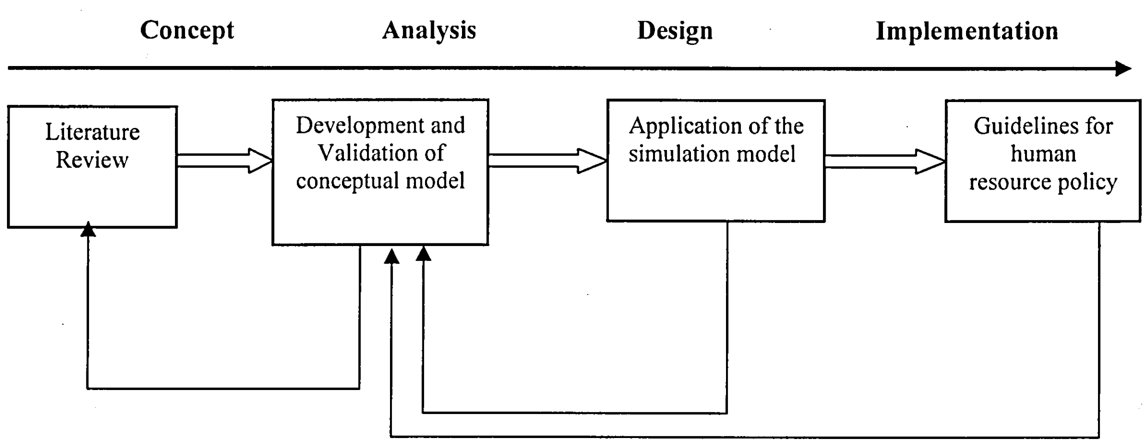

Figure 1.1: Research Framework (adapted from Zhang 1999)

1.7 Structure of the thesis

This thesis is presented in nine chapters. Chapter 1 includes review, general background, the need for research, the research outline and research methodology. The research outline is divided into the research aim, objectives, hypothesis and the research questions. Also introduced is the literature review and its importance as part of the research methodology.

Chapters 2 and 3 give a comprehensive review of the literature on human resource planning, and review the models used in human resource planning.

Chapter 4 covers the research methodology. It discusses the issues related to research philosophies, research approach, research design, research techniques, and research methods (data collection and sources of data). This chapter also provides historical background about the Libyan petrochemical industry

.

Chapters 5, 6 and 7 concentrate on creating system dynamics models for human resource planning and testing these with data relating to the Libyan petrochemical sector.

In Chapter 8 the skill pool models are enhanced to include three grades of staff. By including grades the models can now be used to determine optimum promotion and progression, as well as recruitment polices. In each of Chapters 5, 6, 7 and 8, system dynamics and system thinking is used to develop causal loop diagrams to display all the major influences and feedback loops that exit between variables.

An evaluation of the research carried out against the aims and objectives set for the research is carried out in Chapter 9, where recommendations for future work are also summarised. Figure 1.2 below shows the structure of the thesis in diagrammatic form.

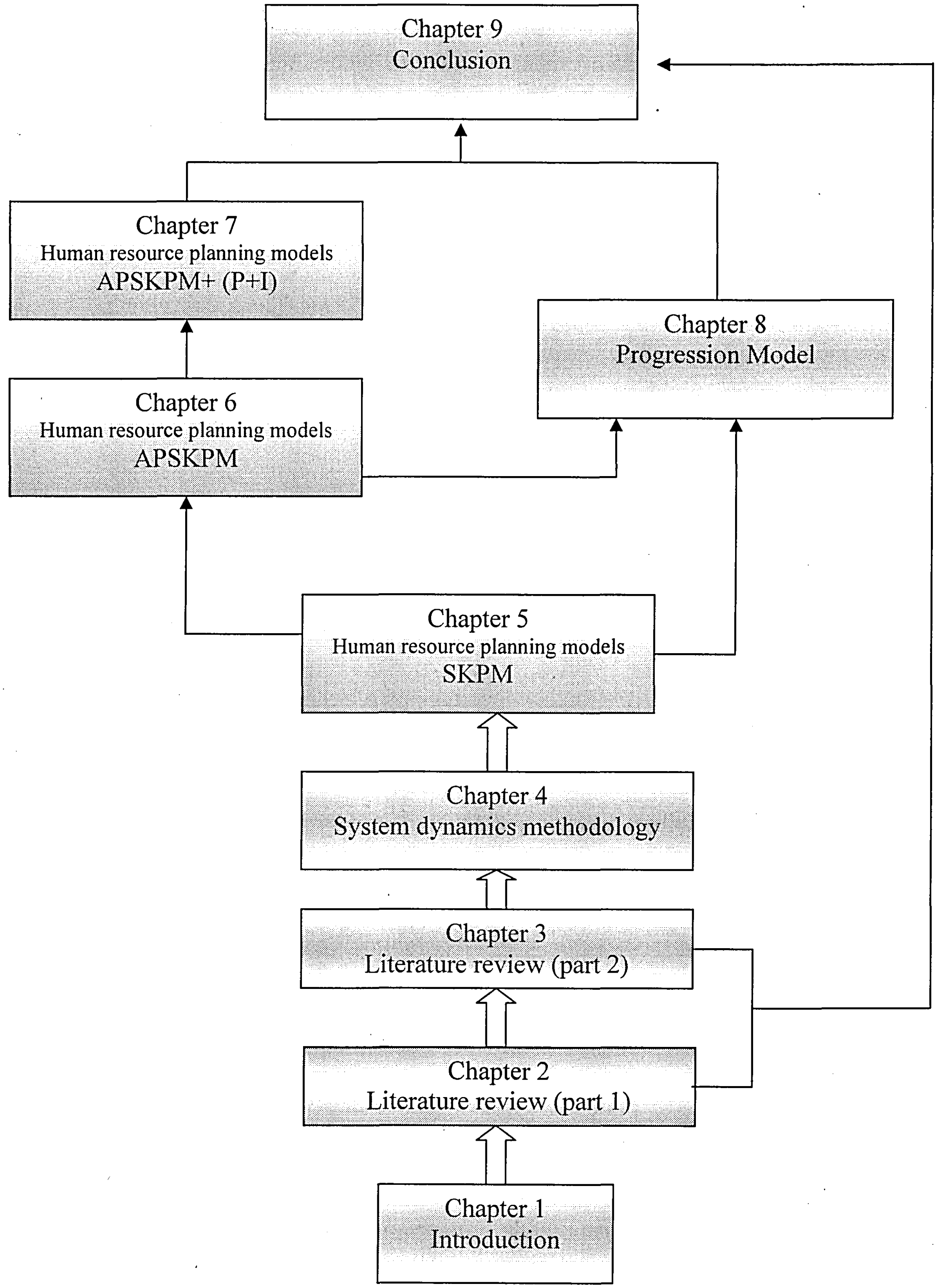

Figure 1.2: Research Structure

1.8 References

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CHAPTER 2

REVIEW OF LITERATURE (Part 1)

2.1 Chapter overview

This chapter presents a review of the literature related to the role of human resource planning and the approaches involved. It looks specifically at the essential duties performed in carrying out the human resource planning function.

2.2 Introduction

A review of human resource planning literature, dated between 1967 and 2002, indicates that there is increasing interest in this field. Most organizations have been encouraged by the significant role HRP can play within their companies, especially with the turmoil that seems ever present in the business environment. It allows them to plan ahead (Meshoulam & Baird 1987). Technological, economic and social changes are causing organizations to focus their attention on HRP to achieve their objectives, (Tichy, Fombrun & Deranna, 1982).

Furthermore, it was found that definitions relating to HRP, to be used in this study, were sufficiently appropriate since they correlated with effective planning and with Walker's (1980) definition of HRP, as well as with other definitions of planning used by human resource researchers. In Walker's redefined delineation of what steps are necessary for the HR manager to strategically follow HRP activities in an organisation, he also stated that, "Human resource planning is the systematic analysis of current and future HR requirements and the formulation of strategies, plans and programmes for the acquisition, utilisation, development, and retention of employees needed to achieve the goals of the organisation". HRP is fundamentally a dynamic process that endeavours to monitor and manage the flow of people into, through, and out of the organization in order to achieve corporative goals; this process has to take into consideration the total corporate plan and many environmental issues that effect the employment of people.

2.3 Some definitions of Human Resource Planning

Numerous definitions, as stated by Porter (1980), have been given on the subject. Also, different terms have been used to identify it, such as: work force planning, human resource planning, manpower planning, personnel planning, and employee planning. One definition of HRP given by Peter Reilly (1996) is the following: "Human Resource Planning is a process in which an organisation attempts to estimate the demand for labour and evaluate the size, nature and sources of the supply which will be required to meet that demand".

Walker (1974 and 1980) and Tracy (1985) are two influential writers who have proposed good definitions for human resource planning. As indicated earlier, Walker defines HRP as the systematic analysis of current and future human resource requirements and the formulation of strategic plans and programmes for the acquisition, utilisation, development and retention of employees that are needed to achieve the goals of the organisation.

Walker also defines strategic planning as the process of setting organisational objectives. He has emphasised that HRP is the process of analysing an organisation's personnel needs under changing conditions and developing the activities necessary to satisfy an organisation's needs. These include forecasting the demand and supply of the human resources needed, performance management, and career management. Walker (1989) argues that forecasting human resources can be accomplished only if human resource planning is, indeed, in the business plan schedule. Programme evaluation is very important in that an analysis of needs leads to the planning of the programmes to be conducted.

Tracy (1985) also gives a definition of what HRP consists of, that is suitable for inclusion in this research, as follows: "Current human resource planning practices include strategic human resource planning and selection, as well as employee development, career planning, information systems, forecasting, and evaluation of employee performance".

2.3.1 The environment within which HRP takes place

Companies carry out human resource planning in an environment which is always changing. Changes may be of a political nature, an economic nature, a technical nature and so on. The political environment includes executive orders (e.g. government instructions regarding production), legislation, and regulations that could have a major impact on corporate HRP activities. The economic environment concerns include major changes in economic factors, such as the unemployment rate and inflation rate that can have a potential impact on the HRP process. The technical environment may include the impact of using advanced technology on production, communications, computers and energy use. The use of materials and natural resources have brought major changes in the way organisations function.

2.4 Human Resource Development

Human resource planning concerns forward looking analysis of current and future human resource development needs, issues and challenges facing the particular occupation concerned such as the supply and demand of skilled people, the impact of changing technology, the need for skill upgrading and the efficiency of the existing training. Walker (1980) indicated that HRP can be defined as the process of analysing an organization's human resource needs under changing conditions and by developing activities necessary to satisfy these needs.

Furthermore, human resource planning, as defined by Kastens (1979), is the organised learning experiences in a specific period of time to increase the possibility of improving job performance or growth. And the development of human resource is based on the level of staff skill; it is conducted in an organisational setting, and should aim to change the behaviour of individuals so as to improve their performance. Gordon McBeath (1992), however, defined HRP as the individual development of knowledge and skills, as opposed to organisational development, which focuses on improving structures and processes that characterised working relationships..

Human resource development is commonly referred to as training and includes employer sponsored efforts to improve the skill and competences of employees through education, training and development. Human resource development is therefore equivalent to employee development or staff development, and the training is focused on learning about the present job. In this connection, Kao & Lee (1998) found that maximised utilisation of the human resource depends on effective flexible training programmes. In this regard Garavan et al(1998) investigated that human resource development is the strategic management of training and development of professional education to achieve the objectives of the organisation, while at the same time ensuring the full utilisation of the knowledge and skills of individual employees.

2.5 The Contemporary purpose of HRP

As researchers have reported, there are many definitions and terms used to describe the human resource planning function. Here, as elsewhere, development of terminology has moved on at different speeds and in different directions, leading to something of a mismatch between the concepts and the labels used to describe them. In this section we want to clarify what we mean by the concept of HRP.

"Manpower planning is an essentially quantitative technique concerned with forecasting the demand and supply of workforce"- Bramham (1994). Arguably, it now has a wider meaning, including plans made across the whole range of personnel and development activity. HRP is concerned with looking ahead and using systematic techniques to assess the extent to which an organisation will be able to meet its requirements for workforce in the future (Taylor, 1998) in order to have the right people at the right places at the right time. According to Taylor (1998), the main distinction is between those who see the term 'human resource planning' as having broadly the same meaning as the longer established terms 'workforce planning' and 'manpower planning', and those who believe human resource planning to represent something rather different.

Mullins (1996) has argued that effective human resource planning can help anticipate potential future difficulties while there is still a choice of action. Forward planning should enable the organization to develop effective personnel strategies related to such activities as recruitment and selection, training and retraining, management development and staff progression, early retirements, salary levels and accommodation requirements.

Bramham (1987) presents a more detailed view of six basic objectives which are similar to those mentioned by Mullins (1996) that are thought to constitute the purpose of human resource planning.

The first objective, and the main purpose behind the use of human resource planning, is to give a forward looking insight into, not just the number of staff, but also the type of skills, and attributes of the people that will be needed in the future. HRP provides the information on which recruits base their activities and it reveals what gaps there are between the demand and supply of people with particular skills (Storey, 1995).

The second objective aims to look at what training and development activities need to be undertaken to ensure that existing employees and new recruits posses the required skills at the right time (see also Bramham 1988).

The third objective is looking for work force costing and to explain how HRP assists in cost reduction by aiming to work out in advance how organizational operations can be staffed most efficiently.

The fourth objective is redundancy. HRP is an effective tool in the anticipation of future redundancies and therefore allows remedial action to be taken, such as recruitment freezing, retraining, and early recruitments so as to reduce staff numbers involved (Bramham 1988).

The fifth objective is, HRP provides important information for use in the bargaining process. It is particularly significant when long term deals are being negotiated to improve productivity and efficiency. In such situation, the information provided by human resource forecasts enables calculations to be made concerning how great an increase in pay, or how great a reduction in hours, might be conceded in exchange for more productive working methods and processes (Bramham, 1988).

The sixth objective deals with planning of accommodation, such as future need for office space, car parking and other workplace facilities.

2.6 The importance of Human resource planning

Skilled staffs are needed to coordinate the human, capital, and material resources required to achieve the organisation's goals. Companies give more than lip service to the importance of human resource planning in achievement of business objectives and necessary staff are recruited in the market place to meet future needs. Business planners tend to focus on financial and marketing aspects of planning, in parallel with linkages between human resource planning and strategic business planning. Kastens (1979) has said, "Planning is a technique to establish and maintain a sense of direction. Planning would ensure that activities were oriented toward a chosen goal and, therefore, would create progress toward that goal". It would allow people to question current planning methods and would evoke new ways of thinking and acting strategically.

HRP is also concerned with improving morale and productivity and limiting job turnover. It helps companies effectively use employee skills, provide training opportunities to enhance those skills, and boost employee satisfaction with their job and working conditions. On the other hand, Human resource planning is concerned with forward looking analysis of current and future human resource development needs, issues and challenges facing a particular occupation such as the supply and demand of skilled people, the impact of changing technology, the need of skills upgrading and the efficiency of the existing training.

2.7 Promotion and Progression in Human Resource Planning

One of the main aims of HRP is to create a situation in which staff know what is going on in the organization and understand what their contribution is. Most organization tend to be hierarchical with a finite number of job grades where individuals can stay in their existing grade, leave or be transferred to another grade (normally a higher grade). The number of staff in any grade is known from personnel records and the probabilities of leaving or transferring to another grade can be estimated reasonably accurately from past data. However, most organizations feel the need to predict future human resource levels in order to forecast recruitment and training needs and to ensure that sufficient experienced people are rising through the ranks to fill vacancies at higher levels. The nature of the problem seems ideally suited to the use of statistical analysis as it clearly involves probabilistic transitions from a set of known initial states. So, it is hardly surprising that HRP is the subject of many academic publications on statistical processes. Of course, these approaches can be easily solved using a variety of application software, and evidence suggests that the use of such software is increasing in popularity, especially since the later part of the 1980s (Raghavendra, 1991). Zeffane and Mayo (1994) discuss more complex approaches based on probability.

Promotion and progression has always been an important part of human resource planning. The research undertaken in this thesis will look specifically this aspect of HRP and models will be developed to describe and understand the impact of promotiona and progression within a hierarchical company.

2.8 Effective Human Resource Planning

Effective human resource planning is the process of analysing an organisation's human resource needs under changing conditions and developing the activities necessary to satisfy these needs in a timely, accurate and professional fashion. Beardwell and Holden (2001) summarise the need for HRP as one that involves a quantifiable and quantitative dimension leading to:

- *recruitment plans*: to avoid unexpected shortages.
- *the identification of training needs*: to avoid skill shortages.
- *management development*: in order to avoid bottlenecks of trained staff and to avoid managerial shortages.
- *industrial relations plan*: to avoid industrial unrest by seeking to change the quantity and quality of employees.

On the other hand, effectiveness of human resource planning largely depends on how relevant it is to practical managerial concerns and practices, and in turn to the demands prevailing upon an organisation. Benefits associated with effective HRP and management include for example, the identification of sources of manpower which are likely to provide sufficient numbers of employees having the appropriate levels of training and appropriate patterns of work attitudes, the development of a system for providing a suitable worker job "fit" and the capability of integrating important elements of manpower planning into the overall corporate planning system in the organisation (Moore 1977).

2.9 The Role of HRP

Many authors report on the importance of the roles of HRP. They contend that there has been mounting enthusiasm for awarding human resource management a more strategic role in organizations. The researchers have noted that HRP is being encouraged to link specific HRP programmes to strategic outcomes (Martell, Carrol & Gupta, 1992). Studies also indicate that by matching HRM with strategy, critical HR skills, attitudes, behaviours and performances, that are needed to successfully implement planning strategies, can be achieved and maintained (Brockbank 1999).

HRP can provide organizations with the tools it needs to address the human capital management challenges. Effective workforce planning requires a strong manager, clearly articulated vision, mission, and strategic objectives, and cooperative, supportive efforts by staff in a variety of functional areas. When done properly, workforce planning can be a powerful tool to help public sector organizations meet their human capital needs and achieve their objectives (Reichenberg 2002).

Human resource planning is the strategic alignment of an organizations human capital with its business direction. It is a methodical process of analysing the current workforce, identifying future workforce needs, establishing the gap between the present and the future, and implementing solutions which help organization to accomplish its mission, goals, and objectives. Workforce planning affects the full range of human resource activities including recruiting, hiring, promotion, transfer, redeployment, attrition, and employee training and development. There are several steps that must be included in any comprehensive workforce planning effort:

- Analyzing present workload, workforce, and competencies.
- Identifying workload, workforce, and competencies needed for the future.
- Comparing the present workload, workforce, and competencies to future needs to identify gaps and surpluses.
- Preparing and implementing plans to build the workforce needed for the future.
- Evaluating the success of the workforce planning model to ensure it remains valid and objective.

2.10 Essential human resource planning duties

As the field of planning has emerged, the human resource aspects of management have grown in importance. Human resource planning is the responsibility that all managers have in performing human resource duties (Mathis & Jackson 2000).

A centralized human resource management function results in decisions being made by top managers and human resource planning professionals; a decentralized human resource planning function results in decisions being made by all managers and human resource professionals throughout the organization. The contrasting views of how the human resource management function is carried out represent extremes, not choices, along a continuum. How an organization organizes its human resources function is related to its culture, leadership, geographical dispersion of employees, internal and external environment and size. Regardless of how an organization organizes its human resource management function, line managers have an explicit role in managing human resource (Jackson & Schuler, 2000).

Vijayaragvan and Singh (1997) state that human resource planning is the key to increased employee productivity. These authors regard human resource planning as comprising the following activities: job analysis, recruiting, selecting, training, appraising, leading, compensating, and organization development.

2.10.1 Job Analysis

Job analysis is the most basic activity in human resource management. It is the process by which information about a job is collected and ordered. The most visible output from job analysis is written job descriptions. Information from job analysis is used in selection, training, performance appraisal, and compensation (Buford, 1991). Competition for employees and equal employment opportunity legislation make job analysis an essential organisational function (Ford, 1979).

Job analysis informs the human resource practitioner about the nature of a specific job - in particular the major tasks undertaken by the staff position, the outcomes that are expected, the job relationships with other jobs in the organisational hierarchy, and job holder characteristics, (Heneman, & Judge 1997). Where a practice must be defended on the basis of content validity, job analysis must establish the rational link between the content of a practice and the content of job.

In much of the research carried out in this thesis job analysis will not feature prominently. The emphasis will be on the recruitment of staff with the potential to carry out a range of similar jobs. Once recruited staff will require to be trained for these jobs, and the assumption will be that training requires the same amount of time (determined by the company).

2.10.2 Orienting, Training and Development

Employee orientation, training and development programmes help organisations retain competent employees. Training and development is a human resource planning concern for several reasons (Bedeain, 1993).

It is a central element for human resource management and the principal vehicle for developing skills and abilities of employees other than through job assignments. It is a major area of expenditure, in out-of-pocket costs and in the time devoted by staff and participants. It is an important means of influencing management values, attitudes, and practice in human resource management, it is a communications medium controlled by a company, and it is becoming a subject of concern with regard to legal responsibility.

Orienting, training, and development programmes help employees learn about the organization and their jobs, help employees improve job performance, and help employees contend with new responsibilities (Nadler, 1980).

Orientation introduces newly hired individuals to their job and supervisors. Effectively performed, it serves five main purposes (Bedeian, 1993). Orientation makes employees feel valued, reduces start up costs for new employees, reduces the amount of anxiety people experience, reduces turnover, and saves time for supervisors. Training and development helps improve employee performance by developing and enhancing worker competencies.

2.10.3 Recruitment, Selecting, and Hiring

Recruitment, Selecting, and Hiring are closely related parts of human resource planning (Buford & Bedeian 1988). Recruiting is the process of generating a sufficiently large group of applicants from which to select qualified individuals for available jobs. Selection is the process of determining which applicants meet the requirements of the job. Hiring is the process of employing an applicant identified during the selection process. Recruitment practices are subject to numerous legal issues (Heneman, and Judge, 1997). Equal employment opportunities and affirmative action requirements affect the staffing process (Panaro. 1990). Conformity to legal requirements regarding the staffing process requires that all procedures and tests be reliable and valid (Dessler, 1997).

2.10.4 Demand for manpower

People are the greatest assets in any organization, and the inventory of skills is the key to any management strategy. Analysis of manpower demand is an important area of human resource planning which has made significant contributions to human resource management. Meeting future needs for skills is the most frequently cited reason given by employers for engaging in human resource planning (Greer and Armstrong, 1980). Among the objective methods, regression analysis is probably the most widely adopted forecasting technique.

A similar technique is time series analysis (Bartholomew *et al.*, 1991), which forecasts future demands by projecting from past demands. There are also other objective methods like stochastic modelling and ratio analysis (Dyer, 1982). One trend in the industrialized societies of the world is the continuous increase of labour costs. Another trend is the shifting of the work force by manufacturing industries toward the service sector. To compensate the increase in salaries and shortage in workforce in organizations, the productivity must be improved. Many studies (Burnham, 1982; Chirillo, 1989; El Mhamedi and Binder, 1992) indicate that technology and management are the two broad categories of factors which have major influence on productivity.

2.11 Summary

The objective of this chapter was to highlight the main studies relating to the research problem of this thesis. Reviewing the literature helps in forming a structure for the research and identifying the general conclusions drawn from the previous studies that could be related to the problem of this study.

This chapter focused on definitions used in human resource planning and looked at the theoretical background of the human resource planning process. The literature review of human resource planning shows that HRP is the systematic analysis of current and future human resource requirements and the formulation of strategies, plans and programmes for the acquisition, utilization, development, and retention of the employees needed to achieve the goal of organization. Three important conclusions are drawn from the HRP literature review.

- Human resource planning is about ensuring that the correct number and mix of skills is available at the right place at the right time doing things which result in both the organization and individual receiving maximum long term benefits.
- The success of human resource planning is paramount to the survival of the organization. There must be effective recruitment, initial training, and continued development of the workforce.
- For effective human resource planning, an organization must learn to forecast human resource needs more effectively. There is no doubt that quantitative techniques can enhance problem solving abilities and hence improve decision making effectiveness in this context.

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CHAPTER 3

Review of Literature (Part 2)

3.1 Chapter overview

This chapter presents a review of the literature related to approaches to human resource planning and reviews models that are used in human resource planning. The chapter addresses the issues of modelling complexity, and the need to link business and HRP strategies. The main contribution of this chapter is to review and compare human resource planning models.

3.2 Approaches to human resource planning

HRP is the process for identifying an organization's current and future human resource requirements, developing and implementing plans to meet these requirements, and monitoring their overall effectiveness. (Beardwell, 2004).

In Practice, HRP is concerned with the demand and supply of labour and problems arising from the process of reconciling these factors (Tyson and York, 1989). Many different approaches have been developed to accommodate different types of constraints and the kind of policies under which the planning system might operate (see, for example, Uwakweh and Maloney, 1991; Purkiss, 1981; Edwards, 1995; Gaimon et al., 1987; Zeffane and Mayo, 1994b; Parker and Caine, 1996; Khoong, 1996; Dawson et al., 1990; Castley, 1996). Broadly these approaches have been applied to three sets of issues, which are covered in the following three sections.

3.2.1 Forecasts of the future human resource demand

The purpose of human resource forecasting is to estimate the human resource requirements at some future time period. Demand forecasting is concerned with estimating the numbers of people and types of skills the organization will need in the future, Beardwell *et al* 2004. Basically there are two types of approach to assessing future demands for manpower needed: the objective and the subjective approach.

The objective approach relies upon the projection of past trends and needs to take into account shifts brought about by changes in technology and organisational goals. Simple projections from the past to indicate the amount or type of staff required in the future can be related to results from work study exercises or ratios of customers to staff. These approaches often use techniques such as extrapolation/regression, work/productivity measurement, or econometrics (see, for example, Bartholomew and Forbes, 1991).

The subjective approach, in its most basic form, takes the form of managerial judgement about future needs and, as Marchington and Wilkinson (1996) emphasize, in some cases it can be an excuse for speculation and even guesses based on limited amounts of data. For example, Brian and Caine (1996) refer to the spreadsheet technique as one of the approaches based on managerial judgement.

3.2.2 Forecasts of internal human resource supply

Forecasts of internal human resource supply are based primarily on staff turnover and the movement of people within the organization, (Beardwell, 2004). Walker (1992) suggests that there are two fundamental types of approaches to forecasting internal supply to meet the future demands for labour. These are represented by supply ``push" and demand ``pull" models, although there are certain variants on this theme. In essence, both approaches rely, to various extents, on mathematical modelling techniques and the probability that historical movements of staff will be reproduced in the future. The supply ``push" approaches are usually based on statistical analysis. This analysis is a descriptive technique that falls within the family of mathematical modelling techniques known as stochastic models. This approach relies upon large numbers of employees in an organisation, a relatively stable and predictable career structure, and broadly consistent aggregate wastage rates, that is, the ratio of the number of leavers in a year to average numbers of staff in post during that year.

On the other hand, the demand "pull" approaches are based upon movements out of grades and release from the organisation as a whole, such that flows of staff are triggered by vacancies or promotions.

3.2.3 Forecasts of external human resource supply

Recruiting and hiring new employees is essential for virtually all organizations, at least over the long run. In reality, forecasting external supply seems to be a human resource planning activity to which a majority of the texts devote rather less attention than they do to forecasting internal supply. However, there are a number of factors which determine the supply of staff from the external labour market, both at a national and at a local level, and these are influenced by economic, social and legal issues. Not surprisingly, therefore, there is a growing literature on the need to approach human resource planning, especially education and skills development planning, through labour market signals. Such an approach has come to be known as labour market analysis.

According to Castley (1996), this approach is a much wider concept than human resource planning, since it includes not only enrolment guidance but also the unemployed and underemployed and, therefore, requires additional functions, such as measuring wages as a possible cause of skill shortages, shifting of the cost of training from the general taxpayer to the direct beneficiaries, or encouraging the development of private training institutions, which are considered to be more cost conscious and market responsive. Naturally, it may be difficult to imagine how this can be achieved at an organisational level. However, first, taking this into consideration may help human resource planners in developing economic and environmental scenarios, allowing them to identify external factors that will affect the organisation and to calculate the impacts of such change on human resource plans. Second, this approach seems to be highly relevant for the countries in which the state still plays an important role in company management.

2.3 Modelling complexity

Systems have grown in complexity over the years mainly due to increased striving for performance enhancement combined with a greater degree of uncertainty and imprecision in the system's external and internal environment. Managing any system in day to day operation is usually a complex resource allocation problem. This complexity is always present in real life systems. The complexity is due to the interaction between the various parts, the delays, which inevitably ensue, between action sought and action executed. Most people think of complexity in terms of number of components in a system or the number of combinations one must consider in making a decision. Therefore the complexity lies in finding the best solution out of an astronomical number of possibilities (Sterman, 2000). Dynamic complexity can arise even in simple systems with low combinatorial complexity, and arise from the interactions among the agents over time, Sterman, 1989).

Complexity provides a starting point for discussing the environment a company is operating in. Complexity concepts can be used to develop robust strategies in a rapidly evolving environment. Computer modelling has made it possible to have better understanding of complex systems. Improvements in computers over the past 30 years have given researchers the ability to model complex systems. Furthermore, a considerable number of authors agree that the use of the computer has facilitated the implementation of complex models (dynamic, productivity models, model building, etc) that can consider a large number of variables and determine the effect that they may have upon system behaviour.

3.4 Review of models in human resource planning

Models may be descriptive, representing what is, or normative, representing what should be. Models in HRP are both descriptive and normative. The models in this chapter are divided into two types: (a) Policy models and (b) Mathematical and Statistical models. Policy models are both normative and descriptive. Mathematical and Statistical models are descriptive.

3.4.1 Policy Models

Policy models in HRP aim to provide a comprehensive framework for the evaluation of the organization, that emphasize the interrelationship between programmes (eg between recruitment and training) and the relationship of each programme to external factors. Furthermore, policy models need conceptual models for assessing organization roles in support of human resource planning development and should be grounded in forecasting to provides clear descriptions of the mechanism.

3.4.1.1 Tichy and Devanna model

Tichy and Devanna (1984) are among the few who have attempted to integrate forecast of the demand for skills and forecast of the internal supply of skills, and relate them to human resource planning, emphasizing the interrelatedness and the coherence of human resource activities. Human resource planning, in their cycle model, consists of four key constituent components (selection, appraisal, development and reward) as illustrated in Figure3.1. The main aim of this model is to increase organizational performance and the strength of this model is that it expresses the coherence of human resource policies and the importance of matching internal human resource policies and practices to the organization's external business strategy.

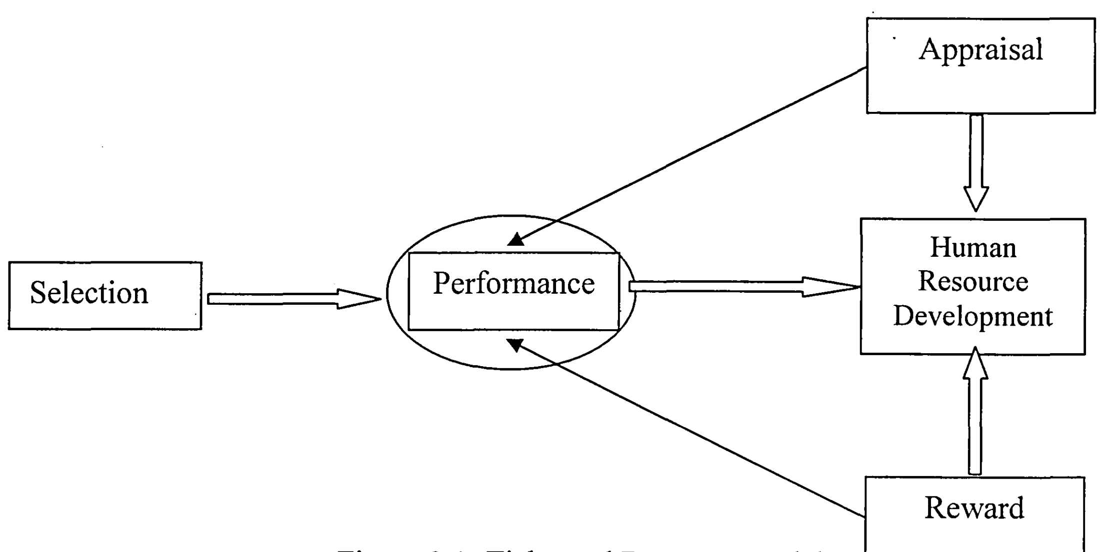

Figure 3.1: Tichy and Devanna model
source: Adapted from Beer *et al.,* 1984

3.4.1.2 Harvard model

The Harvard model was first put forward in 1984 by Michael Beer *et al,* in the book Managing Human Assets. The model recommends that all managers must take greater responsibility for HRP. The Harvard model proposes that many of the diverse personnel and labour relations activities should be taken into account in HRP. The Harvard model emphasizes an analytical framework, which consists of six basic components:

1- Situational factors

2- Stakeholder interests

3- Human resource management policy choices

4- Human resource outcomes

5- Long-term consequences

6- Feedback loop through which the outputs flow directly into the organization and the stakeholder.

The Harvard model for human resource is shown in Figure (3.2). A further recommendation of the Harvard model is that, when making human resource policy decisions, managers should consider four main aspects: commitment, competence, compatibility and cost effectiveness. The model asks that its manager should ask to what extent the polices they implement will: enhance the commitment of people to their work and the organization; attract, retain, and develop people with the needed competence; sustain congruence (compatibility) between management and employees, and be cost effective in terms of wages, employee turnover, and risk of employee dissatisfactions.

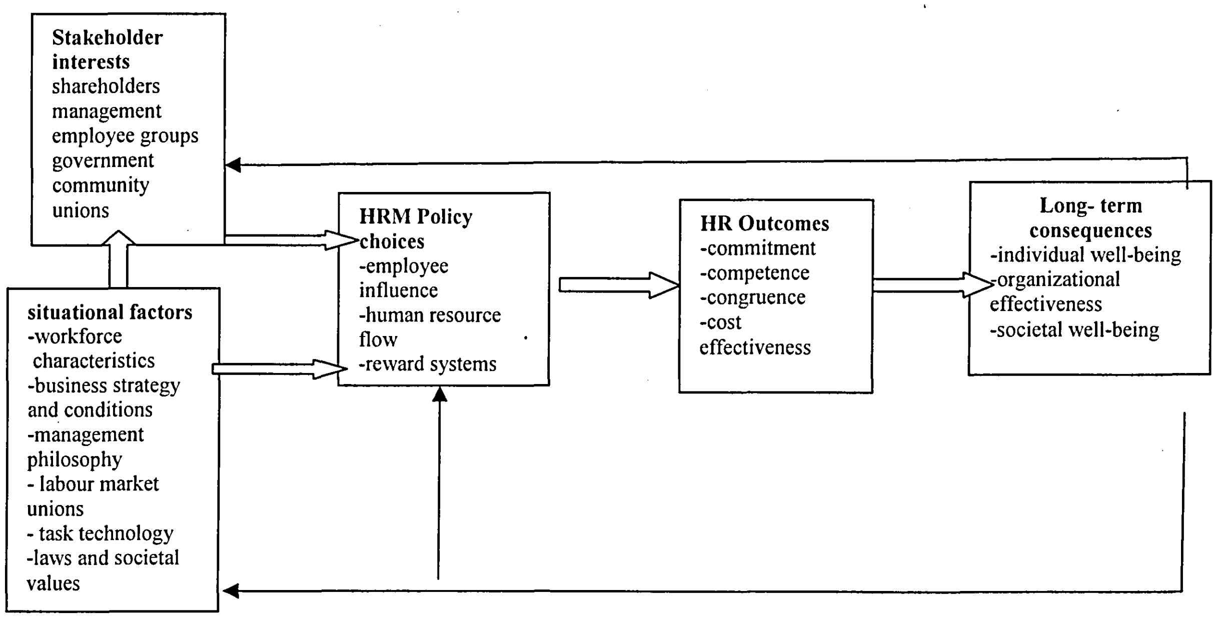

Figure 3.2: The Harvard model of HRM

Source: Beer *et al.,* 1984

3.4.1.3 Walker Model

Walker (1980) explained that most tools being used in human resource planning do not appear to be as suited as they should be in order to meet the needs of management for proper strategic planning and evaluation of HRP practices. He indicated that the amount of money and time that human resource executives invested in HRP was too much. He emphasized that if these investments were to yield a return, there should be more rigorous tool added to HRP practices. He recommended that human resource researchers examine the validity and predictability of his model to predict and validate HRP practices within large organizations.

Rizzo (1984) found that most companies using Walker's model (1980) generally fell within the two lowest levels of Walker's typology. Therefore, Rizzo's evaluation of Walker's model indicated that there was a dependency by major corporations on rudimentary forecasting and placement techniques in the HRP process. Rizzo in his study showed that the respondents were most concerned with internal labour resource management techniques and less concerned with external labour market forces in the corporations. More emphasis was placed on training with less emphasis placed on methods of assessment, career and performance.

Walker emphasises that HR is a process of analysing an organisation's personnel needs under changing conditions and developing the activities necessary to satisfy the needs. Needs that arise within organisations include forecasting, programming, performance, management, and career management.

Walker suggested that effective human resource planning is a process of analysing an organization's human resource needs under changing conditions and developing the activities necessary to satisfy these needs. It is essentially a two step process as shown in Figure (3.3).

1-Needs Forecasting

Analysis of external conditions
- Economic, social, political factors
-Government and legislation
-Population and work force
-Markets and competition
-technologies

Future human resource requirements
-Organisation and job design
-Plans and budgets
-Management policies
development
-Technologies and systems
programs Affirmative action/EEO goals and plans

Future human resource availability
-Current inventory of talent
-Forecasted attrition
-Forecasted movement and
-Effects of past human resource

Forecast of human resource needs
-Immediate and longer term
-External hiring needs
-Reductions and reallocations
-Improved utilization
-Development

2-Programme Planning

Performance management
-Organisation
Activities
Relationships
Responsibilities
Standards
Quality of work life
(climate)

-Performance appraisal
Performance plans and goals

Coaching
Evaluation
-Reward structures
Compensation
Benefits

Career management
-Policies and systems
Recruitment
Selection and placement
Promotion and transfer
Development and training
Termination or retirement

-Management succession
Individual assessmant
position requirements
Replacement charting
Succession planning
Tracking career progress
-Career opportunities
Job requirements
Career phats
Career communications
-Individual career planning
Self-analysis

Figure 3.3 Human Resource Planning Process (source James W. Walker, Human Resource Planning, New York 1980)

3.4.2 Mathematical and Statistical models

The major concern of mathematical and statistical models in human resource planning is to investigate system behaviour over time (Georgiou and Tsantas, 2002). These. models can be very sophisticated and their use helpful to an organisation. Our purpose in reviewing these models is to understand how they work and to classify them appropriately for comparison.

There are several situations in which mathematical and statistical models can be used very effectively in management science. Mathematical models can help decision makers to understand and explore inter-relationships between variables of interest. For example, Regression is a statistical technique to measure the degree of correlation between variables. This technique is based on stochastic processes (Bartholomew, 1971). The stochastic process technique is widely used in human resource forecasting where it is believed that future staffing requirements are correlated with some measurable indicators of output such as actual staff level or staff leaving rate etc. When we can quantify the relationship between staffing and other factors, we have a basis for accurate forecasting. Regression models are most applicable where staffing needs vary directly with other measurable factors. Simple relationships are often difficult to isolate, however, and many planners have searched in vain for such relationships (Gascoign, 1986). Complex, multivariate relationships may be handled by multiple regression analysis, although this technique has not been widely applied in HRP.

3.4.2.1 Markov Model

Most organizations feel the need to predict future human resource levels in order to forecast recruitment and training needs, and to ensure that sufficient experienced people are rising through the ranks to fill vacancies at higher levels. The nature of the problem seems ideally suited to the use of Markov analysis as it clearly involves probabilistic transitions from a set of known initial states.

The Markov HRP model in essence describes the relation between stocks and flow of manpower in the various levels of the organization and seeks to describe their variation over time (Nilakantan and Raghavendra, 2004). These same authors defined Markov analysis as a descriptive technique that falls within the family of mathematical modelling techniques known as stochastic process models. The technique is used to describe the behaviour of a system in a dynamic situation over time and has numerous applications including replacement analysis Raghavendra (1991), HRP, brand loyalty, investment evaluation and stock market analysis. Markov analysis is highly mathematical in nature, being a derivative of probability theory. However, despite this mathematical underpinning, it purports to be part of the practising manager's portfolio of techniques. On the other hand, Markov modelling is a mathematical modelling approach used to help solve business problems. Markov analysis is one type of discrete time stochastic process - a sequence of random events for which the probability of each event is determined by the nature of the preceding event. Markov analysis thus attempts to describe a system as a series of stocks and flows (states and transitions).

A wide variety of mathematical techniques have been developed and while some of them have been used very successfully, many have had little, if any, impact. Ackoff

(1979) epitomized the disillusionment felt by many practitioners in 1979. Managers are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other.

The system is considered to be uncertain, but all the probabilities of movement from one state to another state are known. By describing the movement of the system, this allows management to evaluate the effectiveness of various decisions or scenarios. Implicit movement through time is achieved using matrix algebra. Markov models are a means to analyse the behaviour of dynamic systems to identify steady-state values by using probabilities to predict the movement of the elements of the system over time. Most Markov models are closed systems; they do not interact with the environment of which they are a part. Some interaction can be modelled by treating entities which leave the system as entering an absorbing state Lee and Biles (1990). The mathematics become even more complex and messy where entities also enter the system and a source term is needed. Of course, Markov-type models can be easily solved using a variety of application software, and evidence suggests that the use of software is increasing in popularity.

3.4.2.2 Holonic models (Spreadsheet Models)

Spreadsheet modelling is a practical demonstration that modern computing power and associated software packages now enable many business problems to be analysed. Using spreadsheet techniques, non-mathematical managers can use the armoury of techniques, which were previously the preserve of the "expert", and apply them to give rich descriptions of their real-life problems.

The use of spreadsheet modelling in the context of HRP shows how decision makers who may well lack mathematical ability can now bring to bear the power of mathematical analysis to their subject (Parker & Cain, 1996). Indeed, a rich and flexible set of models can be produced, eliminating many of the limitations inherent within stochastic type models, for example. This often provides the decision maker(s) with greater insights into the problem situation.

There are at least two potential major drawbacks of spreadsheet modelling. First, there is an inherent lack of flexibility to data-driven models. Ultimately, for effective human resource planning, one must be able to easily manipulate models in order to generate alternative scenarios. However, spreadsheet models can easily be designed to allow a user to change a given value, or set of values for a given point in time, and study the effects of these input changes on a given set of outcomes at that point in time. This process can become significantly more complex and burdensome when one tries to test alternative scenarios over several points in time, across several variables; but, with care, the process remains manageable. Secondly, and more importantly, data-driven approaches to problem solving often obscure underlying processes, or quite simply, how the system that produces the given results actually works. However, whilst a spreadsheet is a program, giving outputs from inputs, and to some extent behaving as a "black box", it does require some understanding of the system being described to program it up. This second potential disadvantage is therefore less of a disadvantage than is the case with other black-box type models.

Furthermore, a number of authors agree that the use of the computer has facilitated the implementation of complex models (sensitivity and risk analysis, model building and dynamic predictive models), that can consider a large number of variables and determine the effect they may have upon each other. This permits the use of some variables that have or might have a relationship with human resources data.

In this context, possible changes could be considered, providing a wide range of alternatives and possibilities that can help scan the future upon the premise of what would happen if there were changes in organization policy. Some authors indicated that mathematical expressions such as: balancing equations, linear programming, non linear programming and goal programming may also useful in HRP.

All of the models considered addressed various but different aspects of the HRP process. If we summarise what we have said in this Chapter about models we can deduce that models, if they are to be classified as *useful* HRP models, ought to address some of the following aspects of the HRP process:

- Training and recruitment
- Forecasting human resource needs
- Responding to external conditions
- Human resource flow
- Promotion
- Staff turnover
- Job analysis

- Human resource development

These attributes would apply to both the policy and the mathematical models that were reviewed in this chapter. In addition to the above, it is worth considering further attributes that apply to mathematical models. The fact that a mathematical model can be manipulated to furnish numerical information, for example, is very important in HRP. The additional characteristics of HRP models listed below, that are relevant to mathematical models (and in some cases to policy models), need therefore to be added to the above list when evaluating the effectiveness of any HRP model.

- Ease of understanding and use
- Modelling of complexity
- Forward planning
- Feedback

Below in Table 3.1 we have carried out an assessment against the above characteristics of the policy and mathematical models reviewed in this chapter. All we have done, by way of an assessment, is to allocate two stars in the table if the model addresses the characteristic well, one star if the characteristic is addressed, and no stars (a blank) if the characteristic is not addressed. Nowhere is there any assumption that the star ratings are linearly related or additive. However, the more stars a model has the more useful we may claim the model is (as the model addresses more characteristics).

Characteristic	Tichy and Devanna model	Harvard model	Walker model	Markov model	Holonic model
Trainning and recruitment		*	**	**	**
Forecasting human resource needs	**		**	**	**
External conditions	*	*	**	**	**
Human resource Flow		**	*	*	*
Promotion	**	**	*	**	**
Staff turnover	**		*	**	**
Human resource development	**	*	**		
Hiring and Firing		*	**	**	**
Complexity			*	**	*
Feedback		*			
Forward plan	*		*	**	**
Ease of understanding and use	*			*	**
Controllability and optimisation				*	*

Table 3.1: Assessment of the HRP models against the characteristics listed.

Note: ( ): not addressed,

(*): addressed,

(**): addressed very well

The above table demonstrates that no one model address all of the *usefulness* criteria. However, we will show that system dynamics models do in fact address all of the criteria. Indeed, this fact has been one of the key drivers of the research.

System dynamics modelling is one of a family of continuous system modelling techniques. The technique derives from engineering control theory. Forrester (1961) conducted some pioneering work by combining the fields of feedback control theory, computing, and management science and thereby introduced system dynamics as a modelling and simulation methodology for the analysis of, and long term decision making in, dynamic industrial management problems. Since then, system dynamics has been applied to various business policy and strategy problems (Sterman, 2000). In other examples, Morecroft (1999) has used system dynamics to examine the management behavioural resource system to analyse a diversification strategy based on core and non core business. Coyle (1996) has used system dynamics to manage and control assets and resources in major defence procurement programmes. Hafeez et al (1996) have used system dynamics modeling to re-engineer a supply chain. Also, Hafeez (2003) has used system dynamics to model aspects of human resource and knowledge management - on which this research is based. System dynamics is described fully in the next chapter. Included below in table 3.2, along with the comparison of the policy and mathematical models are the attributes of system dynamics models against the same criteria. As we have stated, the research that follows will demonstrate these attributes.

Characteristic	Tichy and Devanna model	Harvard model	Walker model	Markov model	Holonic model	System Dynamics modelling
Trainning and recruitment		*	**	**	**	**
Forecasting human resource needs	**		**	**	**	**
External conditions	*	*	**	**	**	**
Human resource Flow		**	*	*	*	*
Promotion	**	**	*	**	**	**
Staff turnover	**		*	**	**	**
Human resource development	**	*	**			*
Hiring and Firing		*	**	**	**	**
Complexity			*	**	*	*
Feedback		*				**
Forward plan	*		*	**	**	**
Ease of understanding and use	*			*	**	**
Controllability and optimisation				*	*	**

Table 3.2: Assessment of the HRP models including system dynamics models against the characteristics listed.

Note:

- ( ): not addressed
- (*): addressed
- (**): addressed very well

3.5 The effects of linkage between business and HRP strategies

A review of the literature not only supported the need to integrate the function of human resource planning with business strategies, but also called for a model which would make it possible to integrate the management of the human resource planning function with the planning of organizational goals.

Since the 1970s, human resource planning strategy has become an increasingly important topic for research (Wright *et al.*, 1998). HRP strategy has achieved its prominence because it provides a means by which business organisations can enhance their competitiveness and promote managerial efficiency. By effectively managing their human resources, firms nurture the type of employee behaviour that is essential to the success of their competitive strategy (Schuler, 1992;). Otherwise stated, HRP strategy facilitates the development of a work force that meets the requirements of business competitive strategy, so that organizational goals and missions will be achieved (Collins, 1992; Guest, 1997).

Linking human resource management with business strategy, helps human resource management departments to focus more on skills, behaviours, attitudes and the performance needed for successful implementation of the business strategy Mayo (1990). Research also indicated that strategy evaluation is an activity in the strategic management process that determines to what extent actual change and performance are linked.

The assumption of a close link between business strategy and HRP methods is based on contingency (probability) theory. This theory holds that HRP methods are selected in accordance with the type of competitive strategy adopted by a business. Furthermore, very few studies measure the typologies of business and HRP strategy in exact accordance with the arguments of contingency theory. Guest (1997) suggests that we need to improve our theory and empirical testing of the nature of linkages.

3.6 Summary

The chapter has outlined many issues in human resource planning. The literature review of models used recently in human resource planning shows that organizations forecast their human resource requirements in the medium to long term then they analyse their ability to achieve the forecast level. Much effort has been devoted to developing tools to assist managers with their planning, but many of these were based on the theory of stochastic processes and specifically the concept of Markov chain analysis.

Also a wide variety of basic models and mathematical techniques has been developed and some of them have been used successfully. Unfortunately, these models are often highly mathematical, demanding considerable mathematical sophistication for successful implementation of these techniques, and mathematicians tend not to become personnel managers and even fewer personnel managers subsequently study mathematics. Using transitional probability matrix analysis is complicated, communicating little to the decision maker. In the next chapter we shall show that new models, namely system dynamics models, are easier and more flexible to formulate and solve, prove easier to build and provide a richer picture for the decision maker. Importantly, the use of system dynamics modelling in HRP allows the decision maker to look at system behaviour over time - something which is not readily possible in other HRP models.

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CHAPTER 4

Research Methodology

4.1 Chapter overview

The purpose of this chapter is to present an overview of the research methodology adopted to accomplish the study's objectives, giving a brief justification of the methodology followed by a detailed explanation of the methods employed in this research. Some definitions about system thinking and system dynamics, case study background and the data collection process are also given. The case study, as mentioned in chapter 1, involves HRP in the Libyan petrochemical industry. To contextualise the case study properly it has been necessary to give an introduction to the Libyan economy, the importance of the oil industry to Libya and the importance and necessity to apply good HRP in this sector. It may be helpful to remind the reader that the aim of the thesis is to examine the decision-making process for human resource planning.

4.2 System Thinking and system dynamics

In what follows we aim to show that human resource planning can be successfully implemented if some form of system thinking and system dynamics is used. System dynamics modelling provides an ideal tool for learning about complexity in a system, and is necessary because the accelerating pace of change is transforming our world from the prosaic to the profound.

4.2.1 System thinking

System thinking has its foundation in the field of system dynamics, founded in 1956 by Forrester and then developed by Van Bertalanffy (1986). In general, system theory is now best characterized by the work of Checkland and Scholes (1990). System thinking is now a recognized approach to understanding and testing out new ideas about systems, be they social or mechanical. The approach of system thinking is fundamentally different to that of traditional forms of analysis. Traditional analysis focuses on separating out the individual elements of what is being studied, whilst system thinking focuses on how an entity of the system being studied interacts with the other constituents of the system.

The basis of system thinking is that a holistic approach, in which emphasis is put mainly on the interrelationship of individual parts, improves the results (Kramer and de Smit, 1977). This is based on the premise that "the whole is more important than the sum of its parts", also known as Gestalt, (Wertheimer, 1923). System thinking is a methodology to approach and solve problems. Kramer and de Smit, (1977) give a definition of a system as being a set of interrelated entities of which no subset is unrelated to any other subset .

Therefore the character of systems thinking makes it extremely effective for the most difficult types of problems to solve, such as those involving complex issues, those that depend a great deal on the past or actions of others. And another important concept in system thinking is the environment and system boundary. The boundary is determined by a number of criteria that system entities or elements have to fulfil to be considered part of the system.

4.2.2 System Dynamics

"System dynamics is a computer aided approach for analysing and solving complex problems with a focus on policy analysis and design" (Forrester, 1961). System dynamics modelling is that part of management science which deals with the controllability of managed system over time, usually in the face of external shocks, Coyle (1977). System dynamics is one of a family of continuous system modelling techniques which focuses on the structure and behaviour of systems composed of interacting feedback loops. This technique derives from control system theory. Models generally use Euler Integration. System dynamics models allow highly complex models to be constructed and solved without the complexities and limitations of differential calculus or matrix algebra.

Jay Forrester (1961) conducted some pioneering work by combining the fields of feedback control theory, computing and management sciences as early as 1961 in order to shape the systems dynamics discipline. System dynamics is a method for developing management "flight simulators" to help us learn about dynamic complexity and understand the sources of resistance to design more effective policies (Sterman, 1994). The method allows us to study and manage complex feedback systems by creating models representing real world systems. However, successful intervention in complex dynamic systems requires technical tools and mathematical models. This process is fundamentally interdisciplinary, because it is concerned with the behaviour of the complex system, and is based on the theory of non-linear dynamics and feedback control developed in mathematics and engineering (Coyle, 1996). On the other hand, it is a modelling approach that considers the structural system as a whole, focusing on the dynamic interactions between components as well as behaviour of the system at large.

More recently, tools such as systems thinking have made many gains in soft systems problem structuring as advocated by Senge (1994). In other examples, Morecroft (1999) has used system dynamics to examine the management behavioural resource system to analyse a diversification strategy based on core and non-core business. Winch (1999) has used system dynamics to introduce a skill inventory model to manage the skill management of key staff in times of fundamental change. Coyle *et al* (1999) has used system dynamics to manage and control assets and resources in major defence procurement programmes. Warren (1999) defines tangible and intangible resources for system dynamics model development. Hafeez *et al* (1996), has used system dynamics modelling to re-engineer a supply chain. Mason-Jones *et al* (1998) have extended the work of Hafeez (2000) to show its applicability in an Efficient Consumer Response (ECR) environment by linking it to point of sale inventory triggers. System dynamics has been defined as a methodology to create models of real world systems and study their behaviour in order to improve and re-engineer problematic system behaviour (Wostenholm 1990).

Furthermore, managers in organisations and businesses are faced with a dynamic, complex, and uncertain, environment in which to make decisions. The factors affecting decision outcomes change over time, results are not known at the time decisions are made, and often long delays exist between the time the decision is made and when results are known. One method managers can use to improve decision making in such an environment is to apply sophisticated management tools. These tools allow managers to explore the effects of different decisions, view outcomes, and learn about factors that influence results. That is, management tools can be like flight simulators in that they allow managers to learn about the potential implications of current decisions. Learning about the consequences of different decision options should improve managers' performance.

The System Dynamics approach provides a means of describing rich, complex problem situations in a way that ensures all assumptions are consistent, explicit and easily communicable, as well as providing the analytical power to process this rich model without complex mathematics. The use of simple flowcharting techniques and spreadsheet models avoids all the problem of alienation and distrust associated with "black box" techniques. This not only produces better models but encourages a healthy modelling process with a close relationship between modeller and decision maker (Brian and Cain, 1996). The development of any simulation model starts from a simple model of the system and then to more complex model of the system, and it is not a linear process as can be seen from the Figure (4.1)

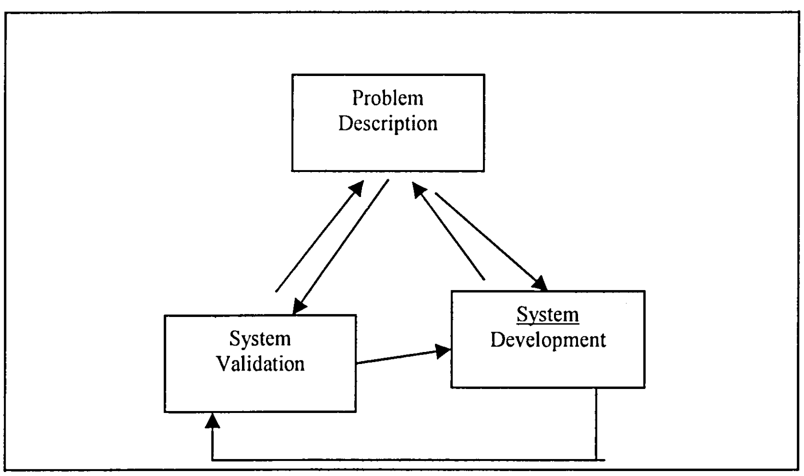


Figure 4.1: Model development process (Strohhecker, 2000)

The model development process is iterative starting from the problem description of the situation and the description of the purpose of the model. The system development deals with the development of the model itself by identifying the structure and main components of the real system and translating them in terms of relationships. Finally the model is constantly validated during the development process; therefore, a key step in model development is the model description with the clear statement of the models aim (Forrester, 1968).

4.3 System Dynamics Methodology

System dynamics has been defined as a methodology to create models of real world systems and study their behaviour in order to improve problematic system behaviour (Wostenholm, 1990). Modeling of any system is fundamentally a creative and intensive process. Assumptions are made at various steps of the modeling process. These assumptions need to be tested from the data that are gathered and analyzed from the field, and the models are then revised based on the results. However, there are no particular strictly defined rules of modeling (Sterman, 2000). The involvement of the decision maker at all the steps of the modeling process is crucial.

Definitions of research methodology vary considerably. In most dictionaries, methodology is defined as a set of methods and principles used when studying a particular subject. Bernardo *et al* (1999) have defined system dynamics as a methodology to create models of real world systems and study their (dynamic) behaviour in order to improve and re-engineer problematic system behaviour.

The methodology used in this research is System Dynamics Methodology. System dynamics is a methodology for studying and managing complex feedback systems. It means exactly what its name implies: it's concerned with creating models for the representation of real world systems of all kinds and studying their behaviour. In particular it is concerned with improving the ability to control problematic system behaviour. System dynamics is fundamentally interdisciplinary, because we are concerned with the behaviour of the complex system, and it is also grounded in the theory of non-linear dynamics and feedback control developed in mathematics and engineering. We apply these tools to the behaviour of human as well as technical system, to improve our abilities to learn about and manage complex system and to develop cause and effect relationships between the variables of a system by using causal loop diagrams which provide an essential tool of system dynamics (Coyle, 1996).

"System dynamics is a rigorous method for qualitative description, exploration and analysis of complex systems in terms of their process, information, organizational boundaries and strategies, which facilitates quantitative simulation modeling and analysis for the design of system structure and control". Sterman (1994),

The methodology of system dynamics consists of two phases: the qualitative phase and the quantitative phase. The definition is expounded in Figure 4.2 which provides a summary of steps involved in the method and their purpose.

The quantitative phase is associated with the development and analysis of the simulation model. The main stages involved in the qualitative phase are system input-output analysis, conceptual modelling, and block diagram formulation. The first step towards the quantitative model building is to transform the conceptual model into block diagram format. The flows of information and materials are to be represented via various paths. Organisation manpower needs, ordering and other physical/administrative operations are to be represented using blocks. The simulation model is to be verified by relevant personnel and validated against the field data

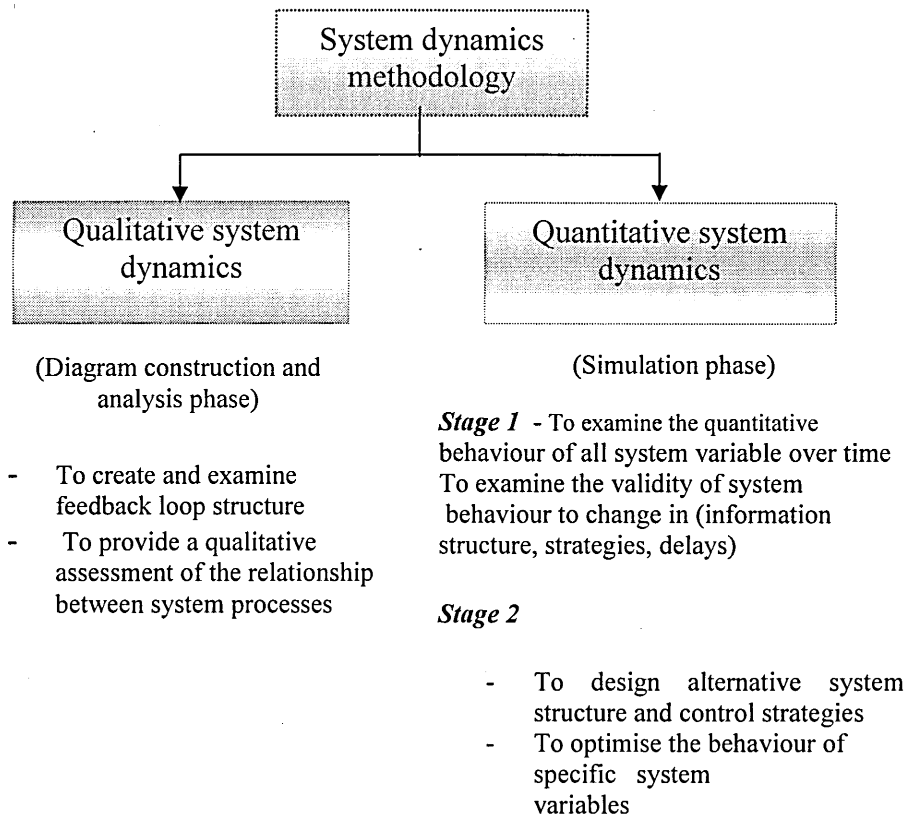


Figure 4.2: System dynamics methodology Adapted from Coyle 1976

Qualitative system dynamics is based on creating cause and effect diagrams and creating and examining the feedback loop structure of the system using resource flows, represented by level and rate variables and information flows. It provides a qualitative assessment of the relationship between system processes. It can be used to estimate system behaviour and to postulate strategy design changes to improve behaviour.

The system dynamics method is based on the premise that a system is composed of two components: process structure and information structure. There are also two generic building blocks which can be used to represent the structures. These are resource flows and information flows. The processes within a system are not easily visible and in order to create a sound process perspective of a system it is usually necessary to stand back from the system. The system dynamics approach to creating the process structure of the system is to recognize that the fundamental process in any natural or managed system is that of converting resources between states. The word resource here should be treated in the widest sense and could include people, material, orders, goods, cash and knowledge. Therefore, the major use of system dynamics is to identify information feedback loops which have been created by linking resource and information flows and analysis of loops which facilitates understanding of how the process information and strategies of systems interact to create system behaviour.

The main objective of system dynamics approach is to capture the dynamic interaction of different system variables and to analyze the impact of policy decisions over the long term horizon. This requires system boundaries to be defined and a model of the system built. The systematic procedural steps in system dynamics modeling include the following (Roberts 1978).

1- Define the problems to be solved and goals to be achieved

2- Describe the system with causal loop diagrams

3- Formulate the structure of the model and develop flow diagram

4- Collect the initial data needed for operation of the model

5- Validate the model

6- Use the model to test various actions to find the best way to achieve prescribed goals.

This research work proposes to use system dynamics as a tool to analyze the human resource-planning problem associated with many organizations. It will highlight the value of modelling and analyzing human resource inventory.

4.3.1 An Integrated System Dynamics Framework

The research work will be conducted by adopting an integrated system dynamics framework developed by Hafeez *et al.* (1996), which is illustrated in Figure 4.3. The framework has been successfully used for modeling and analyzing a number of supply chains. Essentially, it consists of two overlapping phases, namely qualitative and quantitative. The qualitative phase is related to acquiring sufficient intuitive and conceptual knowledge to understand the structure of inventory control (Hafeez *et al.*, 1996).

Quantitative system dynamics is related to computer simulation modeling. This is the more conventional and traditional phase in system dynamics and involves deriving, with system actors, the nature of relationships between all variables within the diagrams, the calibration of parameters and the construction of simulation equations.

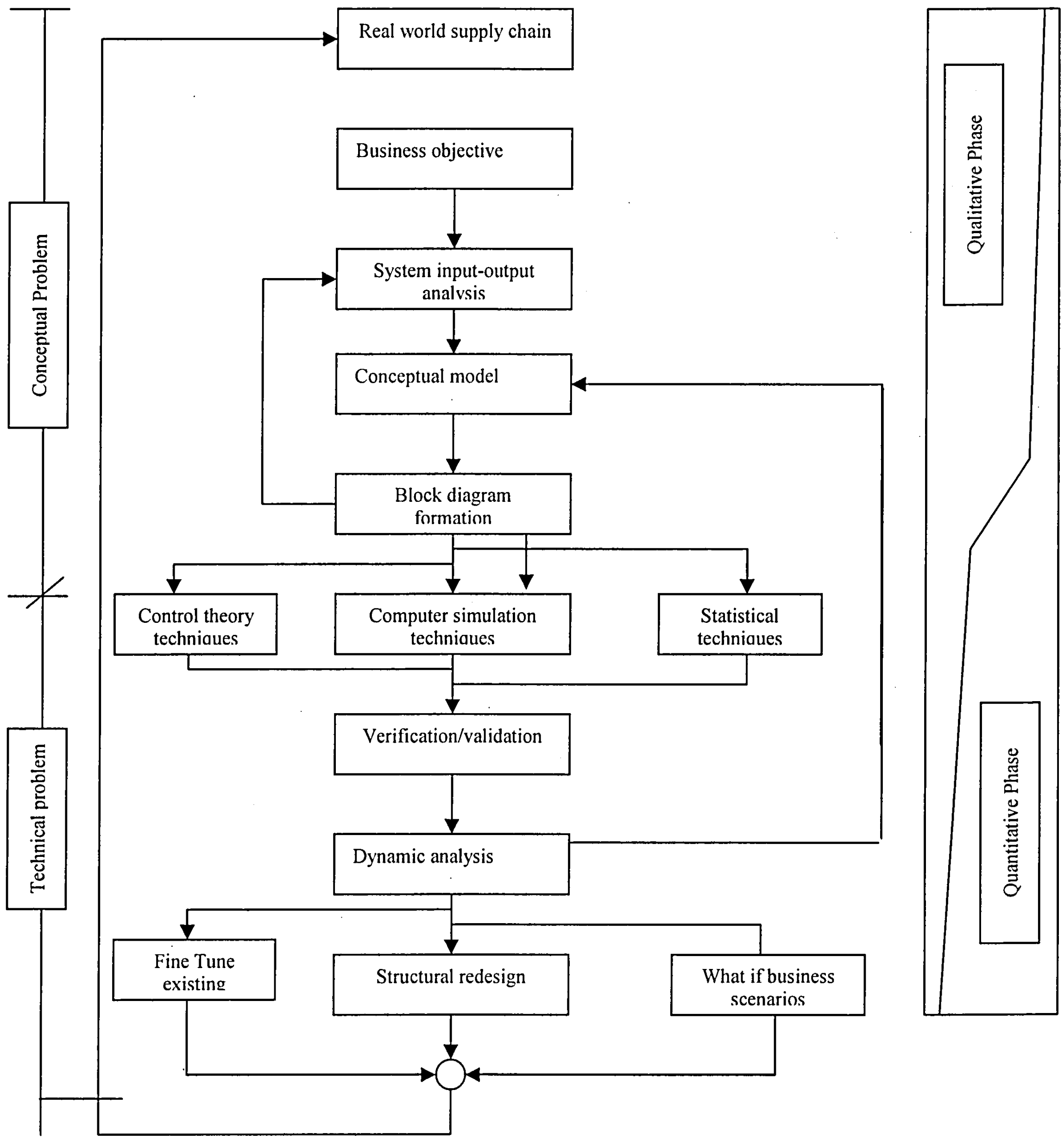


Figure 4.3: Integrated system dynamics framework (Source Hafeez *et al.* 1996)

Therefore, to improve our ability to learn about and manage complex systems, we need tools capable of capturing the feedback processes, stocks and flows, time delays, and other sources of dynamic complexity. The tools must help us evaluate the consequences of new polices and new structures we might design. These tools include causal mapping and simulation modelling.

Table 4.1 lists a number of industrial engineering tools used for information collection and processing at the qualitative stage.

Information source	Knowledge source
Written documents	Content analysis
Individual	Questionnaire Interview Log book
Group of people	Brainstorming Work shops
Investigative methods	Flow charting Fish bone diagrams Pareto analysis Information flow analysis
Numerical methods	Time series analysis Constrained curve fitting

Table 4.1: typical approach used for data collection and information processing (Adapted from K. Hafeez *et al* 1996)

System dynamics lies in discovering and representing the feedback process and other elements of complexity that determine the dynamics of systems. One might imagine that there is an immense range of different feedback processes to be mastered before one can use system dynamics effectively. In fact all dynamics arise from the interaction of just two types of feedback loops, positive (reinforcing) and negative (self correcting) loops.

Towill (1982) in his paper entitled "Dynamic analysis of an Inventory and Order Based Production Control System" introduced the IOBPCS model, which is the acronym for Inventory and Order Based Production Control System (IOBPCS). This means that a company which sells from stock usually takes the stock level (Inventory level) into account when planning future production. If inventory is too high, production will usually be cut back to some extent and vice-versa. This means that the level of production required (order rate) is based upon the level of demand which has been averaged over a period of time and the level of current inventory in comparison with a target inventory. The order rate is a function of stock error (i.e. the gap between actual and target values) and the average demand. This creates a feedback loop, where inventory affects production which affects inventory which in turn, influences production again, and so on.

In HRP the actual staff level is what we are aiming to maintain and control. It will fluctuate as staff leave the company. The only way we can control the staff level, and maintain it at the target staff level, is by recruited staff entering the staff pool. To do this we first forecast the rate at which staff leaves the company. This forecast will be based on past, known staff leaving rates. Staff will leave for a number of reasons and fluctuations in the leaving rate will typically be irregular and possibly seasonal.

This mean that the level of recruitment demand required (recruitment order rate) is based upon the level of staff leaving and the actual staff level in comparison with the target staff level. System dynamics is concerned with identifying and modeling these loops and by analyzing the feedback behaviour over time, improvements in system performance can be implemented.

The strengths of System Dynamics is that it looks at the polices as well as the processes. Because system dynamics enables the polices to be included in the model as well the processes, this enables problems with polices to also be addressed. Many models only look at the processes involved; this is quite narrow thinking as it can be just as likely that policy is important. The policy may be formal or documented or informal.

4.3.2 The process of system dynamics

Coyle in his book "System Dynamics Modelling" has divided dynamics analysis into five stages as bellow :

1. Problem Recognition (To recognize the problem and to find out which people care about it and why)
2. Problem Understanding and System Description (Description of the system by using influence diagram or causal loop diagram)
3. Qualitative Analysis (Bright ideas and pet theories)
4. Simulation Modelling and model testing (Special computer simulation languages)
5. Policy testing and design (Exploratory modelling and policy design by simulation (objective function). Policy design by optimisation

Figure 4.4 shows the technical stages in the system dynamics methodology, but it is also useful to look at the same ideas in another way to emphasize the relationships between stages of work and the results to which they give rise. The left hand side shows the stages of system dynamics and the right hand side shows the results produced. For example, stage 3 qualitative analysis leads from system description to understanding the ideas and may lead back to the problem definition stage. And the stage 5.1 corresponds to use of the model to verify ideas generated and to stimulate new ideas.

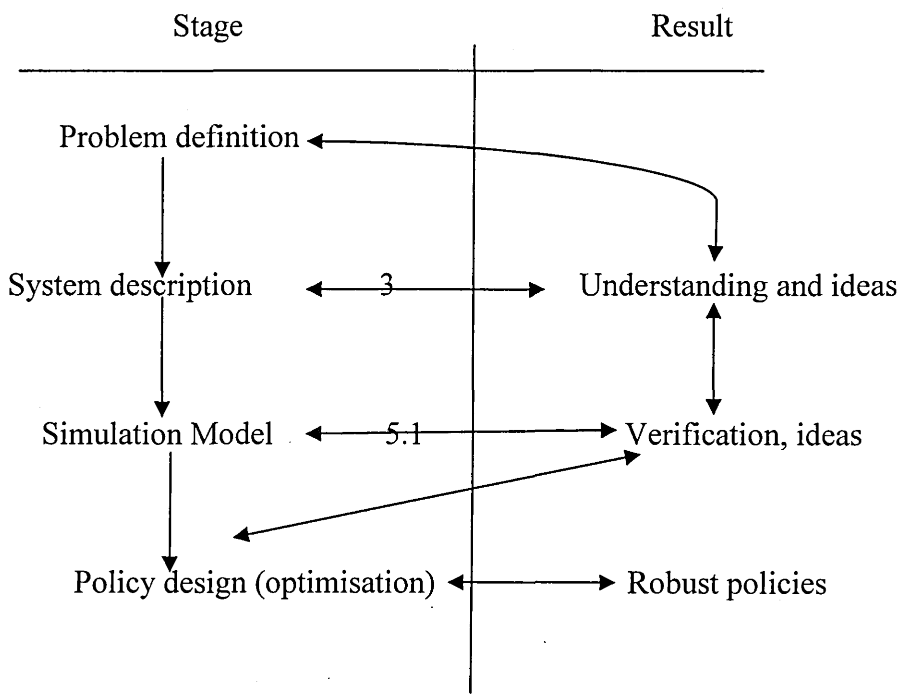
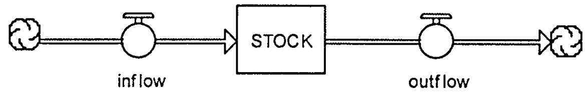


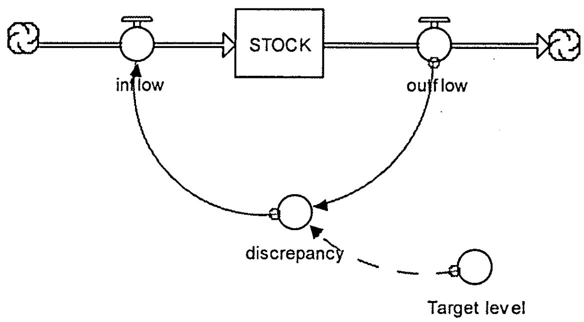
Figure 4.4: Process of System Dynamics
Source Coyle (System dynamics modelling)

4.3.3 System Classification

There are two classes of system: Open loop and Close loop or "*feedback*". In the open loop system, the output arises from the input but has no effect on the input. Which means the output has no influence on the input; the system consists only of a forward path. The system could easily be made into close-loop form by connecting the output to the input (Coyle, 1977). The difference between open loop and close loop systems is shown in Figure 4.5



(a) An open loop system



(b) A closed loop system

Figure 4.5: Open loop and closed loop systems

The distinguishing feature of the close loop system is a feedback path of the information, choice and action, connecting the output back to the system, which creates a closed chain of cause and effect. Much of the art of system dynamics modelling is discovering and representing feedback processes which, along with stock and flow structures, time delay and nonlinearities, determine the dynamics of a system (Sterman 2000). A closed loop system, which tries to regulate a system variable level, requires two factors for its operation

- *A discrepancy between actual level and target level*

- *A policy which specifies the action to be employed for a given size of discrepancy.*

There are two types of feedback loop, Positive and Negative, which are the most common in managed systems

1. Positive Loop: (A positive feedback loop is one which acts to reinforce a change in a system level and moves the level even further in the same direction as the initial change).
2. Negative Loop: (A negative loop is a goal seeking one, i.e. it tries to move a level towards some desired target by creating action in the opposite direction from the discrepancy between the actual and target values of the level).

4.3.4 System dynamics performance measures

The dynamic behaviour of human resource planning is very important, and therefore the dynamic performance also needs to be looked at to complement the static performance. According to Bowersox and Closs (1996), the objectives of performance measurement and controlling activities are to track performance against operating plans and to identify opportunities for enhanced efficiency and effectiveness.

Therefore, the dynamics measures of performance utilized in this thesis need to be selected. The System dynamics performance criteria are used to assess the dynamic behaviour of different models presented in Chapter 5, 6, 7 and 8. The dynamic behaviour needs to be assessed for a change in demand. Many authors on supply chain dynamic simulation showed that the main performance criteria studied are the level of inventory (Strohhecker, 2000), (Chen *et al.*, 2000; Diseny, 2001), the integral absolute error for the inventory level and the production completion rate (Hong-Minh, 1998).

The performance is measured using six criteria: peak value, peak time, order recovery, stock depletion, trough time and stock recovery time (Mason-Jones, 1998). The first three criteria are calculated for the order rate, and the last three criteria are based on actual inventory level. However, these six criteria can be summarised using integral time absolute error (ITAE). When ITAE is calculated for the actual inventory level, the area considered is the difference between the actual inventory level and the target inventory level, Stalk and Hout, (1990).

4.4 Oil Discovery and Production in Libya

The main objective of these case studies is to investigate the development of human resource planning in the oil industry in Libya. This cannot be achieved without understanding the surrounding environment in which managers are functioning. Today, the world is looking at Libya as an important country, which plays a significant role in global, political and economic issues. Its significance derives from many factors; these are political, strategic, religious, and economic. Libya is one of the largest oil producing countries and its huge oil reserves indicate that it will play an important role in the oil market for a long time to come, at least for the first decades of the 21st century. Although the environment affects the conditions and denotes the states and current circumstances which confront managers and shapes their management activities, the historical overview is indispensable for seeing the environment from its wider perspective. This section will provide the reader with a better understanding of Libya. It will provide general background information about

Libya. and we will talk about the Libyan economy and oil discovery and production, and the data collection process.

Libya depends on oil as a major source of income (Selway, 2000). Apart from hydrocarbons, Libya is relatively poor in other resources. Prior to the discovery of oil in 1959, Libya was one of the poorest countries in the world (Higgins, 1968; Wright, 1981). During the Italian and then the British rule (1911-1951), the country's economy had improved compared with the primitive conditions the Italians found the country in when they first came to Libya in 1911. It was the American and the British money in return for the use of military bases in Libya and the aid from the UN and other organizations, which helped the country to survive and overcome the economically severe years of the fifties. The population was engaged in agriculture and animal husbandry (Higgins, 1968). The few relatively large enterprises in the country were controlled by Italian expatriates (Bait El-Mal et al, 1973). In contrast to neighboring Algeria, Tunisia or Egypt, the colonial economy in Libya did not create clear domestic financial, commercial, capitalist or agriculture firms that have close economic relationships with colonial powers (Vandewalle, 1998). Industries, which had been established prior to the discovery of oil, were mainly focused on processing the local agriculture products, which included flour, textiles, tobacco, footwear and clothing. The country's economy was suffering from deficit in the budget and was based on the limited productivity of a primitive agricultural sector and a few small industries (Agnaia, 1996). Benjamin Higgins, an economist specializing in economic development who worked as an economic adviser to Libya in early 1950s, described the country's economic conditions in the following way:

"*We need not to construct abstract models of an economy where the bulk of people live on a subsistence level, where per capita income is well below $50 per year,* *where there are no sources of power and no mineral resources, where agricultural expansion is severely limited by climatic conditions, where capital formation is zero or less, where there is no skilled labour supply and no indigenous entrepreneurship. When Libya became an independent nation...it fulfils all these conditions. If Libya can be brought to a stage of sustained growth, there is hope for every country in the world." (Higgins, 1968*).

The Libyan economic situation did change after the discovery of oil in 1959 and the inflows of foreign capital. After 1959, the need for direct foreign subsidies declined as international oil companies began to invest in Libya. The investment in the oil industry brought surplus to the country's economy in general. The oil revenues accounted for 24.4 per cent of the country's Gross Domestic Product (GDP) in 1962, 61.7 per cent in 1969 and 28.3 per cent in 1992. By 1968, Libya was the second largest oil producer in the Arab world. Per capita income climbed from below $40 in 1951, $1,250 in 1967 (Bait-El-Mal, et al 1973), to $10,985 (LD3,252)[1] in 1980, and then decreased to approximately $6,064 (LD2,426) in 1997 as shown in Table 2.1. The contribution of the oil sector in the GDP reached its highest in 1980 (LD6, 525.7 million) while non-oil sector's highest contribution in the GDP was in 1997 as it reached LD 9,998 million.

	1967	1970	1975	1980	1985	1990	1997
GDP (LDM):	747.8	1,288.3	3,674.3	10,553.8	7,852.1	7,749.6	12,975.5
Oil sector	402.5	812.6	1,961.1	6,525.7	3,500.4	2,740.8	2,977.5
Non-oil sector	345.3	475.7	1,713.2	4,028.1	4,351.7	5,008.8	9,998.0
Per Capita (LD)	430	656	1,369	3,252	2,140	1,600	2,426
Per Capita ($)	1,250	2,216	4,624	10,985	7,228	4,320	6,064

Table 4.2: GDP and Per Capita income in Libya in the period 1967-1997
Source: Economical and Social Development Achievements in 28 years, 1998: 14, and Economic and Social Indexes (1962-1996), 1997: 46 & 52.

[1] LD denotes to the Libyan currency, Libyan Dinner.

During the period 1951-1969 (from the independence to the revolution), the Libyan economic system was mainly capitalist. Private ownership existed with minimum governmental interference. Public ownership was in sectors that required large scale investment. The government initiated a number of measures to encourage competition and the establishment of private businesses. These included the issuance of import and export laws demanding that the import of competitive foreign goods be subject to license, the establishment of the Industrial and Real Estate Bank of Libya (currently the Development Bank) to provide loans to Libyan businessmen to build local industries, and the establishment of the Industrial Research Center to help implement the country's development plans by providing technical and economic services in both the public and private sectors (Bait El-Mal et al, 1988). Since the discovery of oil, the country has changed from deficit to surplus. Since the revolution in 1969, the country has changed from capitalism to socialism. State intervention in the economy has increased and the government started expanding the public sector and cutting back the private sector. The State ownership structure of businesses, started in early 1970s, gained momentum in the mid-1970s and reached its peak in the 1980s where most of the businesses became owned or controlled by the State. The State became to dominate all manufacturing activities, foreign and domestic retail trade, and banking and insurance services.

However, whilst the Libyan economy was characterized by its central control and authority policies, some private companies had emerged and started to operate in Libya in the 1990s-2000s period. This was mainly due to the crises the Libyan economy had faced in the late 1980s and 1990s as economic conditions and standards of living worsened as world oil prices slumped (The Economist Intelligence Unit, 1997-1998). In response to these crises, the State introduced a series of liberalization measures that for the first time since 1969 included a significant role for the private sector. The overall goals of these measurements were to cut public spending, to gradually withdraw subsidies that contribute to such spending, and to promote private sector initiatives in different sectors (Vandewalle, 1998). The first set of reform measures, adopted in 1987 and 1988, allowed the creation of self-management or collective ownership businesses. Other developments included the issuance of regulations governing the privatization of selected public enterprises and the lifting of restrictions on private wholesale trade. In 1992, to enhance economic development, the government passed Act number 9 to enhance and regulate the private sector activities in the national economy and to open the door for the privatization of a number of public-sector companies. The Act's main objective is to regulate and enhance the role of the private sector activities in the economy. The Act specifies the economic sectors that the private sector and individuals can operate in, which include production, distribution and services. These activities are in areas such as agriculture, industry, commerce, tourism, transport, finance and the private practice of professionals. The Act permits the establishment of privately funded companies and family and individual activities. Based on a recommendation of the General People's Committee, the Act allows the selling of publicly held companies to private ownership. In 1997, the State issued Act number 5 regarding Foreign Capital Investment Encouragement, secretary of industry (1999). The Act aims at encouraging foreign capital investments within the overall policy of the State and the targets of economic and social developments. In particular, the Act encourages foreign investments in areas that would result in transferring modern technology, variation of income resources, and contributing to the development of the national products so as to help in its entry into the international markets.

In the period that immediately followed the independence, the first and foremost task for the government was to rebuild the inherited damages, which had accumulated over the long period of struggle against several external invaders. Further, the lack of economic resources at that time had curbed the government from launching the necessary wide scale programmes to repair the inherited damages in all area of the country's infrastructure. However, the discovery of oil in the Zeltin concession by ESSO company in 1958 and the beginning of volume exporter states in 1964, alleviated the government burdens and allowed it to embark on several development plans in order to reconstruct the economy into a developed nation economy and restructure the social and political systems.

The oil revenues have been a major source for restructuring the Libyan economy. In the years following oil discovery a large number of small factories were established for manufacturing agricultural products and other light industries; these factories included plant for olive oil refining, fish canning, leather tanning, and vehicle repairing, and some other production units. The oil revenues affected the industrial production during the first decade of the oil era between 1965-1968. However the contribution of the industrial sector to the country's GDP declined from 11% in 1958 to 5.5% in 1962 and 2% in 1968, (The Secretary of Industry (1999 & 2000)). Oil discovery brought the attention of many International oil companies to invest in this newly lucrative business, and the Libyan people began to experience a new era of spending. Exporting of goods began to increase which, affected external trade to a large extent. Oil revenues contributed to transforming the trade balance from a relatively big deficit of LD 207,677millions in the 1950s to an increasing surplus of LD 593,946 million during the 1960s (Ateiga, 1972). Development plans were drawn up to include all sectors of the economy and political systems as well as social lives of the Libyan people.

4.5 The Growth of HRP in Libya

In Libya the growth of human resource planning can be traced to the middle of the 20th century. From 1960 to 1975 several changes occurred in management thought. These rapid and significant changes have effected the acceptance and the application of human resource management in Libyan planning systems (Secretary of Planning 1981-1985).

Some of the notable changes are (a) planning, (b) organizing, (c) controlling activities at business branches. Decision makers realized the benefits from advances in scheduling methods, time and motion studies, and financial control system of the organizations, while less attention was given to human resource. Labour was seen as an inexhaustible resource that was readily available and easily controlled and adapted to any new conditions and situations as was warranted. Before planning for acquisition of personnel and training, development of human resource generated little interest from management and some primary human resource common planning practices were largely used before 1975; very few corporations had adopted formal human resource planning departments.

The emergence of skill shortages in technical and executive positions in the late 1970s and 1980s in the business organizations gave more attention to acquisition, retention and internal career talented employees.

The emergence of employee rights legislation that began in the mid 1970s stimulated more interest in human resource planning management in the organization. Also the creation of comprehensive human resource planning systems was also emphasized by the decision makers for requirements for affirmative action plans and by enforcing some changes in social attitudes and behaviours toward corporate responsibilities in dealing with employees.

The start of technological innovation is a major force behind the propagation of human resource planning systems in corporations. Technology raced ahead of qualified talented employees and the technological innovation inevitably spawned more jobs in high talent professionals, such as technical and managerial occupations in business organizations. The emergence of technological advancement created conditions that have fostered a need on the part organizations to predict requirements for potentially scarce employees early to focus more attention on the needs of organizations.

Business executive have recognized the benefits to be gained through accurate and more effective use by management of human resource, which has also prompted organizations to utilize human resource methods.

Therefore Libyan oil petrochemical companies often require skilled technical manpower to meet their demand. Most Libyan petrochemical companies recruitment section coordinates closely with recruitment agencies and industrial worldwide, to supports the Human resources development activates by sourcing suitable educational facilities for occupational training by selecting top level courses of highest standard.

4.6 Target Case Companies

The target sector for this study was the Libyan petrochemical sector. The focal companies for this study were the largest Libyan companies involved in oil exploring and oil production. The companies were large-sized subsidiaries employing large groups of staff. The companies had an excellent image and had traditionally enjoyed a privileged position in the market with a certain security of contract and flexibility to regulate prices. This research is going to conduct case studies in Libyan petrochemical sectors; also the model would be extended to see their applicability in human resource planning section.

The following data will be collected for design and use of the model:

-Number of staff in each level for the past 5 years

-Number of people hired in each level for the past 5 years

-Number of people leaving in each level for the past 5 years

-Training programme for the past 5 years.

-Time to recruit new staff for the past 5 years.

Our source data are the personnel files of the selected companies that contain the promotion history of incumbent employees since their entry in the company to our observation point; there are about 2000 valid records, one for each employee, and the data were collected by conducting structured interviews with the executive staff of the above mentioned companies training top and middle managers in the training and human resource department of the company. And obtained from the company annual report in core data. The data will then be implemented to determine rates of change within a model for the staff; the data will be manipulated to determine the retention ratios and several ratios within a cohort survival model.

4.6.1 The Field Study and Data Access

Due to the fact that the Libyan economy is heavily dependent on oil resources, the Libyan government aimed to diversify development plans on its economy. This aim was achieved through establishing new public companies and through converting most, if not all of the private companies through nationalisation into public sectors. This means the public sector companies monopolize the Libyan economy and cover all the principal activities, including manufacturing industrial, petrochemical industrial trade, marketing, agriculture, for example, industries such as cement, steel, foodstuffs, electronics, animal feedings and other supervised by the Secretary of Industry. Oil companies subsume all oil activities such as exploring, producing, manufacturing and marketing which is supervised by the Secretariat of Oil through National Oil Companies (NOC). Before the structural change, when some of the largest companies were moved from the Secretary of Industry to be supervised by the Secretariat of Oil. This decision was taken for several reasons:

- Oil is a depleting resource and its explored reserves are limited. Beschorner and Smith (1991, P. 3) reported that " at current production rates reserves might last another 50 years, but Libya's fields have proved difficult to manage and prognosis for new fields is not particularly encouraging".
- Oil is the main (backbone) resource of the Libyan economy 95% of total Libyan exports in 1992 was oil, with average of 91% for the period from 1972-1993).
- The oil sector recruits large numbers of trained workers, which cannot be found in any other sector. Also the pilot study revealed that it is more organised, producing up to date statements and reports and maintains good archival and documentary records. This point increases the chance that the

research issues are understood by the supplying the information and at the same time allows the researcher to triangulate his evidence from the archival and documentary system.

- Allocation of considerable funds to oil related industries, such as oil refining and petrochemical industries, through a number of development plans as a part of the government policy to diversify its economy is evidence that the oil sector is important for the whole Libyan economy.

4.6.2 Data collection process

Since the oil sector is responsible for the single most important resource in the Libyan economy, the process of obtaining permission to access and to collect the research evidence from the sector was not an easy task. Collecting the data for the study was divided into three parts:

- Interviews
- Document analysis
- Observation of management meetings.

4.6.2.1 Interviews

To assimilate the feelings and behaviour of practising managers towards organisational processes, it is essential to spend considerable time talking to managers in the field (Bogdan, 1984). This was achieved with the help of personal friends who work within and outside of the field, as well as by building cordial relationships with the participants. It is worth mentioning here that the support and corporation for this study was considerable. For example, the researcher was provided with an office at which he could organise his work, and be easily approached by or approach participants to meet, discuss or to consult regarding day to day work. The office was at the Department of Planning and Control.

In addition, support of the company general manager, personnel and comptrollers greatly assisted the researcher to fulfil his mission. This support was usually offered in two ways: formal and informal. The formal support including issuing permission, memos, and verbal orders from general manager to another departments, from the executive manager to the heads of departments of the companies, from the head managers to the departmental managers, from departmental managers to the office managers, and from the office managers to the personnel under them. The informal support included personal friends introducing and recommending the researcher to managers at all levels of the oil sector. Formal support was important to satisfy management routine and bureaucracy, and the informal support was important to hear, observe and discuss what managers or decision maker actually do rather than what should be done. Although, the researcher informally started his pilot study and data collection before the permission was granted, the researcher was able to take part in the day to day work of managers by attending their meetings and discussions or by consulting with them on certain issues and problems.

Although an interview schedule was devised for interviews during field work did help the researcher to collect data unobtrusively by attending the demonstrations, explanations, etc. The success of the interview as well as other phases of data collection was two fold: friendly relationships and the importance of the study. Close friends provided unlimited favours to help this study in that they introduced the researcher to and arranged appointments with the important managers, and encouraged interviews to describe the phenomena in a relax way, without fear of highly confidential information being misused. Also a number of the people supplying information were themselves close friends of the researcher and were keen to draw a real picture of the phenomena. The second reason was that the managers seemed to believe that there were substantial problems in management controlling their companies and believe also that solving this problem should start from works like this study, which describe and understand the existing situation.

Arabic was the language of all interviews, except with non Arabic managers and most of managers prefered using Arabic language because they felt more confident using it rather than using English , Hence, minor translation problem can not be avoided in attempts to translate the feelings and behaviour of managers from one language to another. The technique which is widely used to deal with this problem is called back translation (Mitchell, 1965).

After spending about two months collecting data from Libyan petrochemical companies the researcher started the second phase of the main study, namely document analysis.

4.6.2.2 Document analysis

The study of documentary materials was very important in understanding the planning programme, and in collecting empirical data several documents were collected for example the personnel files of the selected companies that contain the promotion history of incumbent employees since their entry in the company to our observation point. There are about 2000 valid records, one for each employee. The data will be manipulated to determine rates of change within a human resource planning model for the staff; the data will be manipulated to determine the retention ratios and several ratios within a cohort survival model.

4.6.2.3 Observation of management meetings

Bogdan & Taylor (1975) argue that no single method can completely capture all the relevant features of reality. They argue that a researcher needs to employ multiple methods to analyse a phenomenon in depth. Therefore, along with the interviews and documents analysis it was thought that attendance at management meetings would be useful for understanding control systems in the companies. Some management meetings were observed, exploring phenomena as they emerged during observations (Yin 1984). This helped cross check the information obtained from interviews and documents. The potential problem of observing meetings was that the presence of an outsider sometimes could affect the normal conduct of the meetings as staff regard the researcher as an outsider who was not supposed to be in their meetings. As discussed earlier the researcher was friendly and informally treated so this problem was not encountered in this study.

4.6.2.4 Participant observation

Participant observation is an core field strategy to gather information about the phenomena in practice (Patton, 1987). Participant observation, according to Denzin (1978, p 183).

> *Simultaneously combines document analysis, interviewing of respondents and information's, direct participation an observations and introspections.*

The importance of Participant observation is to develop an insider view of what is happening in the settings. The researcher worked directly with managers in general administration, planning as well as other departments of control of the case company, attending most of the introductory, explanations and discussing meetings for planning programmes. This helped the researcher observe and gain first hand knowledge of the preparation and use of planning programmes and control systems in the company. The company provided full support in this respect: an office, staff support, actual visit, workshop, training centre, and other supporting facilities. Thus, direct observations allowed the researcher to get close to the setting. This allowed the researcher to gain personal knowledge of the decision process in the case company.

4.7 Summary

This chapter has reviewed in detail system dynamics, system thinking, system techniques and the methodology used in this research. The chapter has also introduced the integrated system dynamics framework. A review of HRP in the Libyan petrochemical industry has also been presented. To contextualise the case studies properly it has been necessary to give an introduction to the Libyan economy, the importance of the oil industry to Libya and the importance of applying good HRP in the petrochemical sector. Further background about the case studies was introduced and described the data collection process, where collecting the data for the study was divided into three parts: interviews, document analysis, and observation of management meetings.

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CHAPTER 5

An Elementary Analysis of the "SKPM" Model

5.1 Chapter overview

This chapter presents a basic analysis of the Skill Pool Model (SKPM). Simple influence and block diagrams are presented to aid understanding of the model along with transfer functions. The model is then applied to data relating to our case studies to improve our understanding of the dynamics of staff turnover in a company. By analysing the behaviour of the model under certain inputs it will be possible to find the optimum policy parameters with regard to recruitment and training in the two case companies.

5.2 Introduction

The modelling and analysis of systems, be they manufacturing, electrical, mechanical or social, enables greater insight into their behaviour for a given set of test conditions. The modelling process used for the development of the skill pool model follows the steps and guidelines presented by Sterman (2000) in Business Dynamics, System Thinking and Modelling for a Complex World. Mathematical analysis will be used to develop an understanding of the model's behaviour and this behaviour will be simulated using *Ithink* software and the spreadsheet, Excel.

The model presented in this chapter is constructed by adopting an integrated system dynamics framework developed by Hafeez (2003), which is illustrated in Figure 5.2. In our research work we are going to investigate a skill pool model of staff recruitment where the level of new staff recruited depends on the current staff leaving rate. Therefore, during this investigation we are going to develop tools and techniques to assist managers to plan their human resource requirements. This method is facilited by harnessing *Ithink* and modern spreadsheet technology to implement the underlying mathematical analysis. Therefore, this model concentrates on forecasting the actual staff level of the future manpower needs of the organisation. Our model is based on an inventory and order-based production control system (IOBPCS) given in Towill (1982). The aim will be to use company data to analyse the dynamics of the staff pool (especially the staff leaving rate) so that the decision maker can obtain a better understanding of the dynamics of staff acquision - particularly during times when the company is going through major change. This better understanding of its human resource planning processes should enable the company to improve its productivity in the long term.

5.3 System input-output analysis

Input-output analysis has been found to be a powerful and comprehensive tool in system analysis and system investigation work. The use of input-output analysis is helpful in building up both a conceptual as well as more concrete, block diagram model, (Parnaby, 1979). Once the conceptual model has been produced, the next step of producing the block diagram is made that much easier. The most common use of input-output analysis is to evaluate the impact of exogenous changes in the external components on the interdependent (internal) components. Input-output analysis has most frequently been used in the study of economic systems (Correa and Craft, 1999).

Figure 5.1 shows the input-output block diagram of the case companies' staffing scheduling system. The planning methods used by human resource planning managers were investigated by means of interviewing and observing the managers at work. The philosophy of our approach to human resource design, summarised in the input-output diagram, are divided into three categories: system inputs (design constrains), system inputs (optimization process) and system outputs (recommended design settings), as shown in Figure 5.1

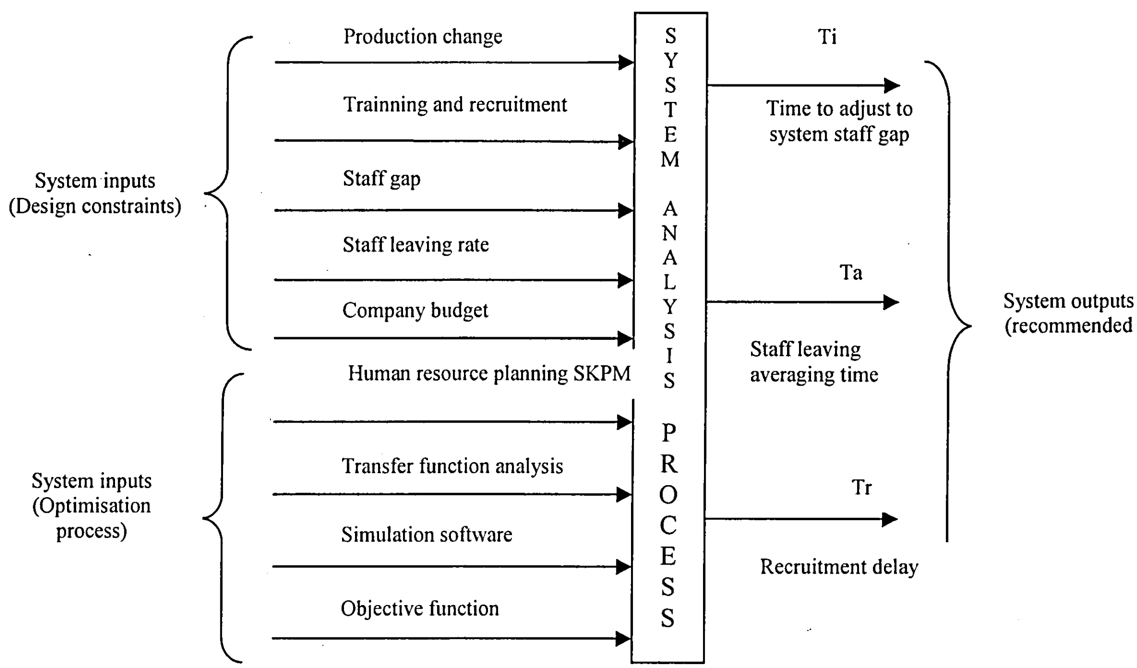


Figure 5.1: Input-output analyses indicating the sources of company data for the system analysis process

5.4 Influence diagram representation of SKPM

The influence diagram for the Skill Pool Model (SKPM) is shown in Figure 5.2. The diagram was produced using the *Ithink* software package, which allows anyone with elementary feedback-control knowledge to construct similar diagrams to represent time-based dynamical systems. The actual staff level in the diagram is what we are aiming to control. It will fluctuate as staff leave the company. The only way we can control the staff level, and maintain it at the target staff level, is by recruited staff entering the staff pool. To do this we first forecast the rate at which staff leave the company. This forecast will be based on past, known staff leaving rates. Staff will leave for a number of reasons and fluctuations in the leaving rate will typically be seasonal and irregular. A forecast, based on single exponential smoothing, as described in Kazmier and Pohl (1987), can therefore be used. This forecast leaving rate together with the staff gap (target staff level minus actual staff level) will enable us to calculate the recruitment demand rate. A key feature of any recruitment process is the delay that occurs between the start of the recruitment process and the time that recruited staff can enter the staff pool. This delay has to be incorporated into the model and we have to calculate a so-called recruitment completion rate that takes this delay into account. The recruitment completion rate is the mechanism by which we control the staff level.

The model as shown in Figure 5.2 consists of two parts: feed-forward control, based on the forecast staff leaving rate, and feedback control, based on the staff gap. Also the company recruitment demand rate comprises two parts, one is the staff gap, and the other is the forecast staff leaving rate. The recruitment demand rate is therefore effectively controlled by an exponential smoothing constant, which in turn will depend on the average time to determine the forecast staff leaving rate (Ta), and the time over which the present staff gap is to be recovered (Ti). The difference between the present staff leaving rate and recruitment rate is accumulated to give the present actual staff level in the pool. In order to analyse the dynamic response of the SKPM, recruitment process delay is represented by a time delay Tr (recruitment lead time) and the time over which the staff leaving rate is averaged by Ta. Towill (1982) suggests using exponential delay for industrial dynamics simulation when a delay has to be modelled and we have used his ideas here to represent recruitment delay.

Furthermore, it is important to recognise how to manage the actual staff level of the pool. To reach the target value, a simple and appropriate policy is proportional control, where information concerning the magnitude of the actual staff level is fed back to control the recruitment rate. The recruitment demand rate is calculated by dividing the discrepancy between the target level and actual level by a time factor, which represents the average delay in performing the recruitment rate.

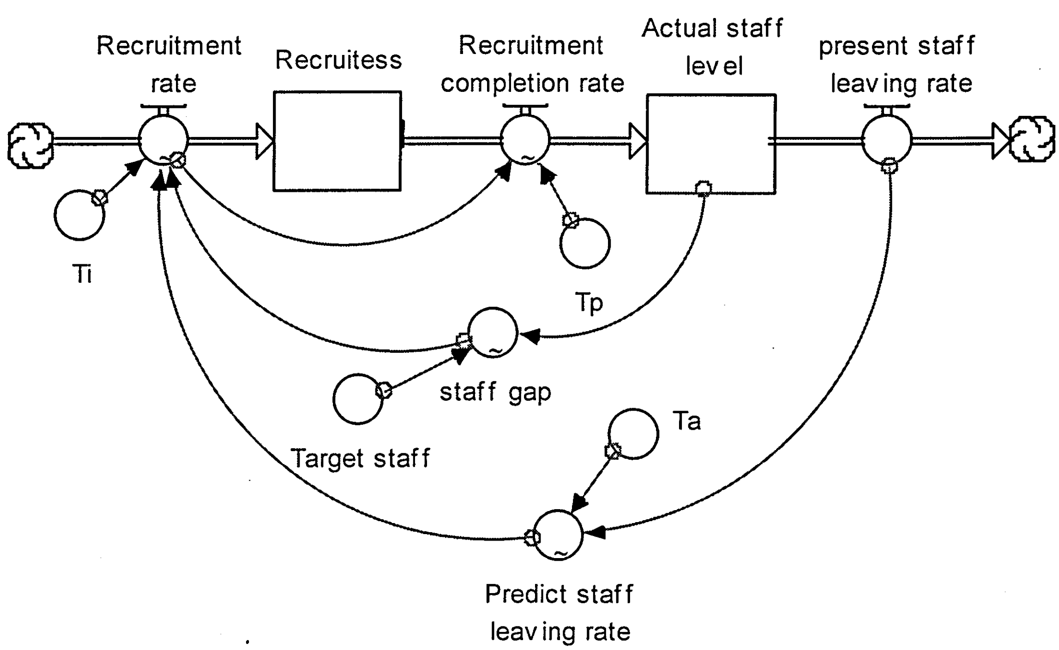


Figure 5.2: Influence diagram of the SKPM

5.5 Skill Pool Model Block Diagram (SKPM)

A block diagram shows the operation, interrelationships and interdependencies of components in a system. Boxes, or blocks (hence the name), represent the components; connecting lines between the blocks represent interfaces. There are two types of block diagrams: a functional block diagram, which shows a system's subsystems and lower level products and their interrelationships and which interfaces with other systems; and a reliability block diagram, which is similar to the functional block diagram except that it is modified to emphasize those aspects influencing reliability.

Further definitions relating to different kinds of block diagrams can be found at (www.asq.org/info/glossary/b.html). Here we are going to present the functional block diagram.

We have used the Skill Pool Model as described by Hafeez and Abdelmeguid (2003), and tested it using staff pool data from two large overseas petrochemical companies. Each operates in a relatively stable "push market" with staff turn over. In the companies the majority of the workforce have permanent jobs. However, there is the ongoing need to employ a pool of contract workers, with manual to specialist skills, for various projects. A block diagram representation of the case companies' recruitment and training system is given in Figure 5.3. This is the block diagram for the influence diagram in Figure 5.2. In this format the skill pool model is developed to improve our understanding of the dynamics of staff turn over in a company when it is operating in a steady state. Also it allows us to see the impact of going through some major changes. This model is implicitly linked with the organization environment and will enable the company to develop new policies should there be changes to the environment. Also it aims to enable the company to respond to the hiring and training needs as a result of changes to the present staff leaving rate (feed forward) as well as changes to the actual staff level and the staff training completion rate (feedback). Therefore the main aim of using system dynamic models in HRP is to find the optimum policy parameters to manage company recruitment and training policies effectively in the face of "shocks" experienced due to changes in its internal as well as external environment.

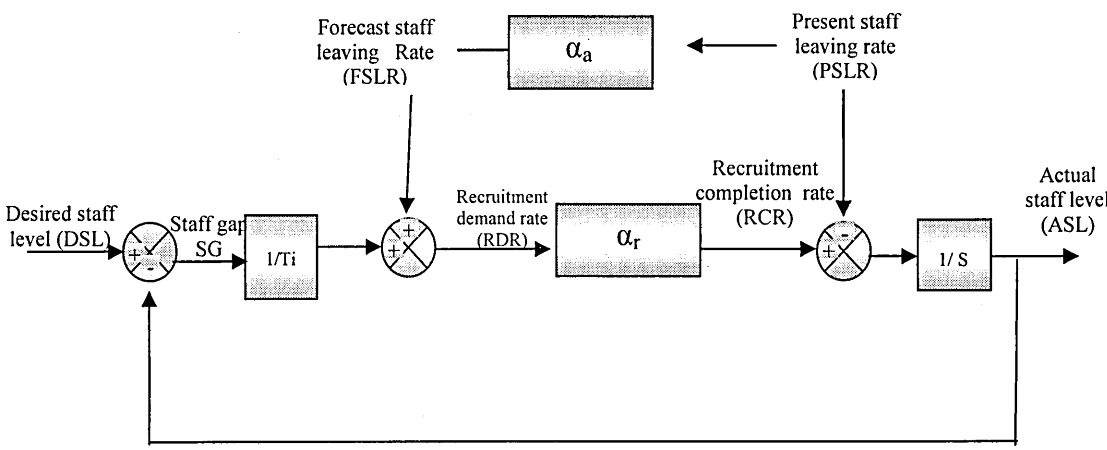


Figure 5.3: A block diagram representation of the SKPM

It is customary to use abbreviations for the various rates, levels, and operations met with in planning dynamic simulation. Those used in Figure (5.2) are defined in Table (5.1). Rates and levels appear as abbreviations at the start and finish of the arrow link lines. The signs associated with the arrow tips are extremely important in establishing the correct behaviour of the system, especially with regard to stability.

Equations (1) to (5) outline the main constructs of the Skill Pool Model and help to established feed forward and feedback structures and associated transfer functions, where k and k+1 refer to current and next time intervals, measured in months.

Terms	Abbreviations	Description
Present staff leaving rate	PSLR	The units of staff leaving rate are staff units/month.
Forecast staff leaving rate	FSLR	It is the time average (exponential smoothing) of staff leaving rates. The units of staff leaving rate are staff units/month.
Desired staff level	DSL	It is the level of target staff required. The units of target staff level are staff units.
Staff gap	SG	It is the difference between desired staff level and actual staff level. The units of staff gap are staff units.
Recruitment demand rate	RDR	It is the demand recruitment rate and will depend on the staff gap. The units of recruitment demand rate are staff units/month.
Recruitment completion rate	RCR	It is the recruited staff completion rate it is refers to the acquired staff. Its units are staff units /month.
Actual staff level	ASL	It is the actual number of staff which company has. The units of actual staff level are staff units.
Ti	Ti	Time to reduce the staff gap to zero measured in months.
Ta	Ta	Time over which staff leaving rate is averaged in months.
Tr	Tr	Recruitment process delay measured in months.
$1/T_i$	$1/T_i$	It is the proportional constant to deal with the discrepancy between target staff and actual staff level. The units are per month.
1/S	1/S	This represent the integration process whereby the actual staff level is accumulated over time through the recruitment and training development.
$1/(1+T_a{*}S)$	α_a	This is the multiplier used in simulation to take account of the time to average the staff leaving rate.
$1/(1+T_r{*}S)$	α_r	This is the multiplier used in simulation to take account of the recruitment process delay.

Table 5.1: Glossary of terms used in the SKPM block diagram

$$SG_{k+1} = DSL_{k+1} - ASL_{k+1} \qquad \text{----(1)}$$

$$FSLR_{k+1} = FSKR_k + \alpha_a (PSLR_{k+1} - FSLR_k) \qquad \text{----(2)}$$

where $\alpha a = 1 / (1+ T_a *S)$

$$RDR_{k+1} = SG_{k+1} / T_i + FSLR_{k+1} \qquad \text{----(3)}$$

$$RCR_{k+1} = RCR_k + \alpha_r (RDR_k - RCR_k) \qquad \text{--- (4)}$$

$$\alpha r = 1 / (1+ T_r*S)$$

$$ASL_{k+1} = ASL_k + RCR_{k+1} - PSLR_{k+1} \qquad \text{----(5)}$$

5.6 A note on Transfer functions

In classical control theory, the transfer function of a system represents the relationship describing the dynamics of the system under consideration (Towill, 1970). It algebraically relates a system input and system output. Figure 5.2 shows the block diagram representation of the key variables of the SKPM model and their interactions.

Equation 1 calculates staff gap as the discrepancy between target staff and actual staff level, Equation 2 calculates the forecast staff leaving rate in terms of the smoothing function α_a of the present staff leaving rate and Equation 3 shows the schedule recruitment rate which aims to meet the forecast staff leaving rate. In order to meet this target we need to undertake some adjustment in staff gap as given by the function $(1/T_i)$.

Equation 4 calculates the recruitment completion rate and it is given in terms of the delaying function α_r. The actual staff level is calculated in equation 5 in terms of its previous level and the difference between the recruitment completion rate and present staff leaving rate.

Equations 1 to 5 may be used to develop the associated transfer functions that relate actual staff level and recruitment completion rate to the present staff leaving rate. These two transfer functions are shown in equations A and B respectively.

$$\frac{Actual.staff.level}{\Pr esent.staff.leaving.rate} = \frac{-Ti[(Tr+Ta).S+TrTa.S^2]}{(1+Ta.S)(1+Ti.S+TiTr.S^2)} \qquad \text{(A)}$$

$$\frac{\mathrm{Re}\, cruitment.completion.rate}{\Pr esent.staff.leaving.rate} = \frac{1+(Ti+Ta).S}{(1+Ta.S)(1+Ti.S+TiTrS^2)} \qquad \text{(B)}$$

Their derivation is given in Appendix 4, and they are useful in understanding how the parameters T_i, T_a, and T_r, affect the time response behaviour of the actual staff level and the recruitment completion rate in terms of the present staff leaving rate. In both cases it is clear that changes to any of the control parameters will affect the behaviour of the two system outputs. Thus, in optimising the system behaviour by changing the parameters (see, for example, Table 5.5) we will have to consider the affects on *both* the actual staff level and the recruitment completion rate together.

5.7 System Performance Indices

To evaluate any system requires tools to measure the system performance and to determine the system behaviour which helps us understand the behaviour of the system. The performance criteria have been chosen to describe the simulation of the model. Dorf (1996) defines the system performance as a quantitative measure of the performance of a system and is chosen so that due emphasis is given to important system specification. Technical performance is the degree to which the system reflects (meets or exceeds) that expected in a statement of requirements characteristics.

Performance is a statement of requirements in terms of required results with criteria for verifying compliance, without stating methods for achieving the required result. A performance specification defines the functional requirements for the item. Therefore, in our system performance analysis we have a number of variables which are important in evaluating and understanding its performance. In our model we will highlight two important measurement criteria. The first is actual staff level, which depends on staff leaving rate and staff level, and the amount of staff acquired during the training programme, and the second is staff recruitment completion rate which depends on staff recruitment demand rate.

5.7.1 Staff Level Criteria

Figure 5.4 shows the typical staff level response plot together with selected performance measures. The system shows the initial staff level drop. The system also shows the duration of the staff deficit and the initial staff drop - which then recovers and remains steady after a few months - and the peak staff level overshoot. The following characteristic response will be useful for any analysis.

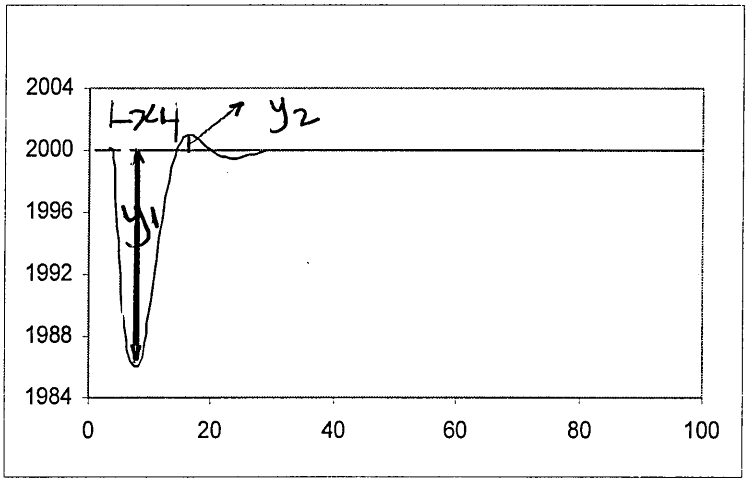


Figure 5.4: Staff Level Criteria

5.7.1.1 Initial drop of staff level (Y1)

A change in the present staff leaving rate will induce a transient in the model resulting in an initial drop in the actual staff level. This drop is due to an initial loss coming from the actual staff level whilst extra staff are being acquired and trained. It is important that this drop (Y1 in Figure 5.4) is kept small so as to minimise the size of the actual staff gap (the quantity we are trying to reduce to zero). An obvious way of elimiting the problem of having a staff drop is to hold a large number of staff recruits, but this has a detrimental effect on the capability of the company to carry out its business.

5.7.1.2 Duration of the staff level deficit (X1)

The duration of the staff level deficit X1 in Figure 5.4 gives an indication of the speed of recovery from the staff level deficit. This is calculated by looking at the time it takes for the actual staff level to return to the steady state target value.

5.7.1.3 Peak staff level overshoot (Y2)

The Peak staff level overshoot, Y2, in Figure 5.4 is an indication of how well the staff-level control mechanisms are behaving. A large value of Y2 will indicate a mismatch between the rate of staff recruitment and the staff leaving rate. In other words a large value will indicate that the staff-level control mechanisms are not working effectively. The staff level overshoot is therefore an essential measurement both in satisfying the company needs and also in having an efficient staff-level control policy. For the purpose of the simulation this overshoot is measured by looking at the difference of the peak surplus value and the initial staff level value.

5.7.1.4 Integral Time Absolute Error

The fourth performance criteria for actual staff level is the Integral Time Absolute Error (ITAE), which is the integral over time of the absolute value of the staff gap, defined as follows (Towill, 1970):

$$\int t|e|\,dt$$

The Integral Time Absolute Error (ITAE) is a time dependent index and penalises errors occurring in the response. And it is particularly useful for measuring the response to unavoidably large initial errors such as the initial staff level drop in staff inventory.

5.7.2 Recruitment Completion Rate Criteria

Figure 5.5 shows the staff recruitment completion rate time response together with relevant performance measures. It shows an initial rise time, X2, an overshoot, Y3, and an overshoot duration, X3.

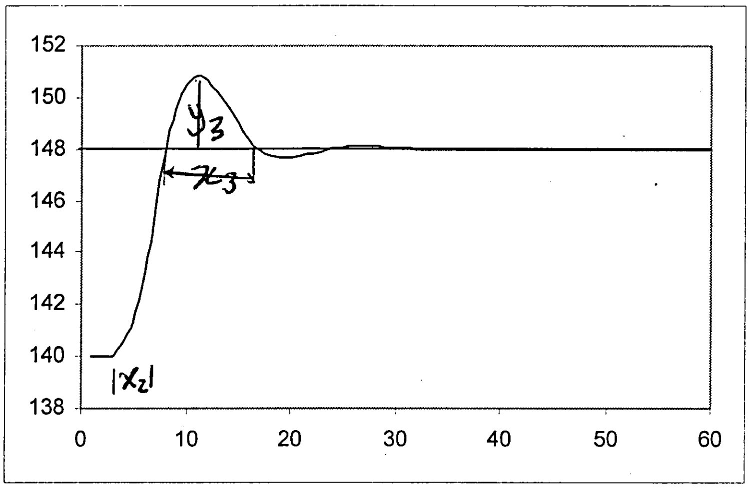


Figure 5.5: Recruitment Completion Rate Criteria

5.7.2.1 Rise time X2

The swiftness of a step response can be measured by its rise time, X2. For the purpose of analysis, the rise time is considered to be the time taken to first attain its final value, which is X2 in Figure 5.5. Measurement of rise time will give the company a useful indication of how long it will take to first hit the steady state recruitment completion rate and hence achieve the new recruitment rate demand.

5.7.2.2 Peak overshoot Y3

A peak overshoot (Y3) will only occur in an "under-damped" system and is defined as the maximum value of the output to a step change in its input (Y3 in Figure 5.5). For the purpose of the analysis, the definition of peak overshoot is the difference of the maximum value of staff recruitment completion rate from the final steady state value. To achieve a level of good human resource management control, large over shoots are to be avoided as they put an undue strain on recruitment capacity. A small overshoot has to be balanced against a rise time that is not excessively long; hence the designer must find a compromise between the two.

5.7.2.3 Duration of overshoot X3

The duration of overshoot, X3, is an important measure that tells us the length of time over which the system is over-recruiting (X3 in Figure 5.5). This period of over-recruiting will manifest itself in a staff level which is too large and a poor turnover ratio level. In the analysis the duration of overshoot is calculated between the time the peak overshoot starts and finishes.

5.7.2.4 Integral Time Absolute Error

As for the staff level considerations, the integrated time absolute error (ITAE) for the recruitment completion rate is also a performance index that will be useful. The ITAE is calculated for the recruitment completion rate using the difference between the actual recruitment completion rate level and target level.

$$\int \underline{[\text{final steady state value of } RCR - RCR(t)] * T\,dt}$$

5.7.3 Statistical Measures

Statistical information can reveal trends and characteristics in data that may not be obvious in a time series representation. Simple statistical measures such as the mean, mean square error, standard deviation and variance can usually give good descriptions of data (Moroney, 1962 and Makridakis *et al* 1998). It can be argued that time series responses are of an auto correlative nature and therefore the simple descriptive statistics outlined cannot strictly be used for statistical hypothesis testing. However, some of the measures are useful to compare between the optimum values of Ta, Tr, and Ti.

Adding all observations and dividing by the number, n, of observations gives the mean value

$$\mathbf{X} = \sum x_i / n$$

The Mean square error (MSE) is a proven measure of control and quality and can be defined as follows.

$$MSE = 1/n * \sum (Xi - T)^2$$

xi = ith value of a group of m values,

T = target or intended, i.e., desired, value for the product variable of interest.

The main reason for using MSE is that it is a standard statistical measure which provides a valid index of control and quality, essential for effective management of processes. It is necessary for assessing process control and product quality, setting meaningful goals for control and quality monitoring and motivating progress toward goals and managing efforts for continuous improvement.

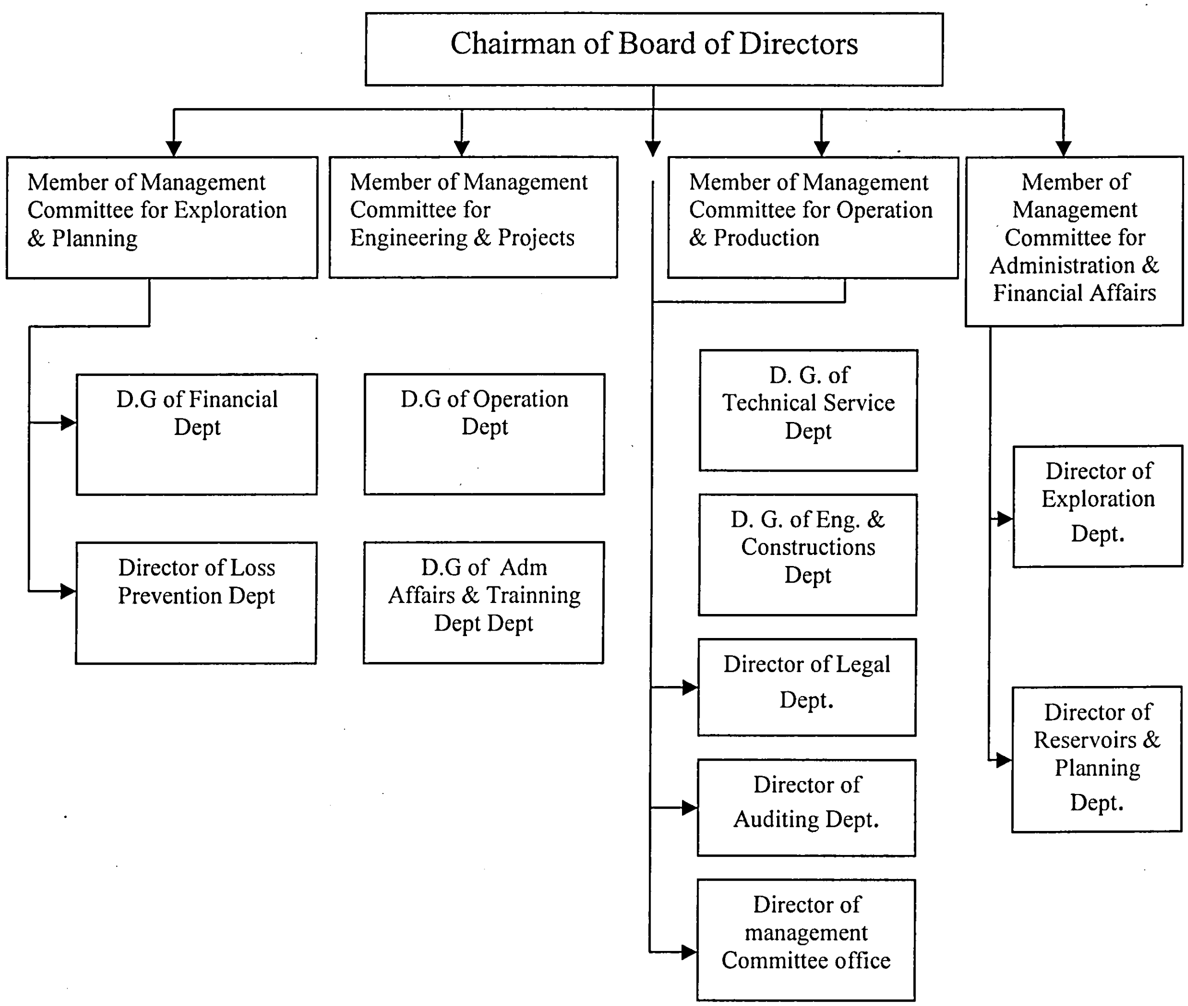
5.8 Case Studies

This section will detail the outcomes of visits to several companies. Each case study lists the historical background of the company, the company structure and culture in force and the effects of introducing human resource planning and system dynamics into the company setting. The companies studied are referred to as company A and company B. The interviewees for the case studies were the general managers and human resource managers. The executive managers in both companies aimed to bridge the gap between target and actual levels by implementing good recruitment programmes and training policies.

Figure (5.6) shows the organisational structure of both companies. The Chairman and main directors confirmed that the implementation of human resource models would change the ability of their company to predict their future human resource needs as stated, for example, by Judith Gurney (1996). The main objectives of both companies for implementing good recruitment programmes and training policies were to:

- achieve better production planning and control
- have a centralised HR database
- increase internal organisation efficiency
- increase turnover
- improve overall productivity through organization of work activities
- provide a coordinated process of recruitment, trainning, and promotion

- forecast future workforce needs
- build a linkage between human resource planning and the company's long-term business objectives
- forecast recruitment and training needs to ensure that sufficient experienced people are rising through the ranks to fill vacancies at higher levels



5.8.1 Dynamic Behaviour Analysis for case study A

The company was established in 1967 as a result of a venture between the American oil companies group and the Libyan Government in the field of oil exploration, development and utilization, as well as transfer of the relevant skills and technologies. The company grew rapidly during 1972 and 1980 and by 1986 was employing over 2000 staff. The company is listed on all the major Libyan exploration oil companies divisions. Today the company produces about one third of Libyan crude oil production, and is classified as one of the biggest Libyan oil companies.

Figure 5.7 gives a five-year record of monthly staff leaving rates for the company. On average the company is expecting about a 7% per month turn over of staff at any time. Model simulations were designed to study the system behaviour against the given design parameters Ti, Ta and Tr as explained earlier.

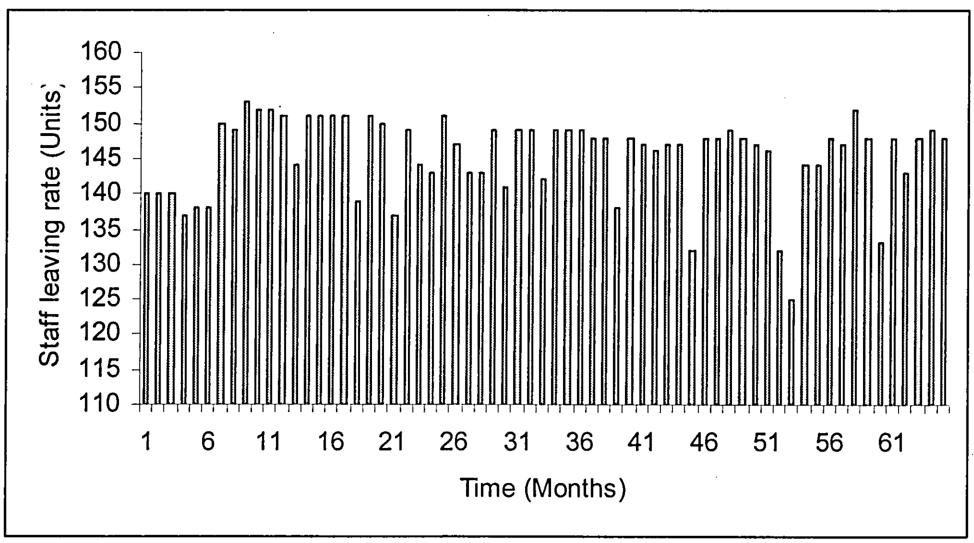


Figure 5.7: Plot of the data collected on Staff leaving rate

As mentioned earlier, the main purpose of this analysis is to find optimum policy parameters for the company to maintain its target staff pool. To secure good system behaviour we have designed appropriate performance indices to determine optimum policy parameters. These indices are given in Table 5.1 and are the ones discussed previously. Once policy parameters have been selected, the system would determine staff recruitment demand automatically governed by Ta and Ti according to a present staff leaving rate and staff gap. The simulations carried out were designed to set parameters Ti, Ta, Tr in a given range to observe and record the dynamic response in order to determine their optimum setting.

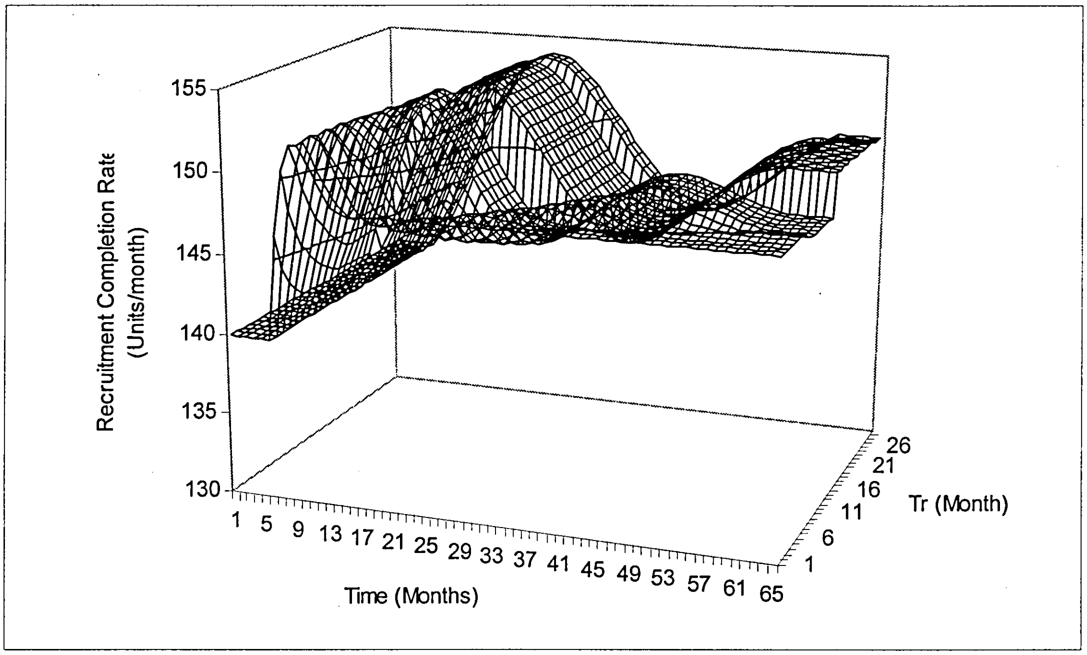
We have used critical simulation strategy by varying one parameter at a time (say staff recruitment completion rate between 1 month to 30 months) to study the overall system behaviour. Similarly, Ta, the time over which the average staff leaving rate is determined, was varied. And Ti, the time to recover the staff pool level, was also varied. So, within these given ranges, the subsequent analysis is used to find the design parameters for optimum system behaviour.

Figure 5.8 examines the response of the actual staff level and staff recruitment completion rate for varying recruitment lead times (Tr). As shown in Figure 5.8(a) increasing recruitment delay Tr would increase system oscillation, which means over staffing and under staffing - a truly unwanted state. As shown in Figure 5.8(b), reducing the value of Tr improves the staff pool deficit.

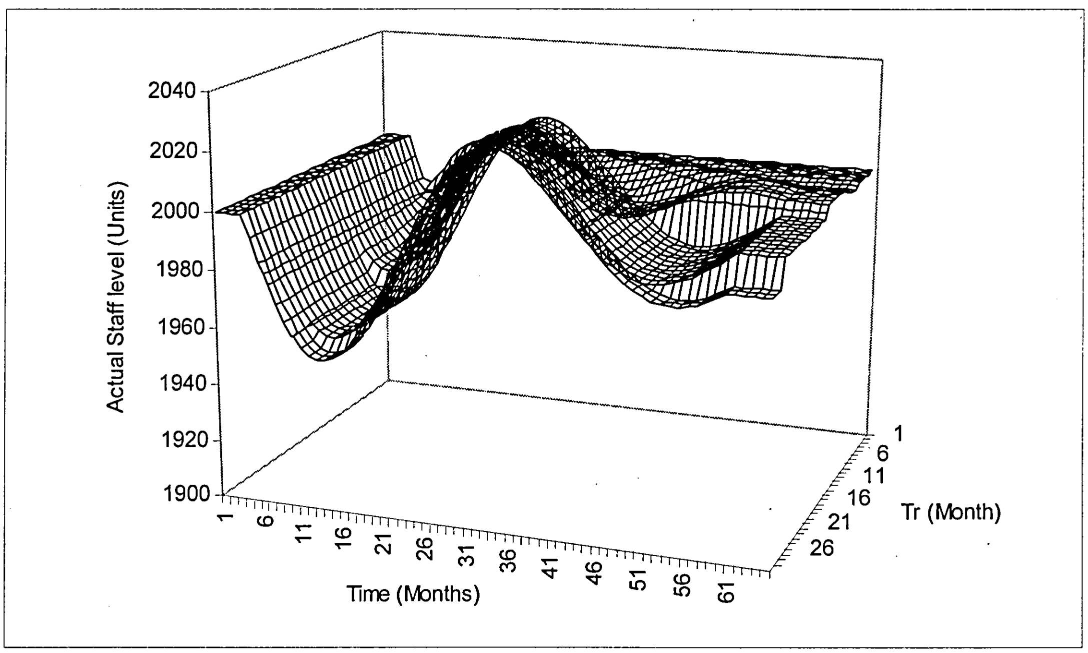
Figure 5.9(a) and 5.9(b), respectively, show the response of actual staff level, and recruitment completion rate for the range of Ti values. The larger Ti values lead to a larger drop in the staff pool, indicating the company is only able to recover from the staff shortages over a long period of time. In the worst-case scenario shown (Figure 5.9(b)), the company faces staff shortages for about 42 months when Ti=18 months. On the other hand, small Ti values lead to large oscillations about, and over staffing above, the required staff pool level for long periods. Clearly, in control theory terminology, this is a bad system design. In reality, this would mean a very aggressive hiring and firing human resource policy for the case company.

Figure 5.10 examines the system response of the staff level and staff recruitment completion rate for varying values of Ta. Ta is gradually varied between 1 month to 30 months, for fixed values of Tr and Ti. As shown in Figure 5.10(a), increasing Ta slows down the recruitment process. However, as shown in Figure 5.10(b) it would mean that the company would experience a relatively prolonged period of staff shortages.

Table 5.2 gives the overall summary of six selected designs showing Ti, Ta and Tr on the human resource policies for company A. Table 5.3 shows the performance index and associated dynamic behaviour for the SKPM, for different sets of parameter values Ti, Ta and Tr. Values of Ta, Ti and Tr have been varied from 1 month to 30 months, but not all combinations have been included in the table for obvious reasons. In determining the optimum set of parameters (shown shaded) the descriptive statistical characteristics given in Table 5.4 were calculated. The optimum set of parameters is that for which the respective values of MSE and ITAE are smallest and whose X values are closest to their target values. From Table 5.3 it can be seen that setting Ti = 2 months, Tr = 2 months and Ta = 4 months provides the optimum policy. Unnecessary fluctuations in staff deficit have been avoided and the time to recover the target staff level is not excessively long. Therefore, Ti = 2 months, Tr = 2 months and Ta = 4 months is as close as we can get to an optimum design, for the criteria used, indicating minimum initial staff level drop for a minimum period of staff pool shortages.

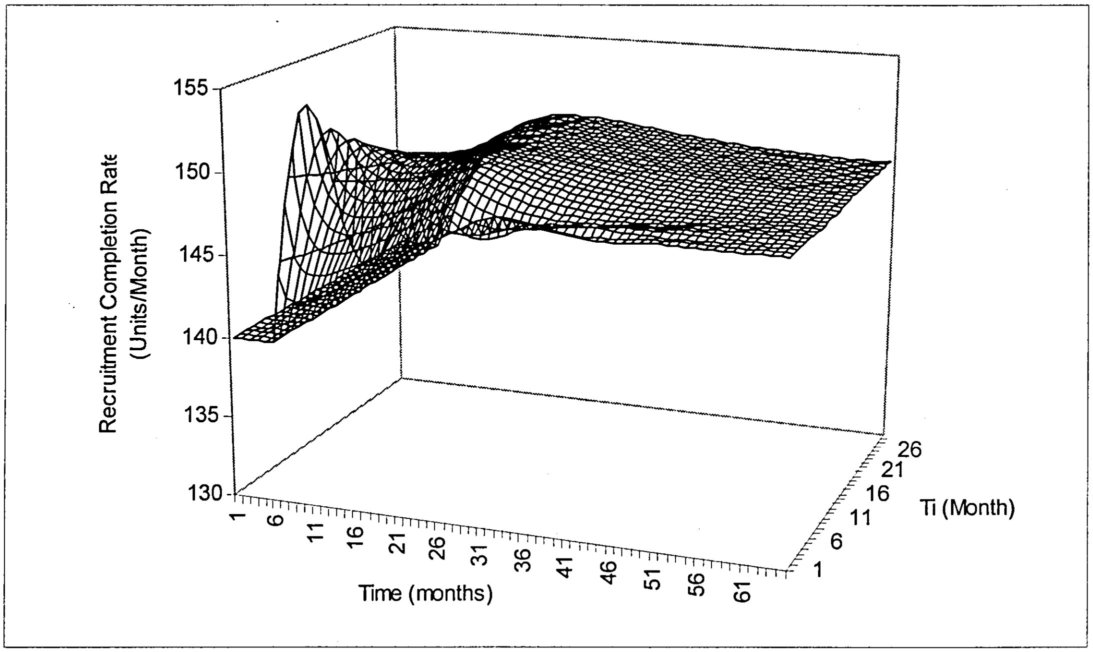


(a) Staff recruitment completion rate behaviour (Ti=2 and Ta=4 months)

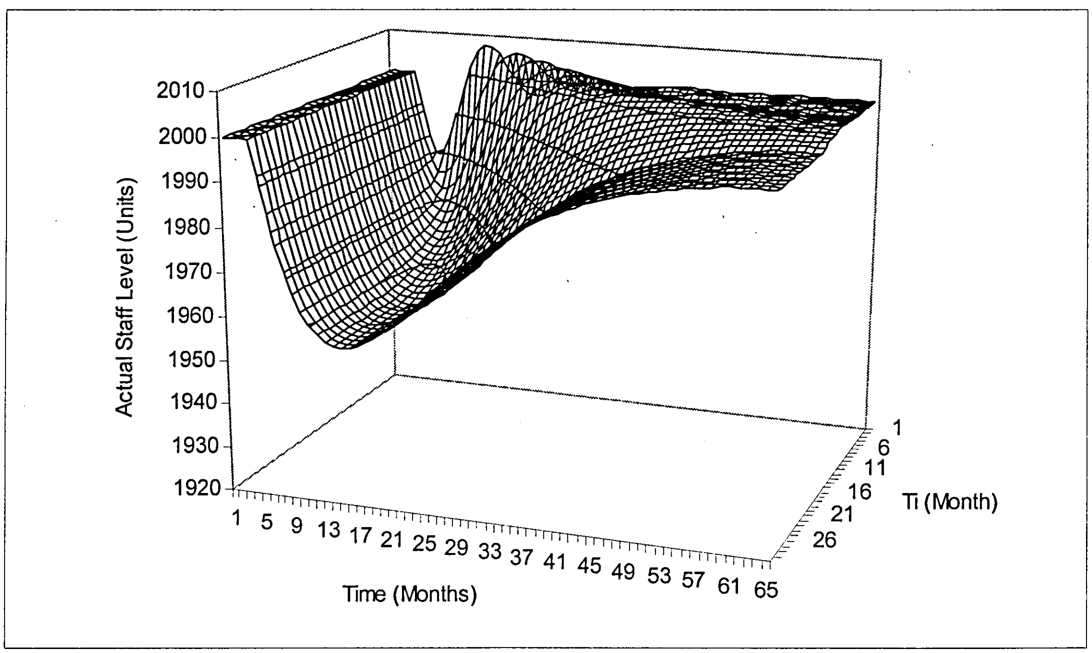


(b)Staff level behaviour (Ti=2 and Ta=4 months)

Figure 5.8: Response of SKPM for varying values of Tr

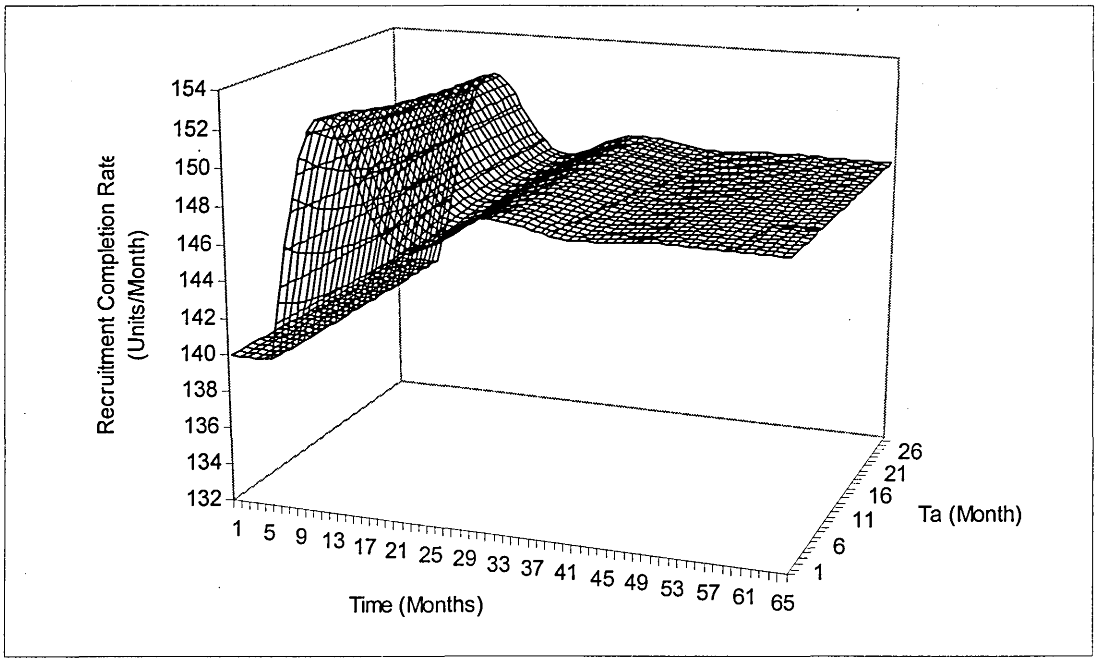


(a) Staff recruitment completion rate behaviour (Tr=2 and Ta=4 months)

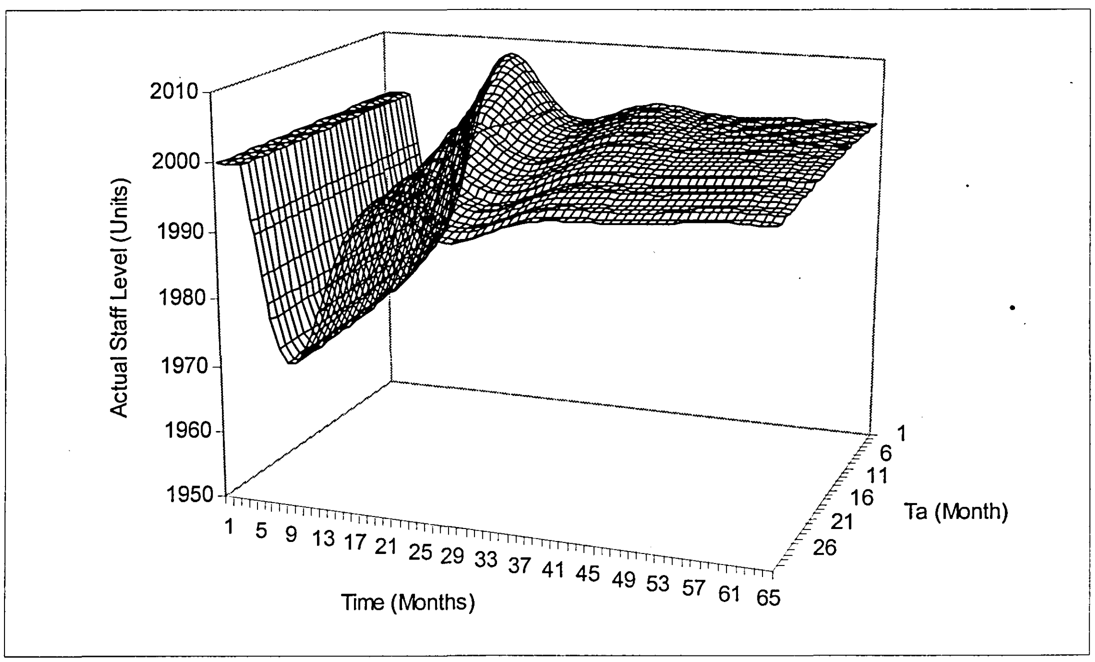


(b) Staff level behaviour (Tr=2 and Ta=4 months)

Figure 5.9: Response of SKPM for varying values of Ti



(a) Staff recruitment completion rate behaviour (Ti=2 and Tr=Ti=2 months)



(b) Staff level behaviour (Ti = 2 and Tr = Ti = 2 months)

Figure 5.10: Response of SKPM for varying values of Ta

erformance index		Skill Pool Model (SKPM) Dynamic behaviour		
		Ti (Time to reduce staff gap to zero)	Ta (Time over which staff leaving rate is averaged)	Tr (Recruitment process delay)
Recruitment completion rate measurements	Rise Time (Months)	Increasing Ti increases slightly the rise time	Increasing Ta increases the rise time	Increasing Tr increases the rise time
	Peak overshoot (Percentage from the nominal value)	Increasing Ti slightly increase the peak overshoot	Increasing Ta decreases the peak overshoot	Increasing Tr increases the peak overshoot
	Duration of overshoot (Months)	Increasing Ti slightly increases the duration of overshoot	Increasing Ta increases the duration of overshoot	Increasing Tr increases the duration of overshoot
Staff level measurements	Initial staff level drop (Percentage from the desired value)	Increasing Ti increases the initial staff drop	Increasing Ta increases the initial staff drop	Increasing Tr increases the initial staff drop
	Duration of staff inventory deficit (Months)	Increasing Ti increases the settling time	Increasing Ta increases the settling time	Increasing Tr increases the settling time
	Peak staff inventory overshoot (Percentage from the nominal value)	Increasing Ti decreases the peak staff inventory overshoot	Increasing Ta decreases the peak staff inventory overshoot	Increasing Tr increases the peak staff inventory overshoot

Table 5.2: Performance index and associated dynamic behaviour for the Skill Pool Model (SKPM)

Performance index at the design Parameters		Skill Pool Model (SKPM) Design parameters									
		Ti=1, Ta=2, Tr=1	Ti=2 Ta=4, Tr=2	Ti=1, Ta=4, Tr=4	Ti=2, Ta=2, Tr=2	Ti=4, Ta=8, Tr=8	Ti=4 Ta=8 Tr=4	Ti=3, Ta=6, Tr=3	Ti=2, Ta=4, Tr=8	Ti=3, Ta=4, Tr=4	Ti=3, Ta=4, Tr=8
Recruitment completion rate measurements	Rise Time (Months)	4	4	3	3	7	5	4	5	4	6
	Peak overshoot	24.7%	1.35%	27%	1.35%	31%	16.2%	0.85%	35%	4.1%	34.2%
	Duration of overshoot (Months)	5	6	6	7	19	14	10	13	12	16
Staff level measurements	Initial staff level drop	1%	0.45%	5.6%	0.45%	20.4%	8.6%	4.55%	16.25%	7.9%	18.6%
	Duration of staff inventory deficit (Month)	8	6	7	7	18	14	10	13	11	16
	Peak staff inventory overshoot	0.15%	0.15%	2.6%	0.1%	6.3%	1.45%	0.75%	7.4%	1.8%	6.9%

Table 5.3: Performance index and associated dynamic behaviour for the Skill Pool Model (SKPM) for case study A, where the shaded region shows the optimum response

Model output	SKPM Model Case Study A		
	X	MSE	ITAE
Recruitment completion rate	147.5	13.3	539.8
Actual staff level	1996	32.3	1153

Table 5.4: Descriptive statistical characteristics for SKPM for case study A for optimal behaviour

5.8.2 Dynamic Behaviour Analysis for case study B

The company was established as the result of a fruitful and constructive relationship between the Italian Eni Group and the Libyan Government in the field of oil exploration, development and utilization, as well as transfer of the relevant skills and technologies. The data of such fruitful co-operation goes back to early 1950 when the Libyan authorities signed exploration contracts with two companies, Eni Group and Agip, for exploration of hydrocarbon formulation in the Sirte area and Sirte basin.

The oil operation in these oil fields remained under management of the concessionaires as per concession contracts signed between both parties at that time, until change of the strategies adopted in the international oil relations which drew up the route of oil industries at the beginning of the seventies in the last century. The company was established in 1972, and by 1992 the number of full time staff reached 1850. Although the company has grown quite rapidly, its main line of business has changed little since its inception. The company is listed on all the major Libyan exploration oil companies divisions.

The data values collected give a five-year record of staff leaving rate for the company and are shown Figure 5.11. On average, the company is expecting about 0.05% staff turn over at any time. Therefore, the SKPM is tested using real data. Experiments were designed to study the system behaviour against the given design parameters Ti, Ta and Tr as explained earlier

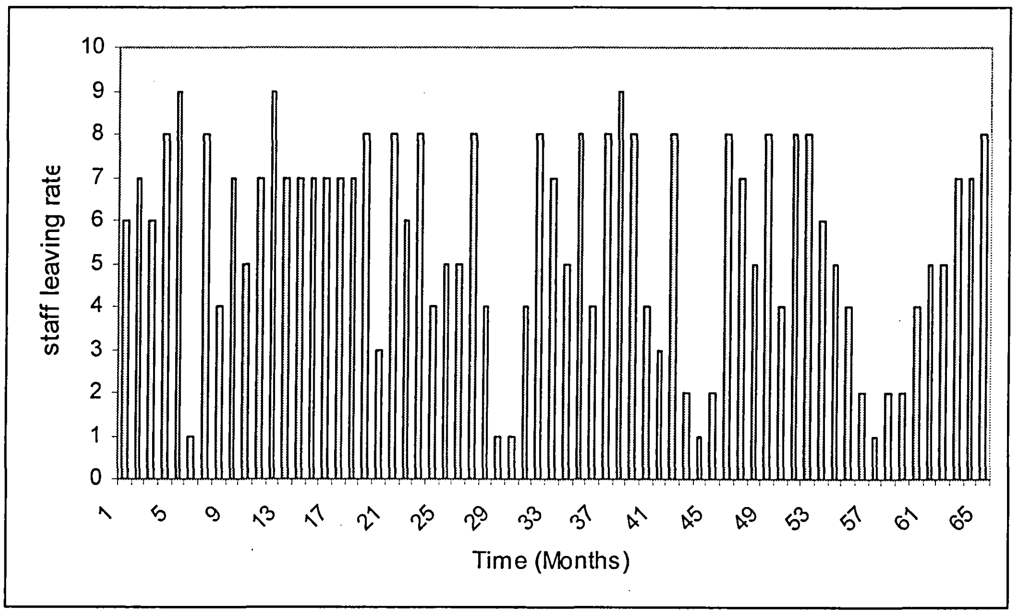


Figure 5.11: Plot of the data collected on Staff leaving rate

As mentioned earlier, the experiments were designed to set parameters Ti, Ta, Tr in a given range to observe and record the dynamic response in order to determine their optimum setting. Again the performance index of the SKPM given in table 5.4 is used to describe the related system behaviour.

The parameters Ti, Ta, Tr are again to be tuned by the decision maker to determine their optimum settings using simulation. Once again the staff completion rate will be governed by Tr, the forecast staff leaving rate by Ta, and the staff gap recovery will be governed by Ti.

The system dynamics model and simulation analysis presented in this work relate to our case petrochemical company employing 1850 staff. In addition, we need to repeat the simulation for a range of values for the variables Ta, Ti, and Tr between 1 and 30 months.

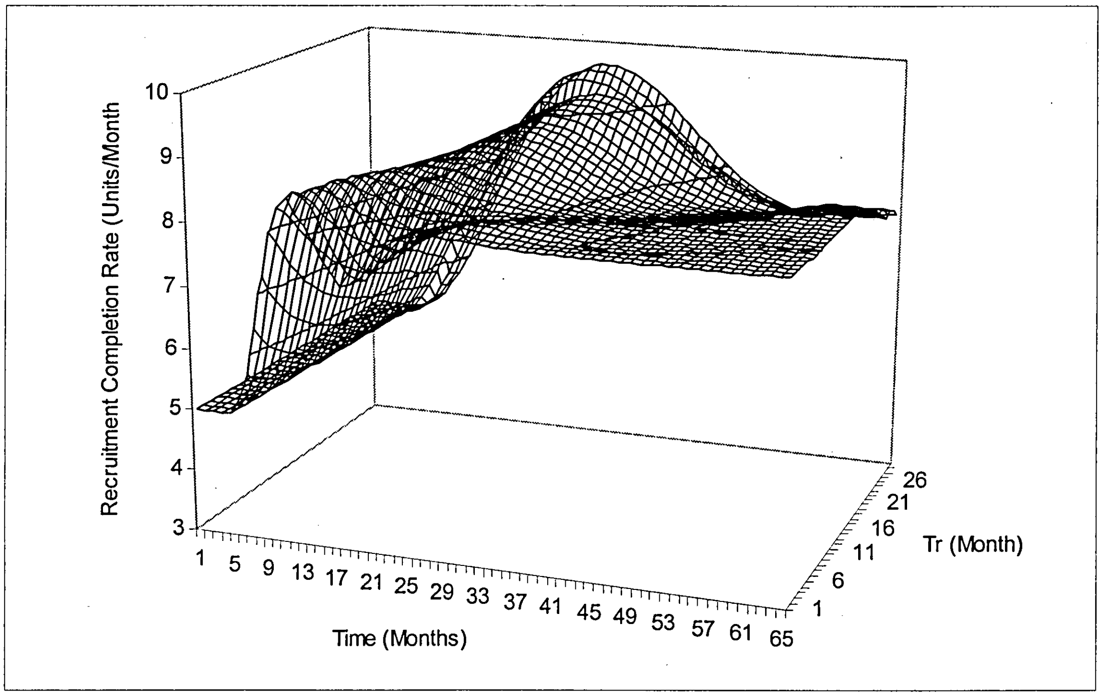
Figure 5.12 shows the staff recruitment completion rate and actual staff level while varying the recruitment lead time, Tr. As shown in Figure 5.12(a), increasing Tr would increase the system oscillation, as well as increase the settling time. Values of the rising time, however, remain more or less the same. As shown in Figure 5.12(b) decreasing Tr improves the system response regarding the staff gap created, but increasing Tr leads to oscillatory behaviour and high overshoot.

Figure 5.13 examines the response of the skill pool model to changes in the parameter Ta. As shown in Figure 5.13(b), the largest value of Ta gives the largest drop in the staff level, and small values of Ta may induce instability in the real system. On the other hand the duration of the staff pool deficit increases for high values of Ta. Also, increasing Ta would decrease the peak staff pool overshoot, and at large value of Ta would give a longer period of time to recruit new staff. Figure 5.13(a) focuses on the influence of Ta on the staff recruitment completion rate. The largest value of Ta gives the smoothest recruitment completion rate, but with the lowest value of Ti some oscillations would occur. Increasing Ta would decrease rise time but smaller overshoots; also increasing Ta would decrease the duration of overshoot as shown in Figure 5.13a. Decreasing Ta leads to initial drop in staff recruitment rate and leads to staff overshoot at the beginning.

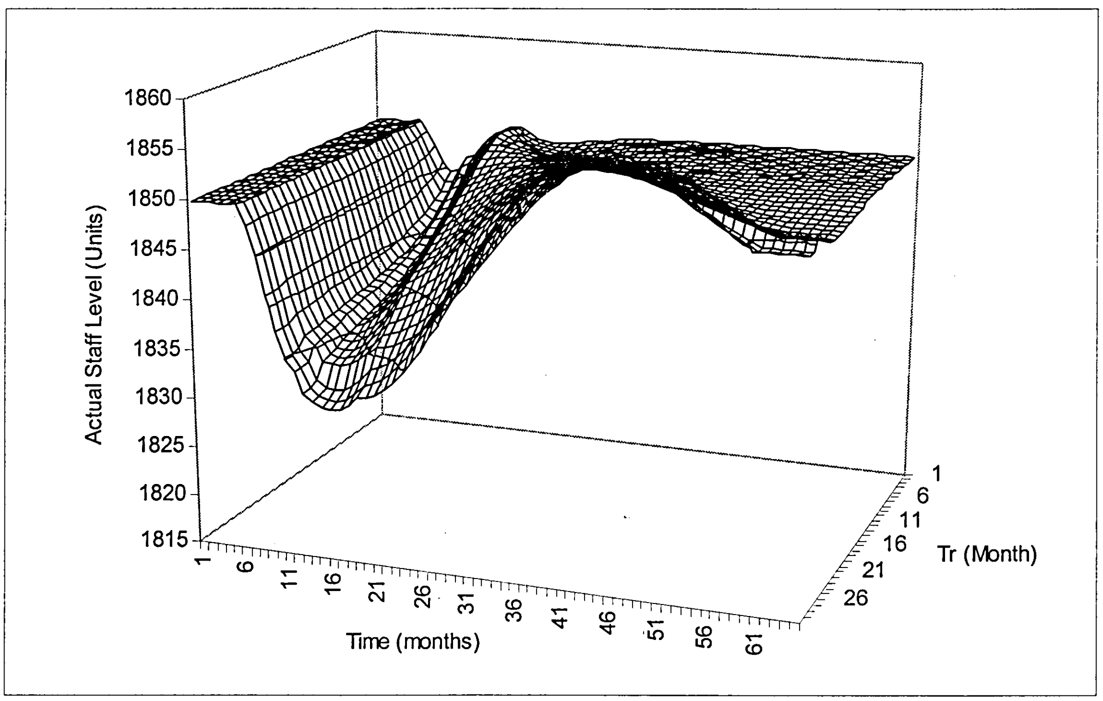
Figure 5.14 examines the response of the staff level and staff recruitment completion rate for various values of Ti. Figure 5.14(a) shows that, for the recruitment completion rate, as Ti increases the overshoot slightly decreases and there is slight increase in the duration of overshoot time.

Figure 5.13(b), showing the actual staff level response, indicates that as Ti increases the overshoot is damped down, although there is a corresponding increase in settling time. Also, decreasing Ti would increase the duration of staff inventory deficit.

Table 5.5 shows the performance index and associated dynamic behaviour for the SKPM, for case study B for different sets of parameter values Ti, Ta and Tr. Values of Ta, Ti and Tr have been varied from 1 month to 30 months, but not all combinations have been included in the table. In determining the optimum set of parameters (shown shaded) the descriptive statistical characteristics given in Table 5.6 were again calculated. The optimum set of parameters is that for which the respective values of MSE and ITAE are smallest and whose X values are closest to their target values. From Table 5.3 it can be seen that setting Ti = 3 months, Tr = 3 months and Ta = 6 months provides the optimum policy.

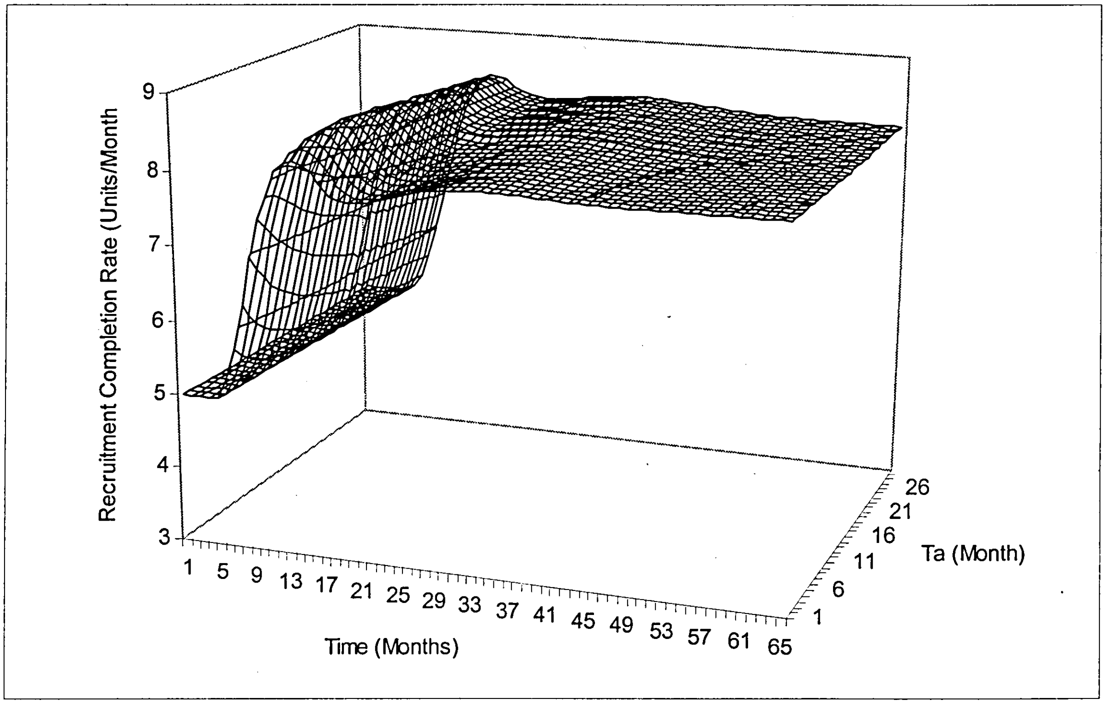


(a) Recruitment completion rate

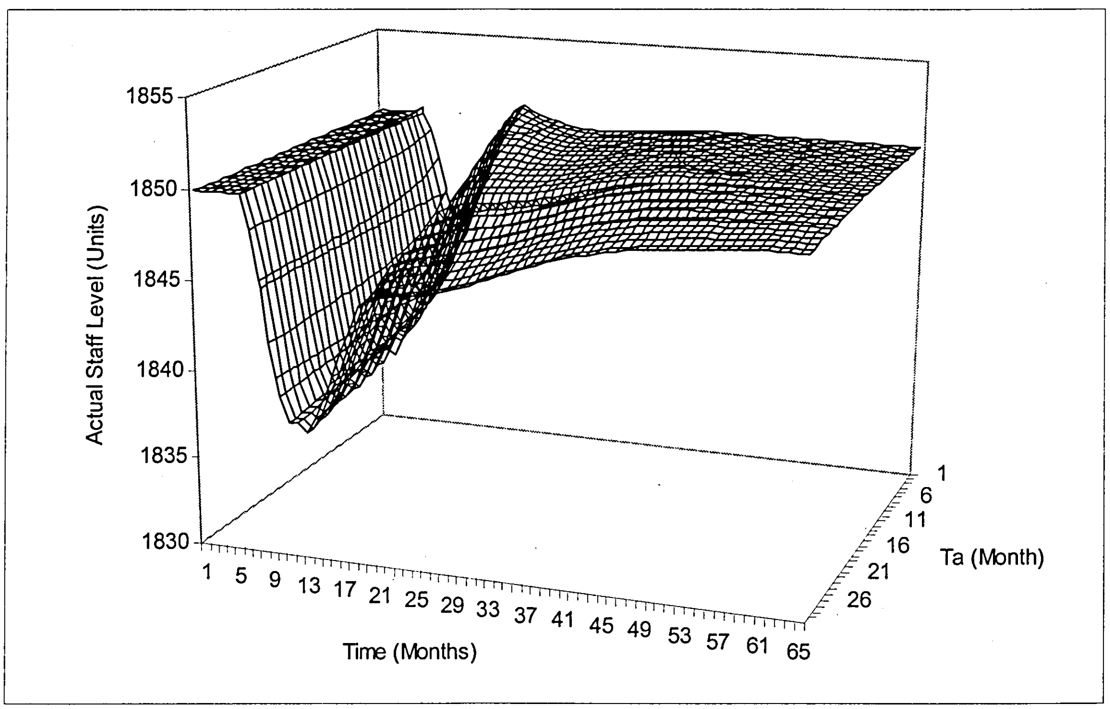


(b) Actual staff level

Figure 5.12: Response of SKPM for varying values of Tr

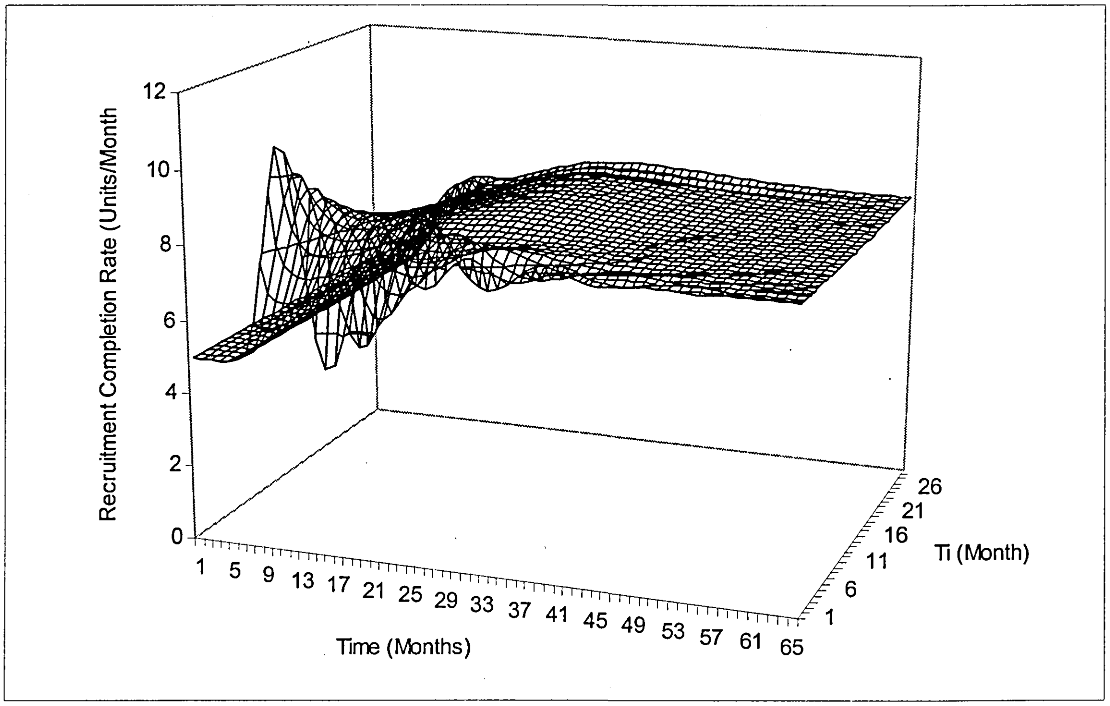


(a) Recruitment completion rate

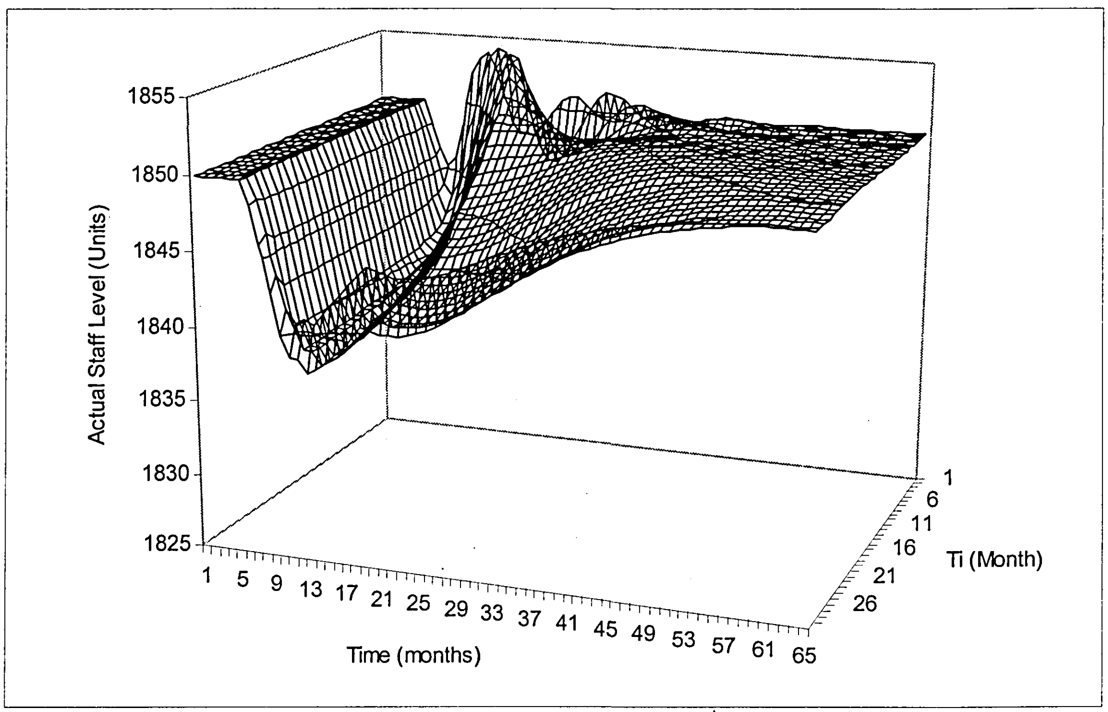


(b) Actual staff level

Figure 5.13: Response of SKPM for varying values of Ta



(a) Recruitment completion rate



(b) Actual staff level

Figure 5.14: Response of SKPM for varying values of Tr

Performance index at the design Parameters		Skill Pool Model (SKPM) Design parameters									
		Ti=1, Ta=2, Tr=1	Ti=2 Ta=4, Tr=2	Ti=1, Ta=4, Tr=4	Ti=2, Ta=2, Tr=2	Ti=4, Ta=8, Tr=8	Ti=4 Ta=8 Tr=4	Ti=3, Ta=6, Tr=3	Ti=2, Ta=4, Tr=8	Ti=3, Ta=4, Tr=4	Ti=3, Ta=4, Tr=8
Recruitment completion rate measurements	Rise Time (Months)	2	3	6	3	10	7	7	8	7	9
	Peak overshoot	50%	12.5%	25%	12.5%	37.5%	12.5%	12.5%	37.5%	25%	37.5%
	Duration of overshoot (Months)	3	8	6	8	18	12	13	13	13	14
Staff level measurements	Initial staff level drop	0.21%	0.21%	0.32%	0.21%	1.35%	0.64%	0.38%	1.02%	0.54%	1.2%
	Duration of staff inventory deficit (Month)	5	8	9	7	22	20	16	15	16	18
	Peak staff inventory overshoot	0.86%	0.054%	0.16%	0.054%	0.37%	0.055%	0.05%	0.48%	0.11%	0,43%

Table 5.5: Performance index and associated dynamic behaviour for the Skill Pool Model (SKPM) for case study B, where the shaded region shows the optimum response

Model output	SKPM Model Case Study B		
	X	MSE	ITAE
Recruitment completion rate	8	1.19	330
Actual staff level	1849	6.9	1041.7

Table 5.6: Descriptive statistical characteristics for SKPM in case study B for optimal behaviour

5.9 Staff Gap Analysis

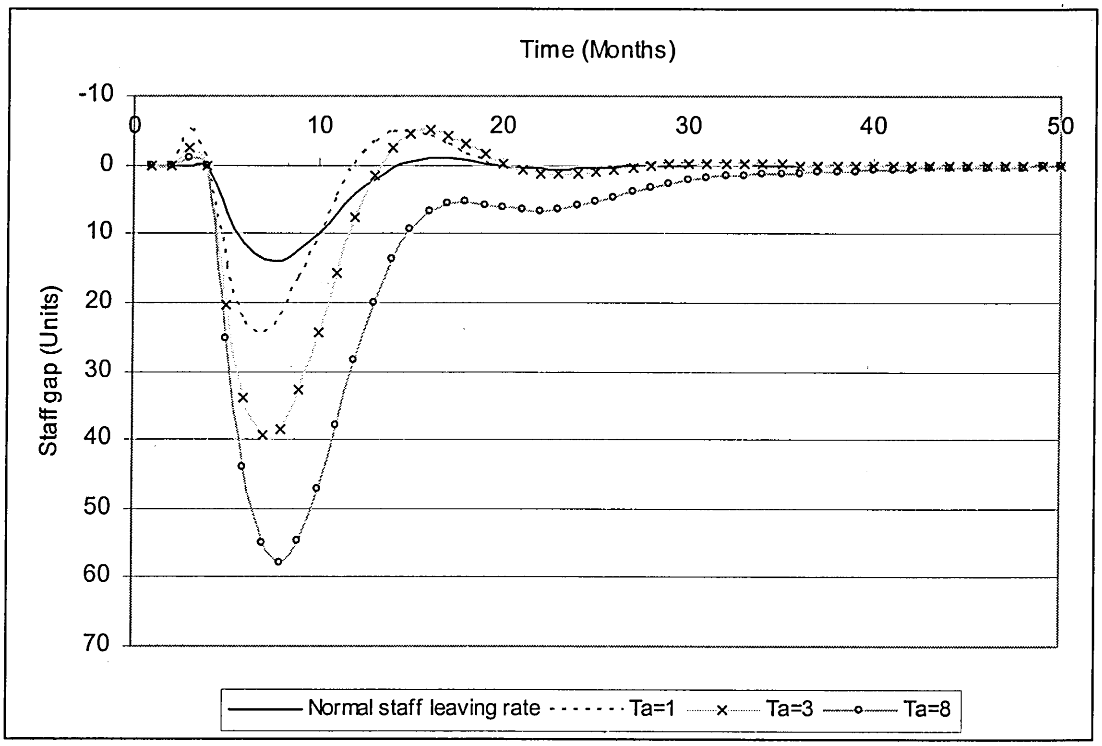
The second important simulation results carried out on the SKPM is staff gap analysis; the staff gap is shown in the figures below. Staff gap analysis is the process of comparing the workforce supply projection to the workforce demand forecast. Identifying gaps (shortages) and surpluses (excesses) in staffing and skill levels is needed to meet future functional requirements. The company will eventually establish workforce strategies based on the results of this analysis. Analysis results will show one of the following:

- A gap (when projected supply is less than forecasted demand), which indicates a future shortage of workers or skills.
- A surplus (when projected supply is greater than forecasted demand), which indicates a future excess in some categories of workers and may

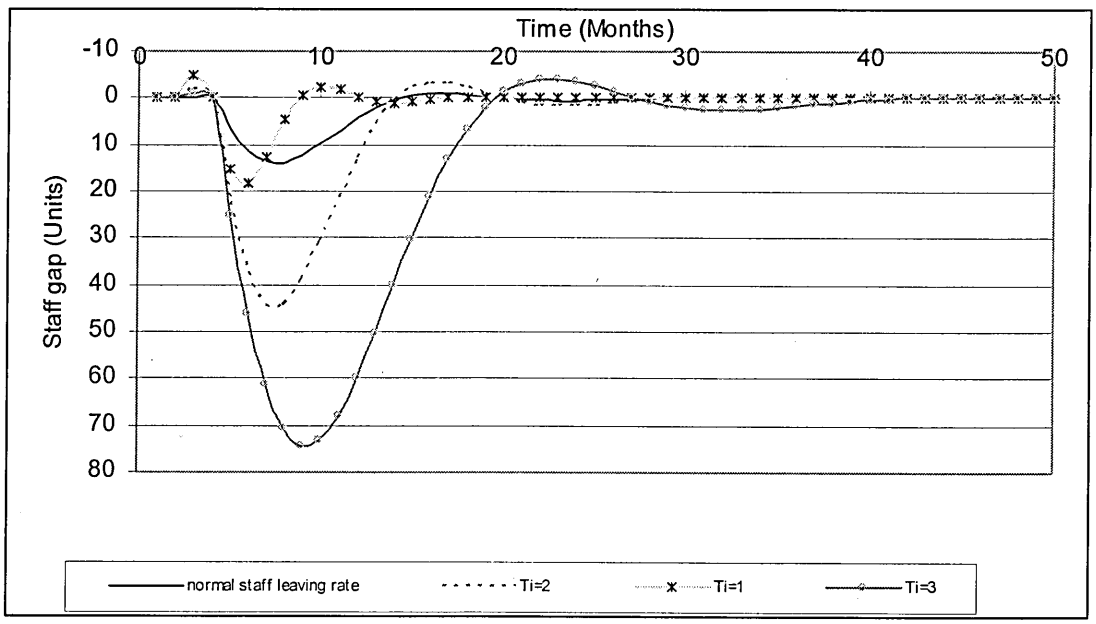
require action. The surplus data may represent occupations or skills that will not be needed in the future or at least not needed to the same extent.

Additionally Figure (5.15) shows some simple results for the behaviour of staff defect to a sudden change in staff leaving rate, eg by +10%. Therefore from previous experiments, the parameters to be tuned by the system designer are Ta, Ti, so we need to repeat the simulation for a range of values of both variables, and to check the behaviour of staff gap to a sudden change in staff leaving rate of +10% units/month.

Figure 5.15 shows the staff gap behaviour for case company A, for various values of Ti & Ta. The recruitment delay has been assumed to be 2 months. Therefore in Figure 5.15 (a) Ta has been varied from 1 month to 6 months, with Ti fixed at 2 months, then Ta has been fixed at 4 months and Ti varied from 1 month to 8 months. Also shown for comparison is the final drop in staff gap would result from a decision to eliminate recruitment demand rate from the company orders rate equations. Therefore the same scenario has been repeated for the company B and the results are shown in Figure 5.16 (a & b).

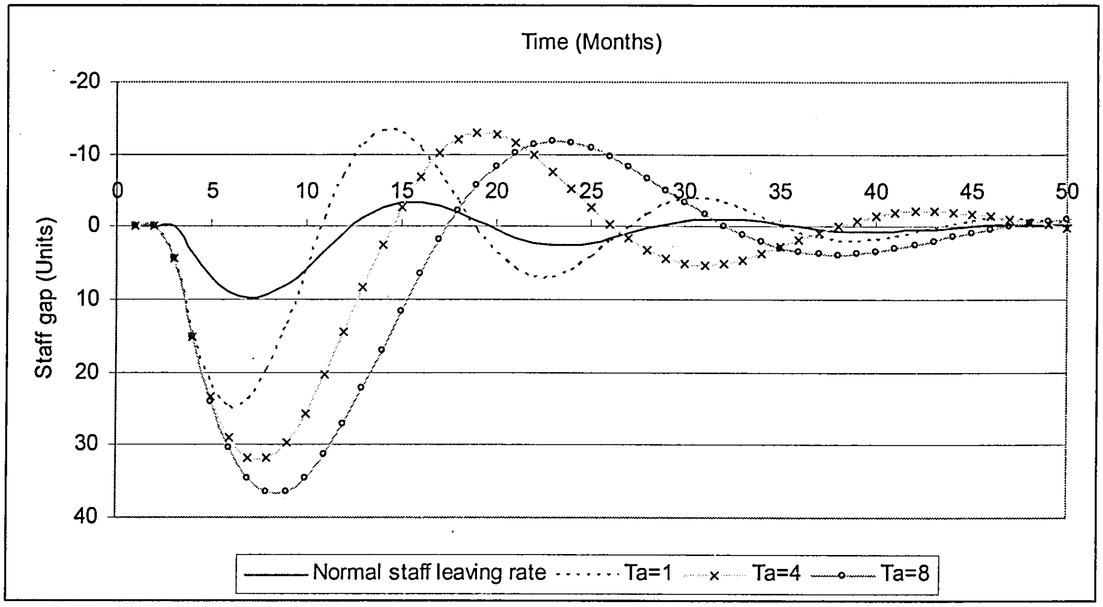


(a) Effect of adjusting Ta

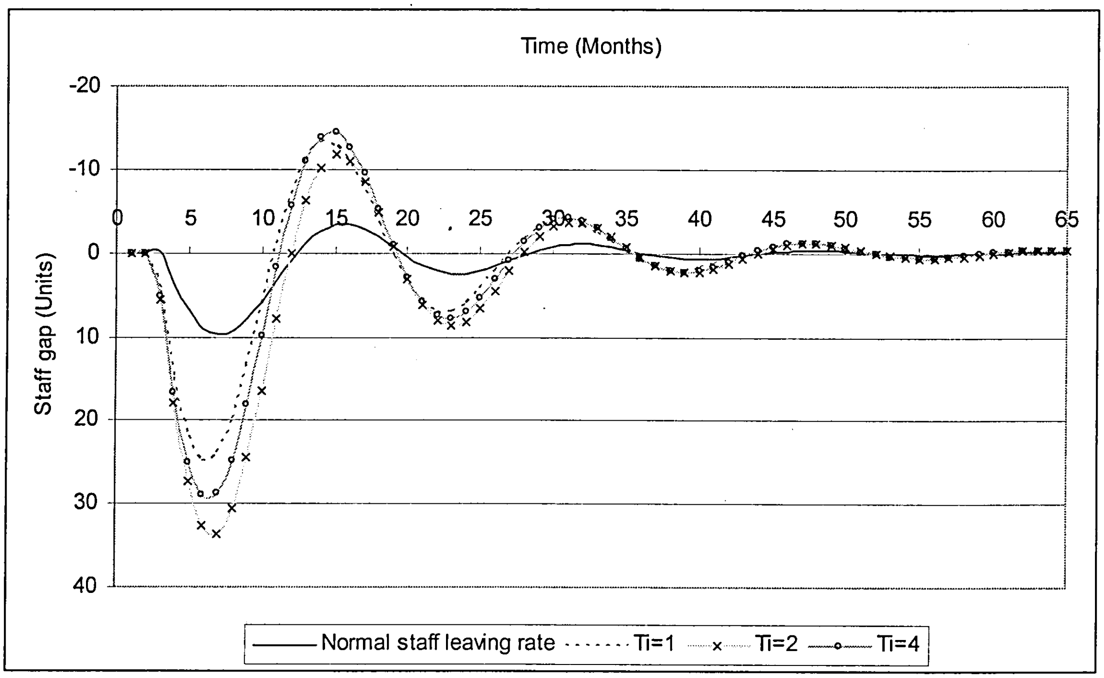


(b) Effect of adjusting Ti

Figure 5.15: Simple results showing effect of varying Ti when staff leaving rate changes by +10% a month in case study A



(a) Effect of adjusting Ta



(b) Effect of adjusting Ti

Figure 5.16: Simple results showing effect of varying Ti & Ta when staff leaving rate changes by +10% a month in case study B

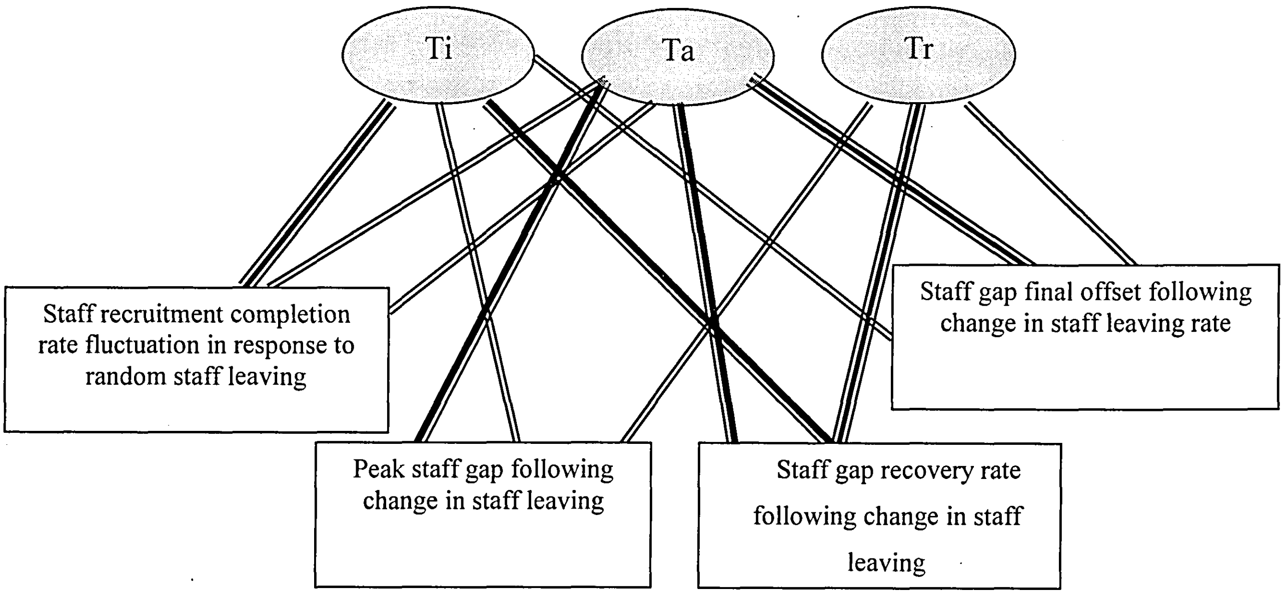
Inspection of Figures (5.15 and 5.16) and checking the results in table 5.3 and 5.5 suggests that setting Ti = Tr and Ta = 2 Tr months is a good design, since unnecessary fluctuation in staff gap have been avoided, and the time to recover target staff level is not excessively long. in this format we should mention that at Ti =1 month the oscillations continuous for long time, and simulation accuracy for Ti = 1 month is becoming poor. On the other hand, a combination of (Tr= Ti = 2 months and Ta = 4 months) for case study A and (Tr= Ti = 3 months and Ta = 6 months) for case study B appears perfectly acceptable, and the staff level behaviour does not appear to have significantly worsened. Indeed the results show at a glance the changes to be implemented by the decision maker in order to improve the performance.

5.10 SKPM Connectance Diagram

It is instructive to construct a "connectance diagram" showing the relative strengths of the relationships between the system design variables (Ti, Tr and Ta), and the output variables of interest to the human resource department manager.

In Figure 5.17, these results are shown and the relative weight is indicated by the width of lines joining the cause and effect variables. Four SKPM output variables have been selected to illustrate the results. Three relate to staff inventory behaviour (two measure the recovery and the third the steady state drop, which is eliminated entirely by the feed foreword of forecast staff leaving rate). The fourth output variable is the important matter of the behaviour of staff recruitment completion rate to random variation in staff leaving rate.

SYSTEM DESIGN VARIABLES



Output variables assessed by decision maker

Figure 5.17: Connectance diagram showing relative strengths of relationships within SKPM

5.11 Summary

This chapter introduced the Skill Pool Model (SKPM) and its possible use in human resource planning. The chapter started by looking at the recruitment process and, by constructing the associated influence diagram, we were able to produce a simple Skill Pool Model. This model was implemented using the standard *Ithink* software package, enabling the easy production of the underlying block diagrams and dynamic equations. The model was tested by using staff pool data from two large overseas petrochemical companies.

Transfer functions were derived for the principal model outputs under investigation as directed by Ashworth, M.J., and Towill, D.R., 1978. Dynamic analysis was carried out for our case studies to improve our understanding of the dynamics of staff turnover in each company, leading to determination of the optimum recruitment parameters. The system performance indices used for this purpose were fully discussed. This chapter also detailed the outcomes of visits to the two companies concerned, including the historical background of the companies, the company structure and the different workforce turnovers pertaining in the companies.

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CHAPTER 6

Optimising Dynamic Behaviour of Skill Pool Model Using the Automated Pipeline Policy (APSKPM)

6.1 Chapter overview

This chapter presents an overview of a basic analysis of the Automated Pipeline Skill Pool Model (APSKPM). This model is a refinement of the Skill Pool Model considered in the last chapter and will be shown to offer companies an improved way of managing their staff recruitment process. The chapter starts by looking at influence and block diagrams, and relevant transfer functions. An analysis is then given of the recruitment process for our two case studies using this model. As before we give the optimum policy parameters and APSKPM Performance indices for the model.

6.2 Introduction

The model developed in this chapter is adapted from the Automated Pipeline Inventory and Order Based Production Control System (APIOBPCS). Much work in dynamic analysis of the APIOBPCS model has been carried out by John (1992). Cheema (1994) has argued that this model is representative of much industrial practice with annual production control systems. Sterman (1989) has emphasized the advantages of the process pipeline control based on the work in progress; also he found that the system response had improved by using pipeline control policy. Cheema (1994) shows how the APIOBPCS model can be shaped to satisfy those conditions under which analogous linear control systems for other applications have been regarded as optimum. Disney and Towill (2002) show how the APIOBPCS model can optimize the dynamic response of a vendor managed inventory system.

In this chapter we will be looking specifically at the recruitment lead time and be concerned with how many people are "under recruitment". The people under recruitment will be referred to as recruit staff in process, which will be a function of the expected staff leaving rate and the time it takes to acquire new staff. A block diagram representation of our case company recruitment and training control system is given in Figure 6.2. In this format the automated pipeline skill pool model is developed to increase the robustness of the recruitment by adding feedback loops (Horowitz, 1963), and to improve our understanding of the dynamics of staff shortages and overstaffing in a company when it is going through some major changes. This model is implicitly linked with the organization's environment. Also it aims to respond to the training and hiring needs via knowledge of the present staff leaving rate (feed forward) as well as actual stall level and the staff training completion rate (feedback). In the skill pool model feedback is used to help counteract drift problems associated with the target staff level. The aim of automated pipeline control is to additionally take into account the people under recruitment, i.e. the recruit staff in process and use this as feedback information. Recruit staff in process is the equivalent of work in progress in production systems.

6.3 Influence diagram representation of APSKPM

Influence diagrams are a method of sketching out what causes what in the system. The emphasis is on understanding the overall behaviour of a complex system in terms of stability, response time, etc. The Influence diagram is a pictorial display of how the variables in the system influence one another (Coyle, 1977). Causal loop diagrams are used to develop causes and effect relationships between the main variables of systems. In our view, key components of a human resource planning model should represent links between staff level, training, recruitment, staff leaving rate and recruit staff in process.

The influence diagram for The Automated Pipeline Skill Pool Model (APSKPM) is shown in Figure 6.1 using the standard *Ithink* software. The model is a time varying extension for the baseline IOBPCS. It is adapted from the simplified work in progress model of Disney and Towill (2001). As with the SKPM model, the actual staff leaving rate is forecast using exponential smoothing to give the forecast staff leaving rate. The smoothing constant involves the same quantity Ta as before. This forecast is then used to arrive at a target recruit staff in process value. This value is taken to be a simple multiple of the forecast staff leaving rate. The multiplier is the value Tc, which is arbitrarily chosen by the decision maker and is therefore used as a control parameter. The actual recruit staff in process value compared to the target for this quantity will give rise to a gap. If we wish this gap to be reduced in time Tw, then we need to feed this through to the recruitment demand rate. The recruitment demand rate will thus be influenced by the forecast staff leaving rate, the staff gap and the time to reduce this (Ti) together with the recruit staff in process gap, and the time to reduce this gap, which is the Tw quantity. This recruitment demand rate will influence the recruitment completion rate as before, and involve the control parameter Tr. Therefore, in this model, the company can control its recruitment process by varying the control parameters Ta, Ti, Tr, Tw and Tc.

The major difference is that here (compared to the SKPM situation) we are explicitly concerned with recruit staff in process. Such staff are a reality. They need to be trained up and inducted into a company, which takes time. The APSKPM model allows the company to control this aspect of its recruitment process.

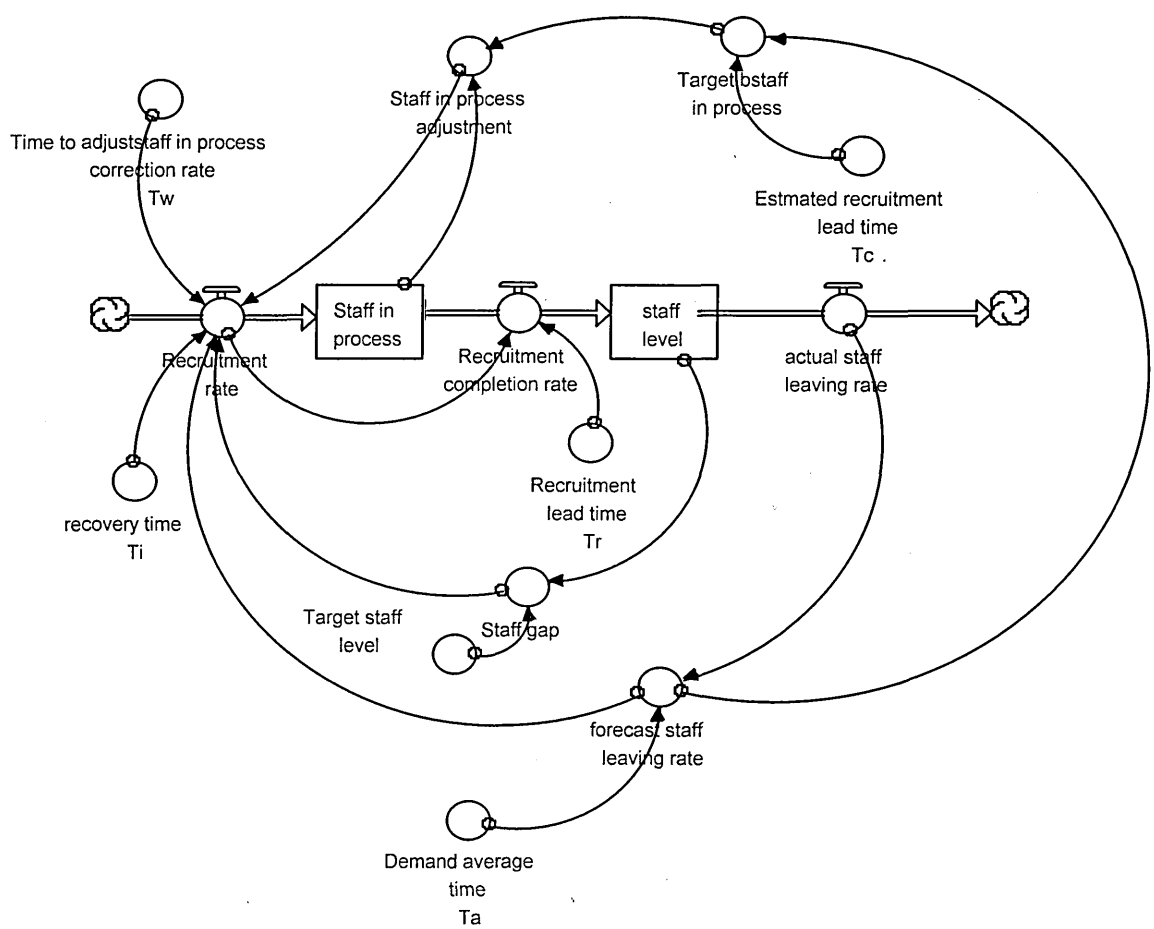


Figure 6.1: Influence diagram of the APSKPM

6.4 APSKPM block diagram

Figure 6.2 shows a simplified Automated Pipeline Skill Pool Model (APSKPM) block diagram model. The model shows that the recruitment rate schedules are derived as a function of current staff leaving rate, staff level and recruit staff in process. The staff gap is the difference between target staff level and actual staff level and the error is recovered over the period of time Ti, where 1/Ti is acting as proportional controller which adjusts the time to recover the staff gap error over the specified time period. Similarly 1/Tw adjusts the staff in process error, and the target staff in process is the average of staff leaving rate multiplied by Tc (the chosen value for the recruitment lead time). The recruit staff in process error is the difference between the target recruit staff in process and actual recruit staff in process. The forecast staff leaving rate FSLR is a function of the present staff leaving rate and the Ta parameter. Therefore, SKPM feedback is provided to help counteract the drift in staff levels and automated pipeline control is provided to counteract the drift in recruit staff in process, ie in those staff already committed to the company but not yet in the staff pool with the skills required.

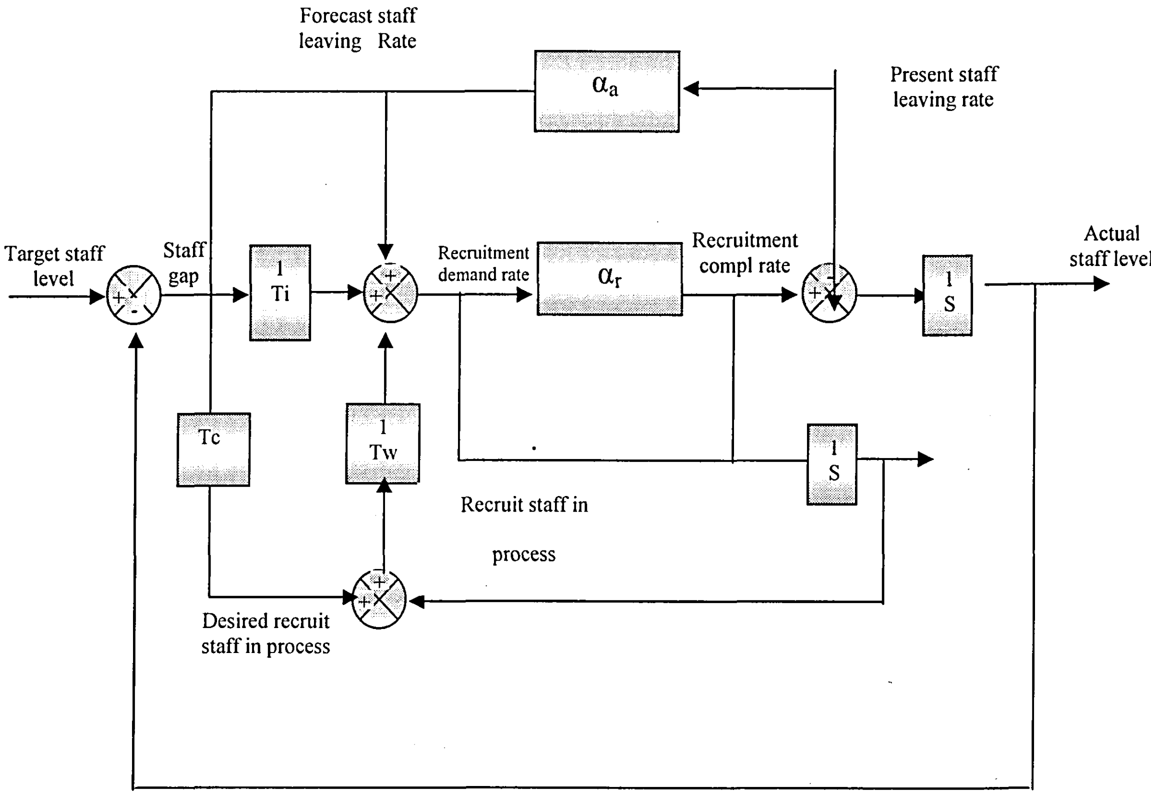


Figure 6.2: A block diagram representation of APSKPM

The equations characterising the system dynamics of out APSKPM are the following:

Forecast staff leaving rate equation

$FSLR_{k+1} = FSKR_k + \alpha_a (PSLR_k - FSLR_k)$ ----(1)

Where $\alpha_a = 1 / (1 + T_a *S)$

Staff gap equation

$SG_{k+1} = DSL_{k+1} - ASL_{k+1}$ ---(2)

Recruitment demand rate

$RDR_{k+1} = SG_{k+1} / T_i + FSLR_{k+1} + DRSIP_{k+1} / Tw$ --(3)

Recruitment completion rate

$$RCR_{k+1} = RCR_k + \alpha_r (RDR_k - RCR_k) \qquad \text{---(4)}$$

Where $\alpha r = 1 / (1+ T_r{*}S)$

Actual staff level

$$ASL_{k+1} = ASL_k + RCR_{k+1} - PSLR_{k+1} \qquad \text{---(5)}$$

Recruit staff in process

$$RSIP_{k+1} = RSIP_k + (RCR_{k+1} - RCR_{k+1}) \qquad \text{---(6)}$$

Desired recruit staff in process

$$DRSIP_{k+1} = FSLR_{k+1} {*}(Tc) \qquad \text{---(7)}$$

Recruit staff in process adjustment

$$RSIPA_{k+1} = DRSIP_{k+1} - RSIP_{k+1} \qquad \text{---(8)}$$

The main blocks and flows of the APSKPM block diagram, shown in Figure (6.2), can be described as follows:-

Terms	Abbreviations	Description
Present staff leaving rate	PSLR	The units of staff leaving rate are staff units/month.
Forecast staff leaving rate	FSLR	It is the time average (exponential smoothing) of staff leaving rates. The units of staff leaving rate are staff units/month.
Desired staff level	DSL	It is the level of target staff required. The units of target staff level are staff units.
Staff gap	SG	It is the difference between desired staff level and actual staff level. The units of staff gap are staff units.
Recruitment demand rate	RDR	It is the demand recruitment rate and will depend on the staff gap. The units of recruitment demand rate are staff units/month.
Recruitment completion rate	RCR	It is the recruited staff completion rate it is refers to the acquired staff. Its units are staff units /month.
Actual staff level	ASL	It is the actual number of staff which company has. The units of actual staff level are staff units.
Ti	Ti	Time to reduce the staff gap to zero measured in months.
Ta	Ta	Time over which staff leaving rate is averaged in months.
Tr	Tr	Recruitment process delay measured in months.
$1/T_i$	$1/T_i$	It is the proportional constant to deal with the discrepancy between target staff and actual staff level. The units are per month.
Tw	Tw	time to reduce recruit staff gap deficit to zero
Tc	Tc	Estimated recruitment lead time
$1/T_i$	$1/T_i$	It is the proportional constant to deal with the discrepancy between target staff and actual staff level. The units are per month.
1/Tw		It is the proportional constant to deal with the staff in process adjustment
1/S	1/S	This represent the integration process whereby the actual staff level is accumulated over time through the recruitment and training development
$1/(1+T_a*S)$	α_a	This is the multiplier used in simulation to take account of the time to average the staff leaving rate.
$1/(1+T_r*S)$	α_r	This is the multiplier used in simulation to take account of the recruitment process delay.

Table 6.1: Glossary of terms used in APSKPM block diagram

6.5 Transfer functions required for APSKPM

There are now three transfer functions of interest, relating to the actual staff level, the recruitment completion rate and the new quantity, recruit staff in process, all in terms of present staff leaving rate. These transfer functions can be derived using the block diagram analysis as shown in Figure (6.2) and are as follows

$$\frac{actual.staff.level}{present.staff.leaving.rate} = -Ti\left[\frac{\frac{(Tr-Tc)}{Tw} + \left(Ta + Tr + \frac{TaTr}{Tw}\right) * S + TaTrS^2}{(1+TaS)\left(1+\left(1+\frac{Tr}{Tw}\right) * TiS + TrTiS^2\right)}\right] \text{--- (A)}$$

$$\frac{recruitment.completion.rate}{present.staff.leaving.rate} = \left[\frac{1+\left(Ta + Ti + \frac{TcTi}{Tw}\right) * S}{(1+TaS)\left(1+\left(1+\frac{Tr}{Tw}\right) * TiS + TrTiS^2\right)}\right] \text{---(B)}$$

$$\frac{recruitment.staff.in.process}{present.staff.leaving.rate} = Tr\left[\frac{1+\left(Ta + Ti + \frac{TcTi}{Tw}\right) * S}{(1+TaS)\left(1+\left(1+\frac{Tr}{Tw}\right) * TiS + TrTiS^2\right)}\right] \text{---(C)}$$

Equation A, B and C are derived in Appendix 4 and, as before, enable us to see the dependency on the parameters T_i, T_a, T_r,T_W and T_c that are to be set by the decision maker when determining optimal HRP policy.

6.6 APSKPM Performance indices

In the case of APSKPM, the measurement criteria are defined in similar terms to SKPM, which are illustrated in section 5.7, for the first two measurements ot the actual staff level, and recruitment completion rate. Recruit staff in process is an important measurement in the pipeline. Therefore the total staff level within the system at any point in time is the sum of actual staff level and recruit staff in process. The pipeline also is a function of the actual staff leaving rate lead time. If the theoretical and actual values are similar this may also imply that RSIP is being controlled, but any deviation would show in highly-variable values of RSIP. Figure (6.3) shows a typical recruit staff in process time response.

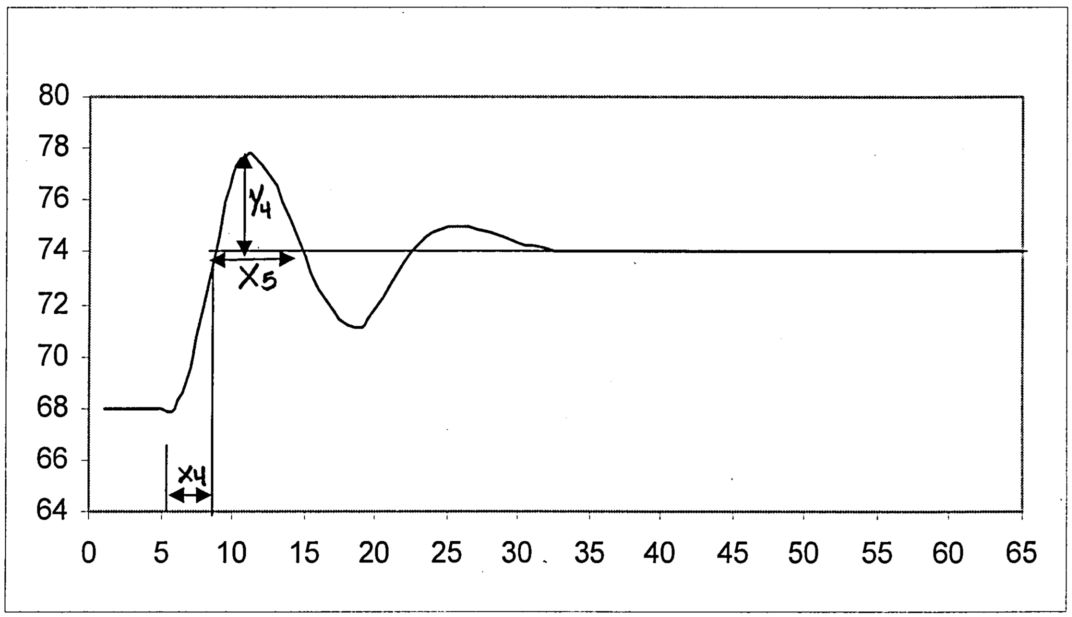


Figure 6.3: APSKPM Performance indices

6.6.1 Rise time X4

The rise time is defined in similar terms to the recruitment completion rate shown in Figure 6.3. This will provide a company with good information about the rate at which Recruit staff in process is building up in the planning pipeline.

6.6.2 Peak overshoot Y4

The peak overshoot in recruit staff in process is defined in similar terms to the recruitment completion rate Y4 in Figure 6.3. A large value may imply leaving rate problems in throughput, large lead times and consequently an excess of actual staff level.

6.6.3 Duration of overshoot X5

The duration of overshoot is defined as the analogous term in recruitment completion rate X5 in Figure 6.3. This measure will give a real picture of the problematic area and inefficiencies in the actual staff level and recruitment programme.

These performance criteria are chosen to describe the simulation model. These criteria are selected so that they give tangible meaning to the decision maker or planning department manager on the company, and the means whereby the decision maker can control the recruitment process.

6.7 Dynamic Analysis of the APSKPM model for case study A

A simulation model was written using the standard *Ithink* software and the spreadsheet, Excel (see Appendix 5). In order to anticipate the staff leaving replacement requirements, some kind of averaging is useful. We have used the exponential smoothing function to average the present staff leaving rate over time Ta and related this back to the original recruitment demand rate to reflect the staff loss history in the recruitment planning. The main aim of using the APSKPM model and simulation analyses in this chapter is to find optimum policy parameters for the company to maintain its target staff pool and the staff recruitment policy. The experiments were designed to set parameters Ti, Ta, Tr, Tw and Tc in a given range to observe and record the dynamic response in order to determine their optimum setting. Once selected, the system would determine staff recruitment automatically governed by Ta and Ti according to a present staff leaving rate and staff gap. Table 6.2 shows the performance index of the APSKPM model and describes the related system behaviour.

Figure 6.4 shows the dynamic response in the staff recruitment completion rate, actual staff level and recruit staff in process for the range of Ti values shown. As seen in Figure 6.4(a), increasing Ti reduces the peak overshoot. The peak overshoot will occur with an under damped system and is defined as a maximum value of the out put and to achieve a level good control, large overshoots are to be avoided. A small overshoot has to be balanced against a moderate staff recovery rise time.

Figure 6.4(b), shown the actual staff level behaviour for various values of Ti (Ti is gradually varied between 1 month to 30 months), for fixed values of Ta, Tr, Tw, and Tc. An increase in the staff leaving rate will cause an initial deficit in actual staff level as staff losses are met from the existing staff level. The response then shows a moderate overshoot before settling to its steady state value. This is due to the initial staff loss being met from actual staff pool whilst extra staff are being recruited on the training programme, or new staff start to be recruited. As Ti increases, the duration of staff pool deficit would increase, and the peak staff pool overshoot would decrease as well. Figure 6.4(c) shows the behaviour of recruit staff in process. Because the recruit staff in process is one of the important controllers in the recruitment and training delay, the response of recruit staff in process shows similar properties to that of the recruitment completion rate, but with the actual values multiplied by Tr.

Figure 6.5 examines the responses of the staff recruitment completion rate, actual staff level and recruit staff in process for varying values of Ta. The quantity Ta is gradually varied between 1 and 30 months, for fixed values of Ti, Tr, Tw, and Tc. As shown in Figure 6.5(a) the largest value of Ta gives less of an oscillatory response for the recruitment completion rate. As Ta decreases, the recruitment completion rate overshoot increases, but the settling time decreases. Figure 6.5(b) shows that large values of Ta give a slow actual staff level recovery; decrease in Ta would lead to a decrease in staff level drop as well as a decrease in settling time. Smaller value of Ta would induce instability in a real system. Figure 6.5(c) represents the recruit staffs in process response, which is similar to the recruitment completion rate with the multiplied factor of Tr.

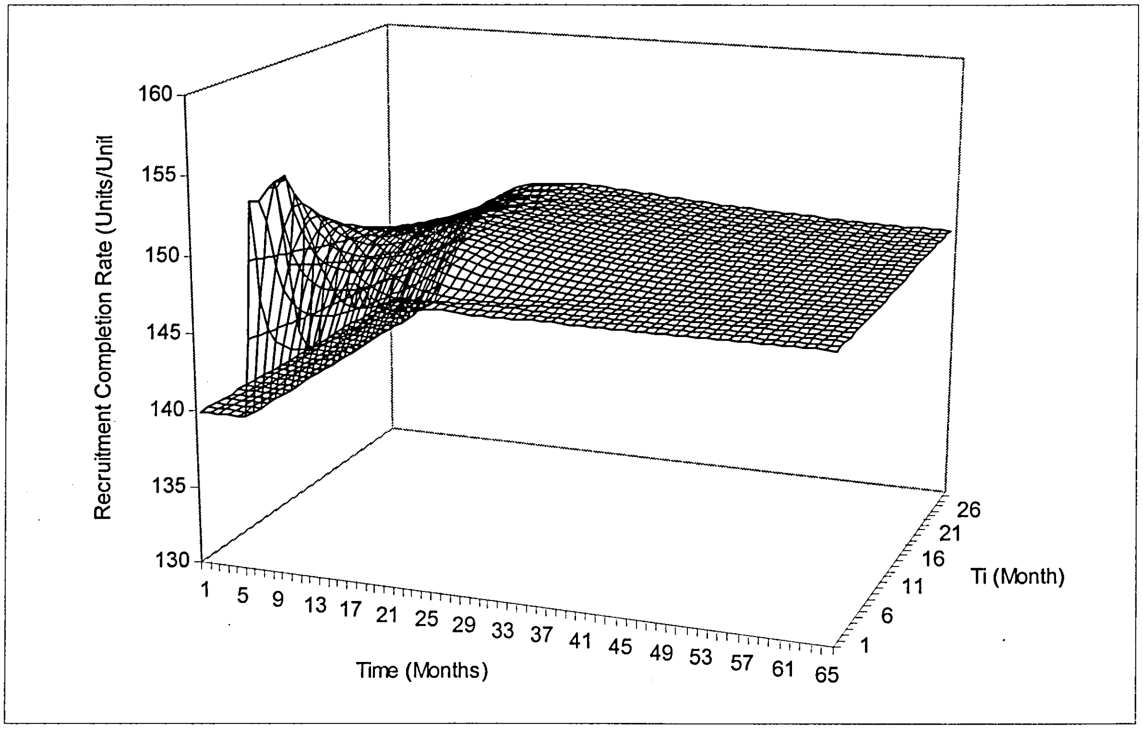
Figure 6.6 illustrates the behaviour of the three controllers namely, staff recruitment completion rate, actual staff level and recruit staff in process for varying Tr. Figure 6.6(a) shows that at Tr =2 months the behaviour of recruitment completion rate approaches from the optimum response, as Tr increase more than 4 months, the system response show a permanent overshoot, while for Tr greater than 6 months the initial staff level drop gets worse. Figure 6.6(b) illustrates the behaviour of actual staff level at various values ot Tr. As Tr increases from 6 to 30 months, the response is under the initial value and it doesn't recover completely, but at Tr at 2 months the recruitment completion rate has a good behaviour, therefore the maximum peak overshoot at Tr equal 8 months is 42.5 % of the nominal value and the duration of overshoot about 13 months. Figure 6.6(b). Figure 6.6(c) shows the response of recruit staff in process for various value of Tr. As Tr increases the oscillatory response increases, and for Tr less than 2 months the recruit staff in process is under the initial value. For Tr greater than 6 months the response is a pronounced overshoot. Obviously at Tr =2 months and 3 months the recruit staff in process has a good response.

Figures (6.7) show the behaviour of recruitment completion rate, actual staff level and recruit staff in process at different values of staff pipeline control parameter Tw. The aim is to observe how the system recovers from input changes. Figure 6.7(a) shows the recruitment completion rate behaviour. As shown in the figure, as Tw decreases the recruitment completion rate overshoot decreases; however, the time taken by the system to reach its steady state value slightly increases. As Tw decreases the dynamic recovery to the input improves. Figure 6.7(b) indicates that Tw values of less than 3 months give less peak overshoot but the duration of overshoot is longer. For Tw values greater than 4 months, the actual staff level overshoot increases. The actual staff level response indicates that as Tw decreases, the overshoot damps down, and at the same time the initial staff pool deficit increases slightly for smaller values of Tw. The recruit staff in process has similar behaviour to the training completion rate but with there is a multiplying factor of Tr as shown in Figure 6.7(c).

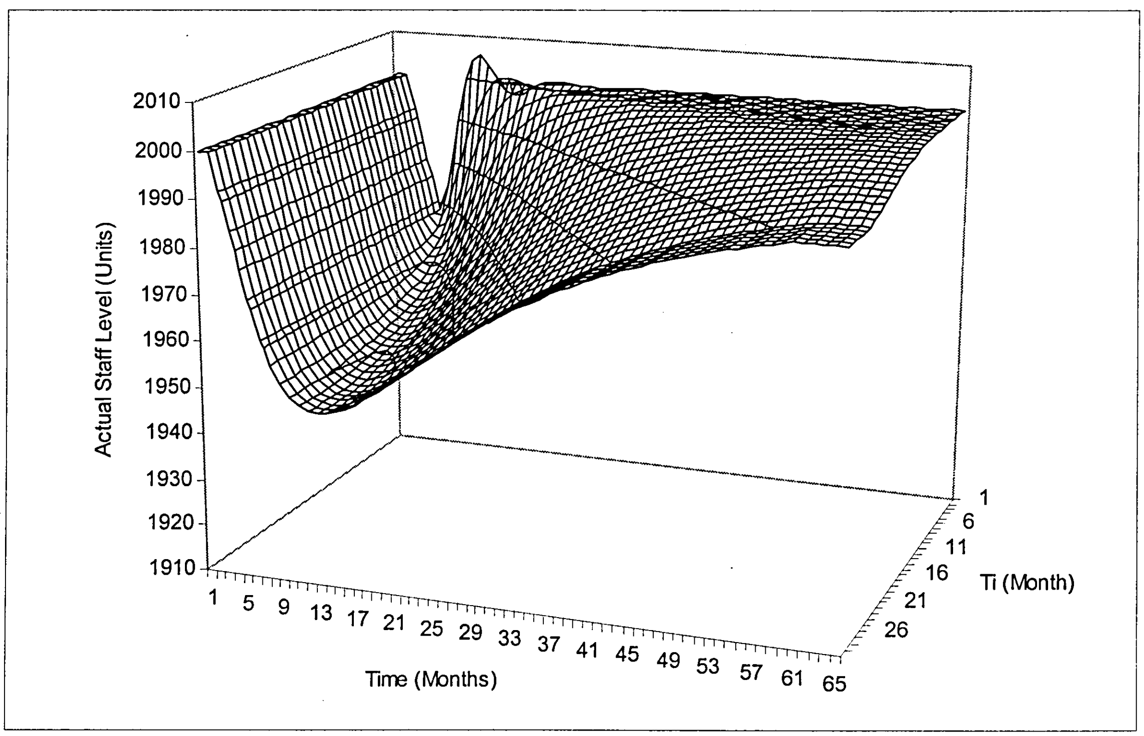
Figure 6.8 illustrates the influence of the parameter Tc on the three controllers, staff recruitment completion rate, actual staff level and recruit staff in process. This parameter is used to estimate the recruitment lead time to control the desired value of recruit staff in process. Figure 6.8(a) shows (Tc is gradually varied between 8 month to 21 months, for fixed values of Ti, Tr, Tw, and Tc) that at Tc less than 10 months the starting value is less than the nominal values. As Tc increase the peak overshoot increases as well as the duration of overshoot increase. Clearly for all Tc values the recruitment completion rate is completely recovered to the initial value.

Figure 6.8(b) shows that at Tc less than 12 months the actual staff level decreases below the initial value. The staff level pool has satisfactory behaviour for Tc between 12 and 15 months and the actual staff level drop, and the duration of the staff deficit, are small compared to other values. For Tc greater than 15 months the actual staff level increases and does not reach a steady-state value.

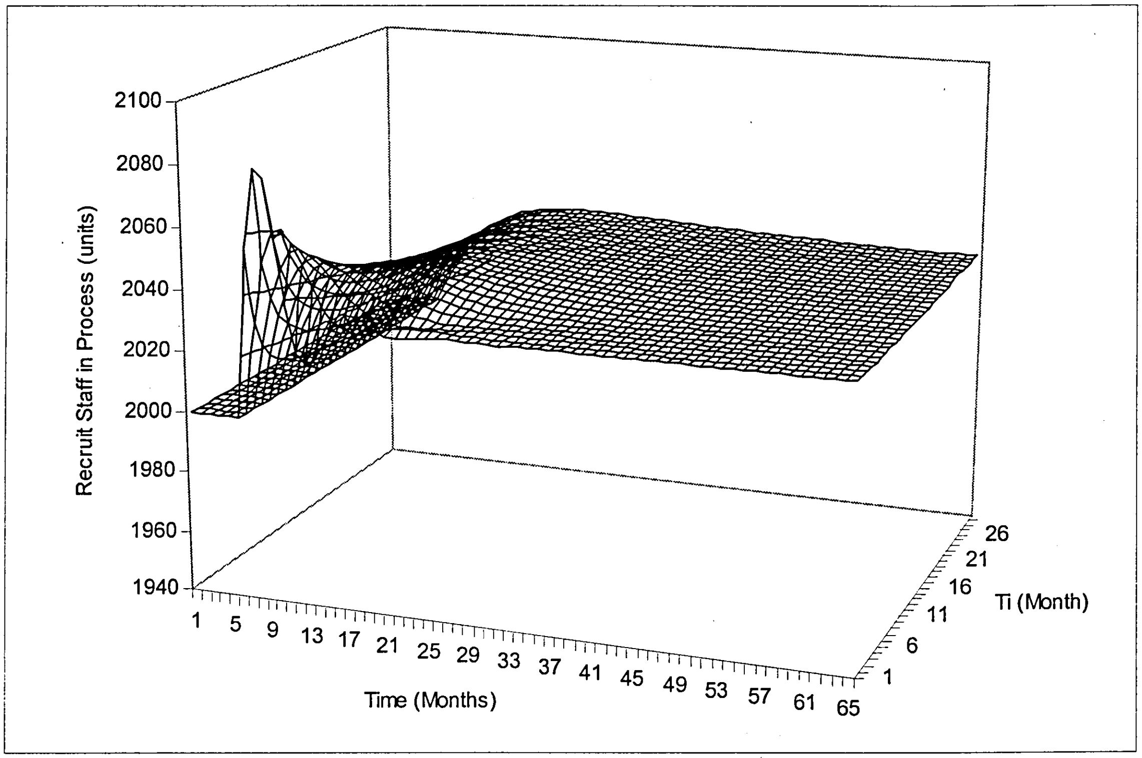
Figure 6.8(c) shows the recruit staff in process response for different values of Tc. By inspection of Figure 6.8(c), at Tc= 14 months the response is behaving acceptably. As Tc decreases less than 12 months the initial recruit staff in process level drop increases, and as Tc increase above 15 months the recruit staff in process level overshoot increases permanently. The results shown in Figure 6.8(c) indicated that Tc should be equal to 14 months. Tables 6.2 and 6.3 give the overall summary of the effect of varying Ti, Ta , Tr and Tw on human resource policies for APSKPM. Table 6.4 describes the descriptive statistical characteristics for recruitment and actual staff level at optimum design parameters for APSKPM in case study A. The optimum parameters in this case where determined in the way described in Chapter 5, by minimising the values of MSE and ITAE and determining those X values closest to the target values.



(a) Staff recruitment completion rate behaviour

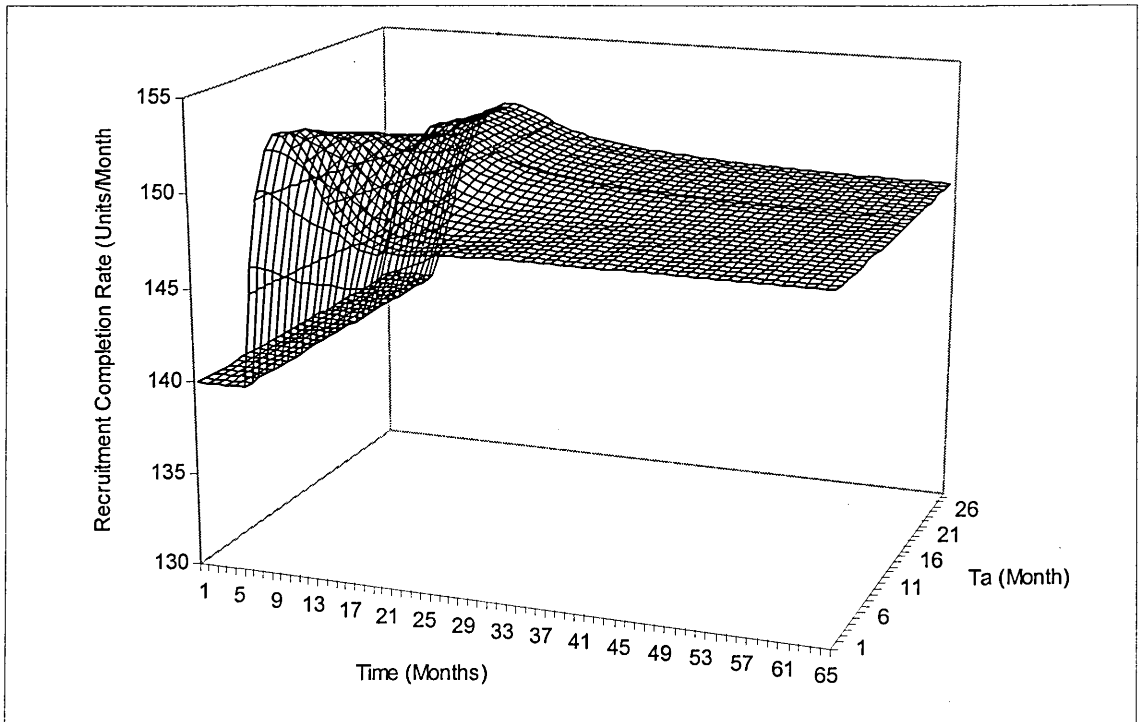


(b) Staff level behaviour

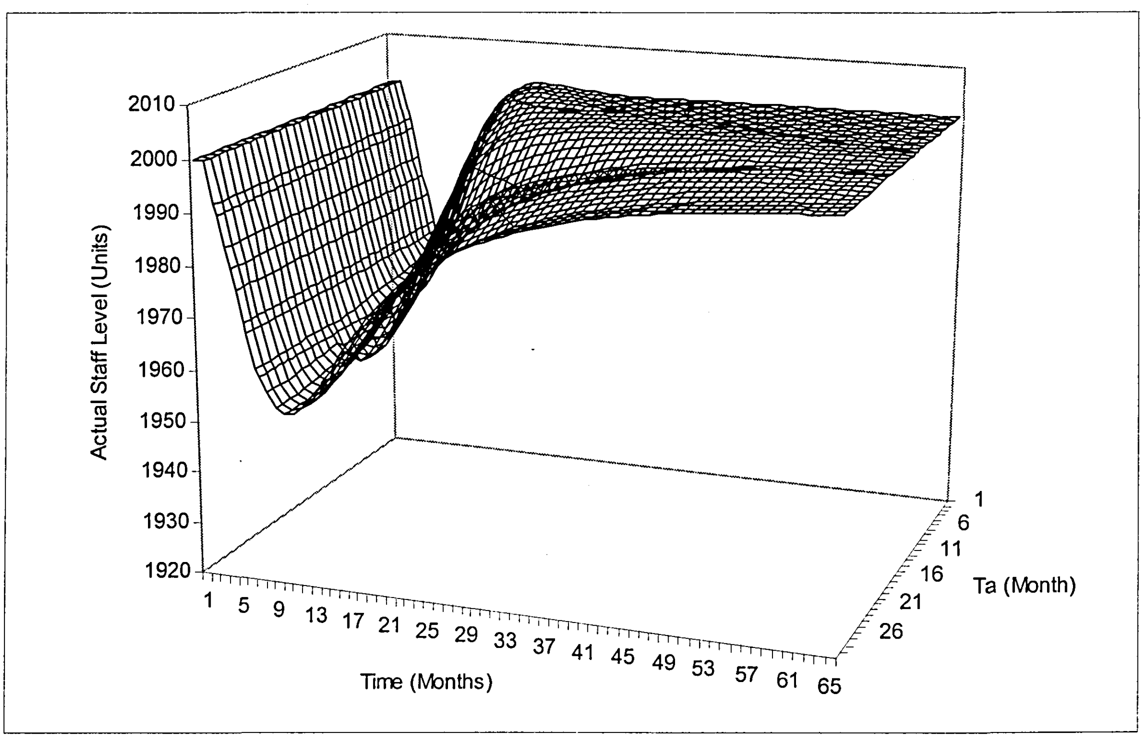


(c) Recruit staff in process behaviour

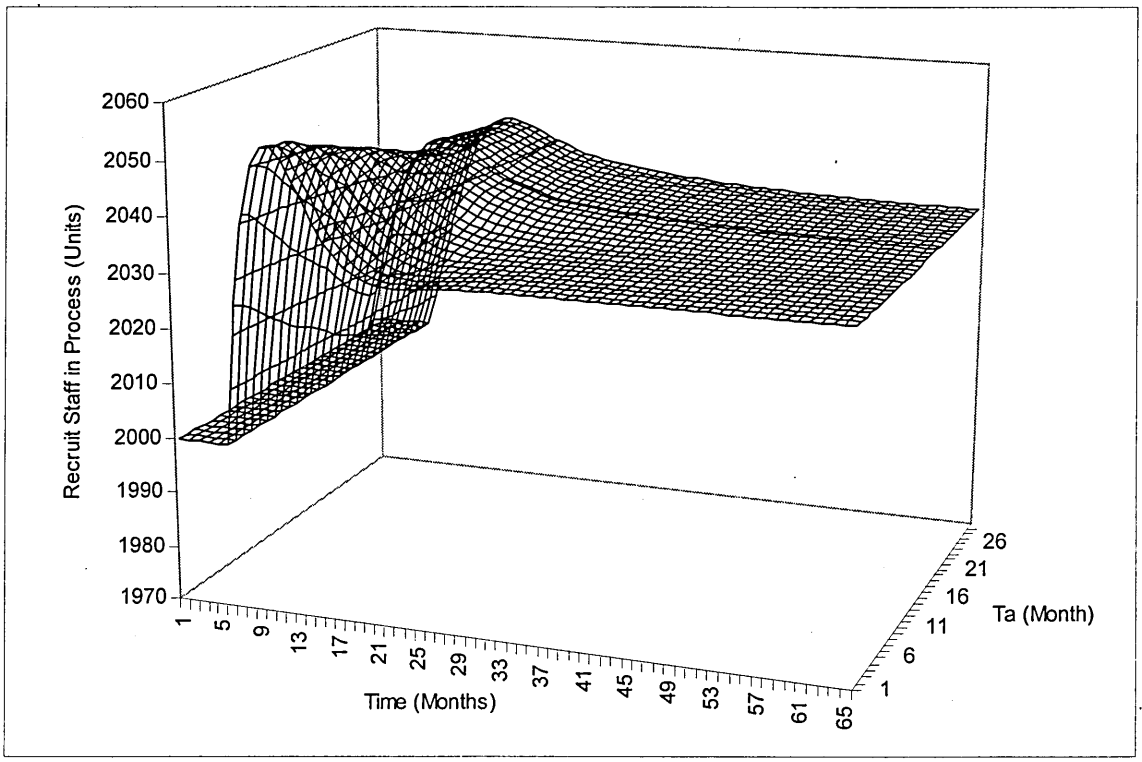
Figure 6.4: Response of APSKPM for (Ti=Ta=Tw=4 months) and varying values of Ti



(a) Staff recruitment completion rate behaviour

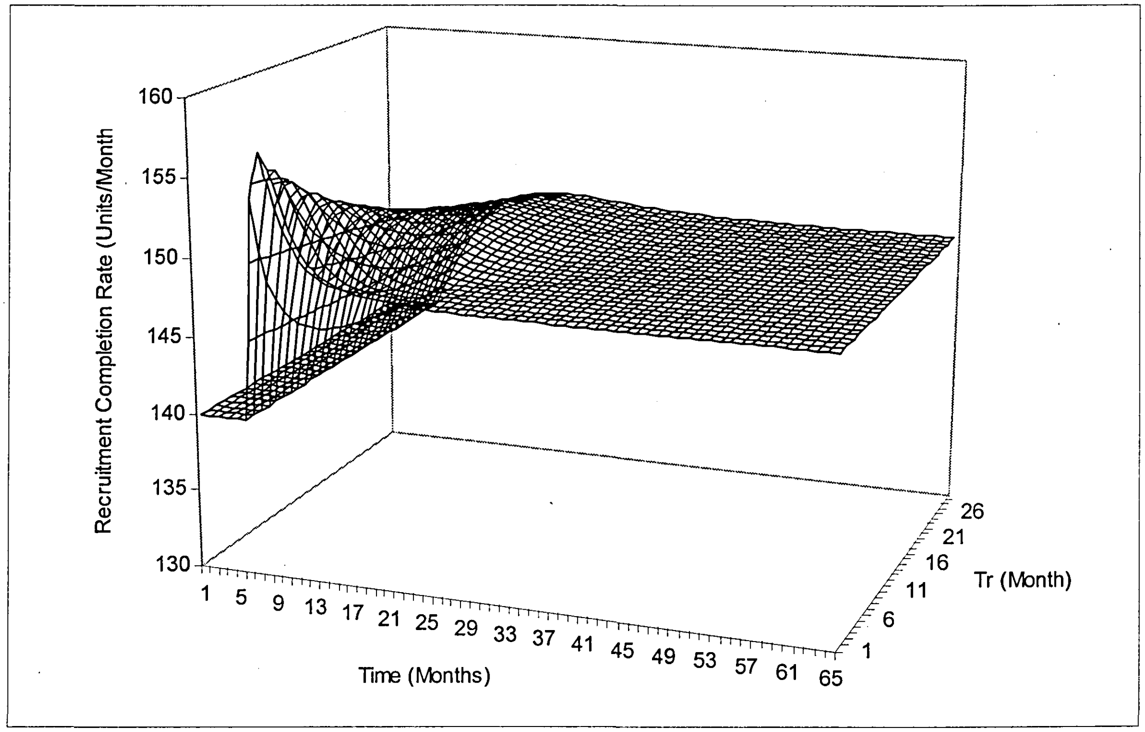


(b) Staff level behaviour

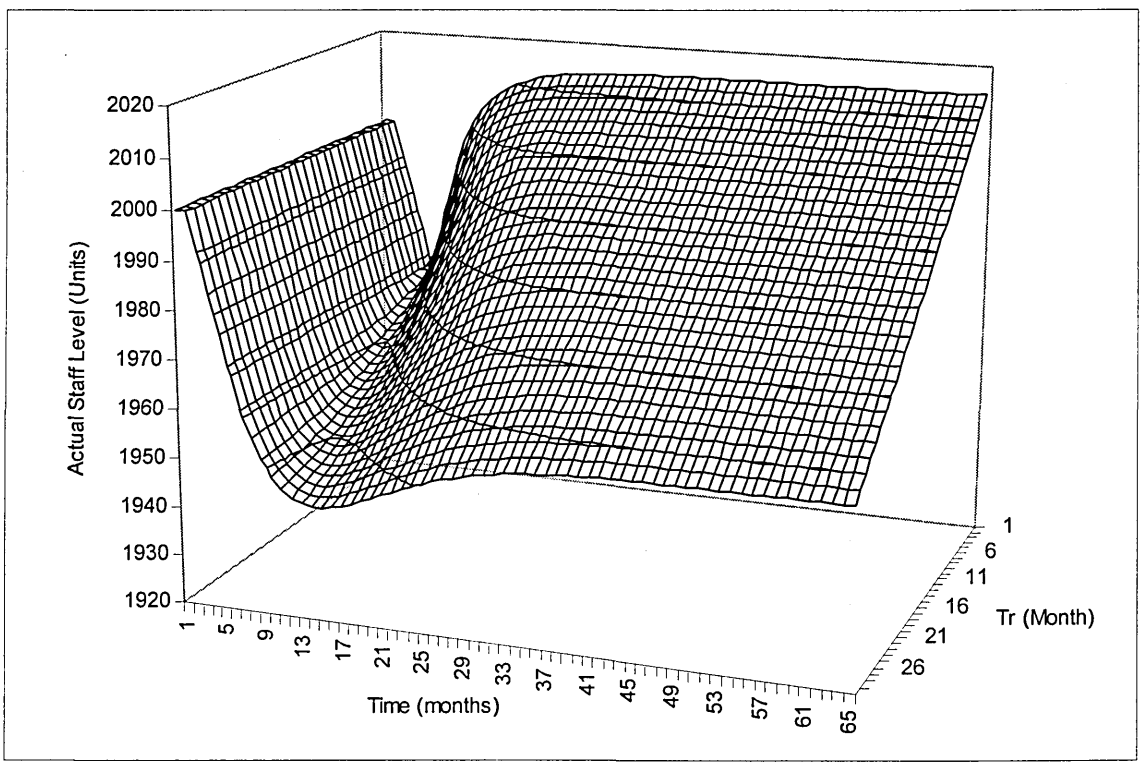


(c) Recruit staff in process behaviour

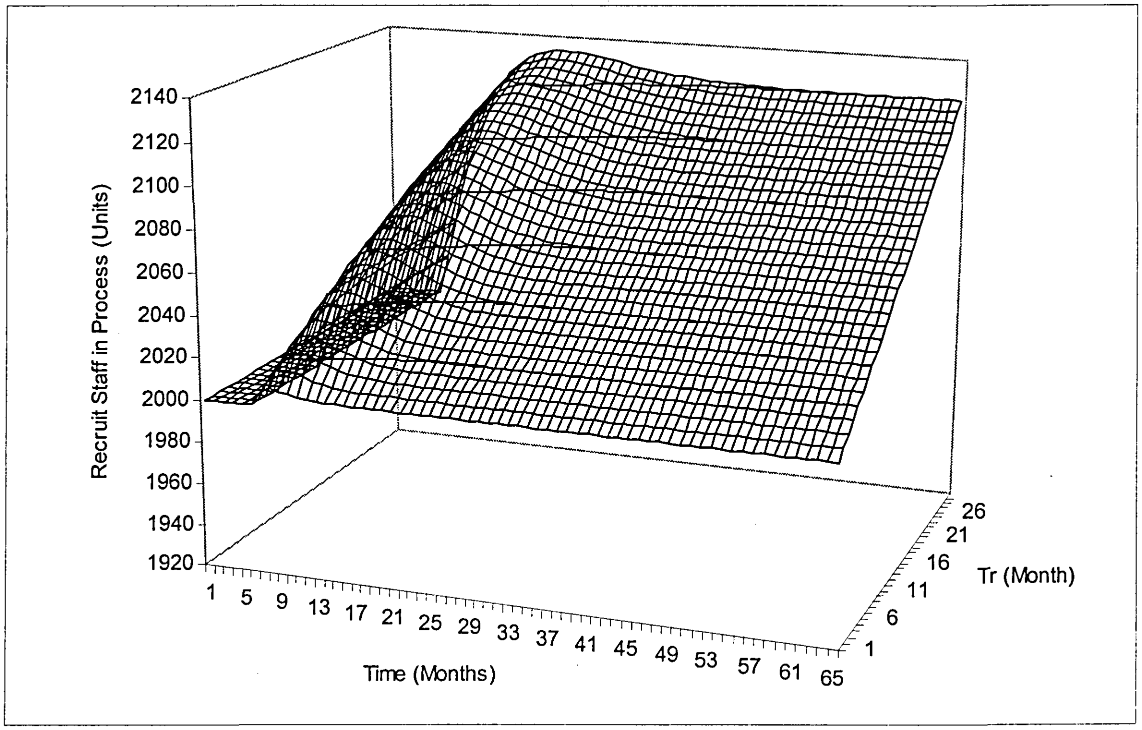
Figure 6.5: Response of APSKPM for (Ti=Ta=Tw=4 months) and varying values of Ta



(a) Staff recruitment completion rate behaviour

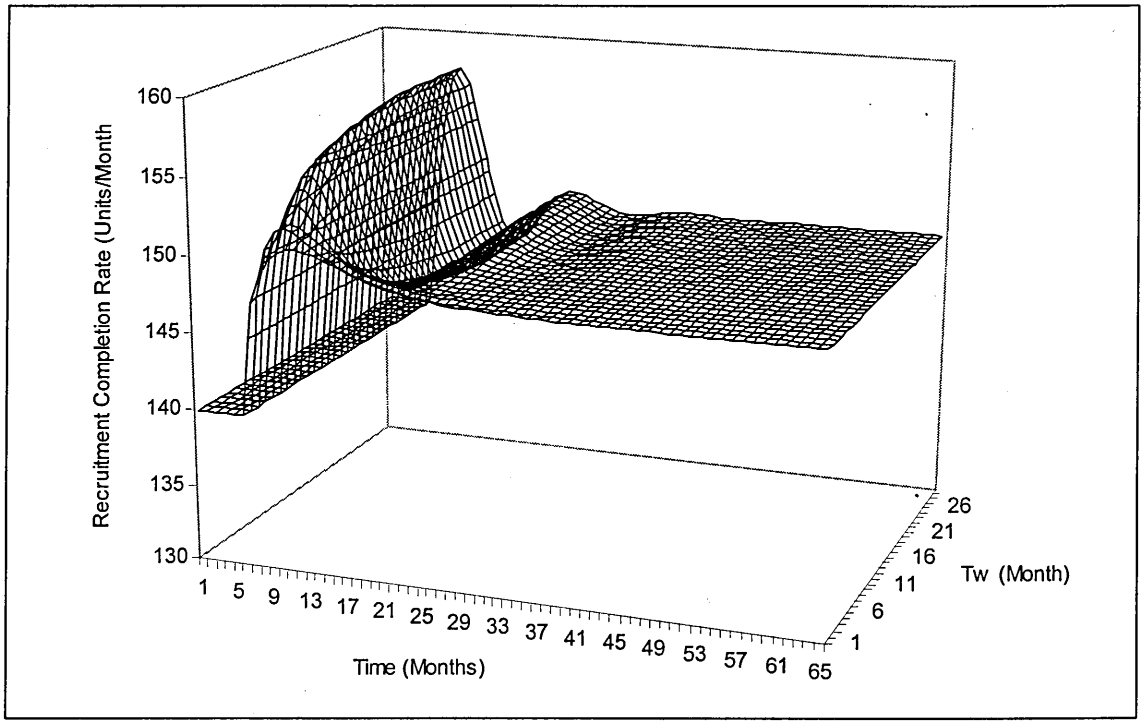


(b) Staff level behaviour

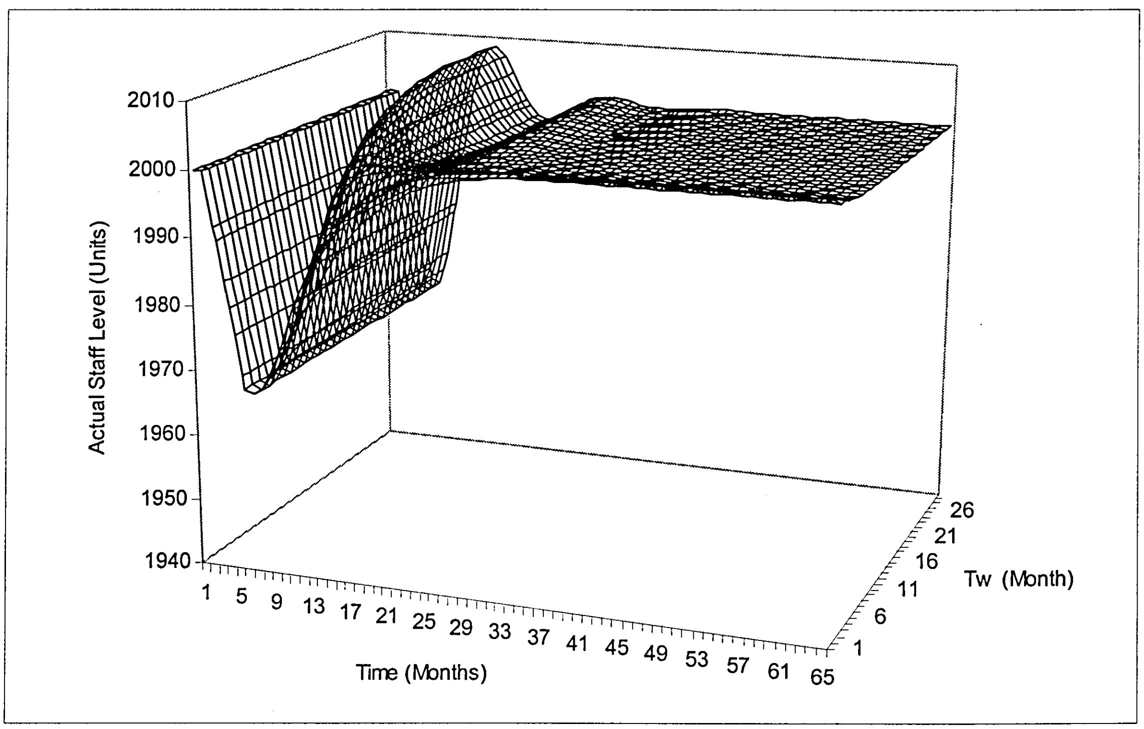


(c) Recruit staff in process behaviour

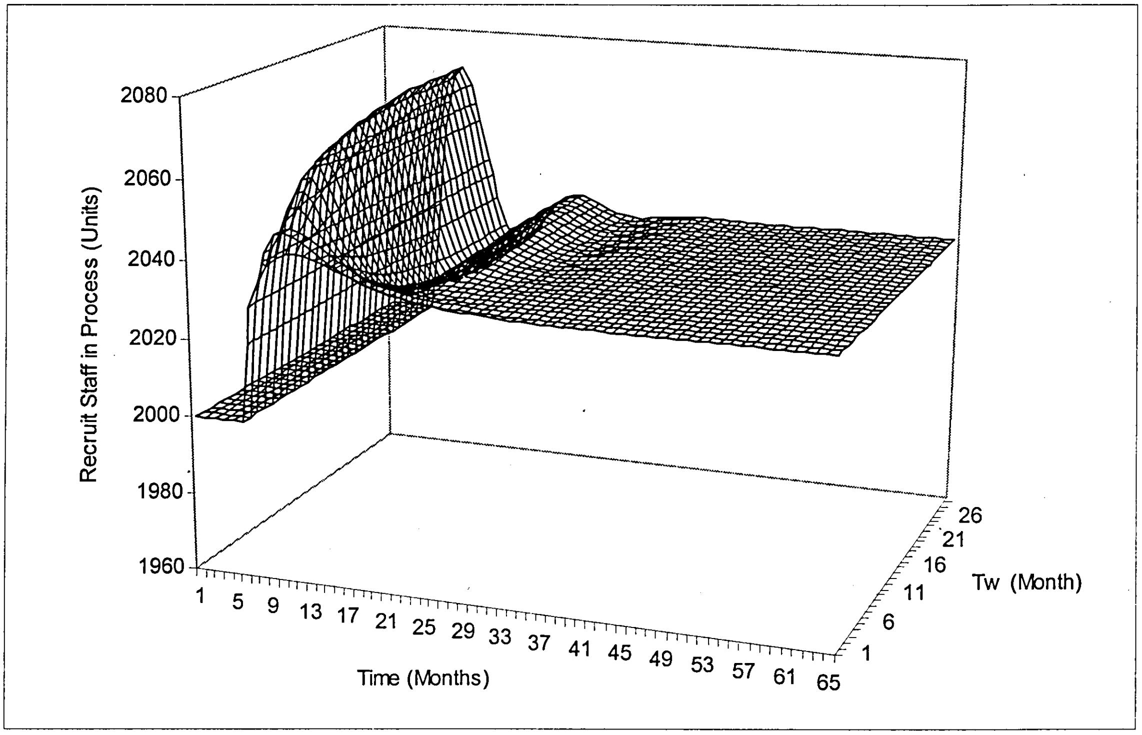
Figure 6.6: Response of APSKPM for (Ti=Ta=Tw=4 months) and varying values of Tr



(a) Staff recruitment completion rate behaviour

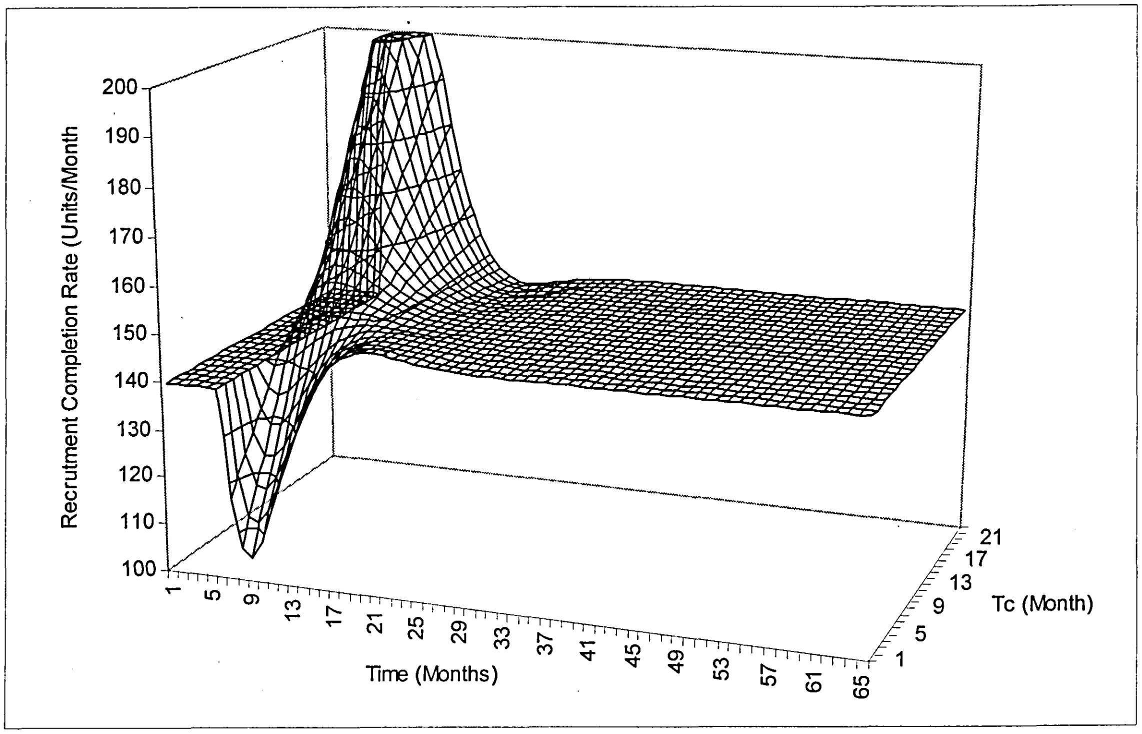


(b) Staff level behaviour

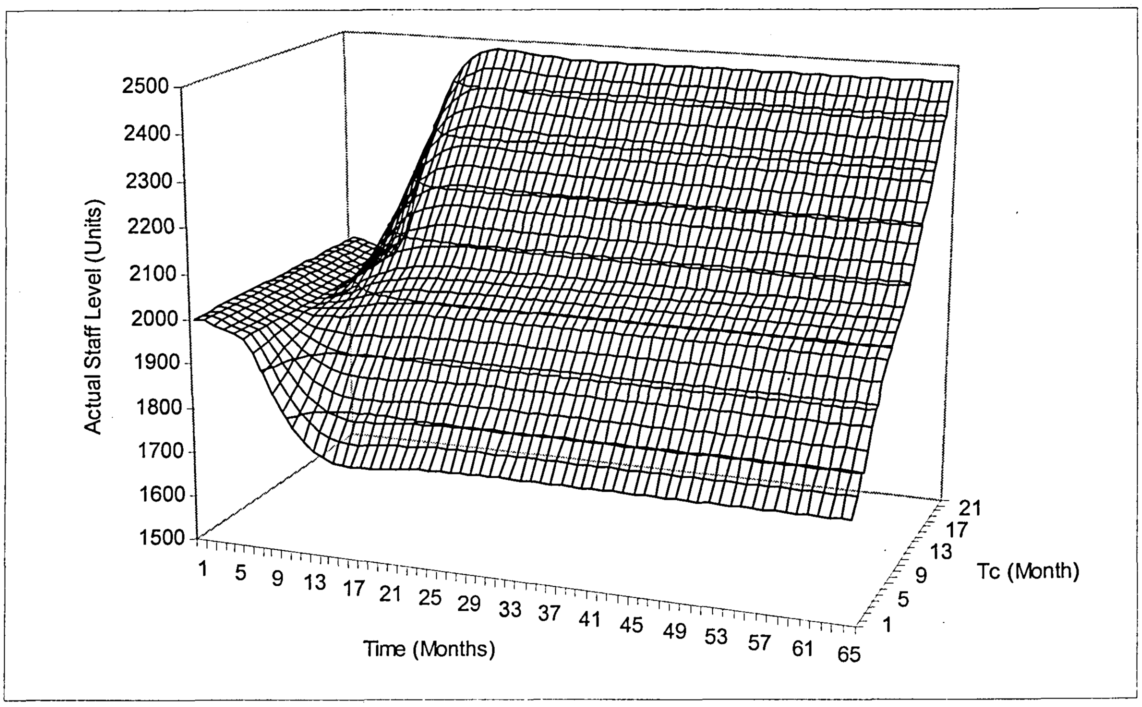


(c) Recruit staff in process behaviour

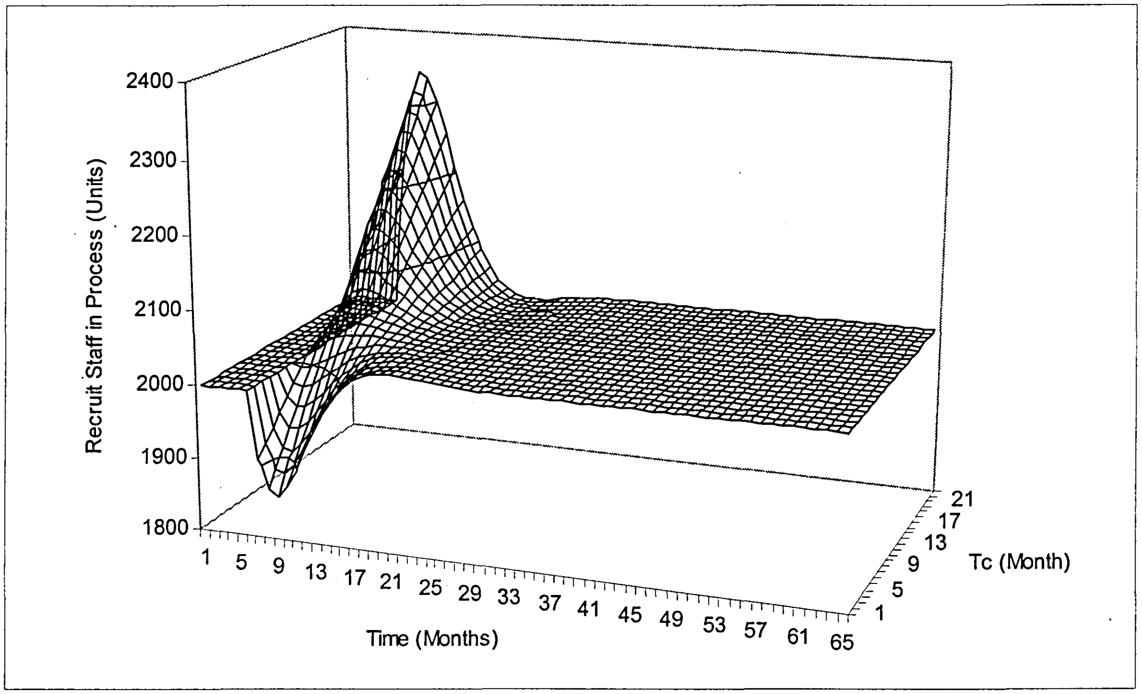
Figure 6.7: Response of APSKPM for (Ti=Ta=Tr=4 months) and varying values of Tw



(a) Staff recruitment completion rate behaviour



(b) Staff level behaviour



(c) Recruit staff in process behaviour

Figure 6.8: Response of APSKPM for (Ti=Ta=Tr=Tw=4 months) and varying values of Tc

Performance index		Automated Pipeline Staff Pool Model (APSKPM)				
		Ti	Ta	Tr	Tw	Tc
Recruitment completion rate measurements	Rise Time (Months)	Increasing Ti increases slightly the rise time	Increasing Ta increases the rise time	Increasing Tr increases the rise time	Increasing Tw increases the rise time	Increasing Tc increas the rise time
	Peak overshoot (Percentage from the nominal value)	Increasing Ti slightly increase the peak overshoot	Increasing Ta decrease the peak overshoot	Increasing Tr increases the peak overshoot	Increasing Tw slightly increase the peak overshoot	Increasing Tc slightly increase the peak overshoot
	Duration of overshoot (Percentage from the desired value)	Increasing Ti slightly increases the duration of overshoot	Increasing Ta increases the duration of overshoot	Increasing Tr increases the duration of overshoot	Increasing Tw slightly decreases the duration of overshoot	Increasing Tc slightly decreases the duratior of overshoot
Staff level measurements	Initial staff level drop (Percentage from the desired value)	Increasing Ti increases the initial staff droop	Increasing Ta increases the initial staff drop	Increasing Tr increases the initial staff drop	Increasing Tw decreases the initial staff drop	Increasing Tc decreas the initial staff drop
	Duration of staff inventory deficit (Month)	Increasing Ti increases the settling time	Increasing Ta increases the settling time	Increasing Tr increases the settling time	Increasing Tw decreases the settling time	Increasing Tc decreas the settling time
	Peak staff inventory overshoot (Percentage from the nominal value)	Increasing Ti decreases the peak staff inventory overshoot	Increasing Ta decreases the peak staff inventory overshoot	Increasing Tr increases the peak staff inventory overshoot	Increasing Tw decreases the peak staff inventory overshoot	Increasing Tc decreas the peak staff invento overshoot
Recruit staff in process measurements	Rise time (Months)	Increasing Ti increases slightly the rise time	Increasing Ta increases the rise time	Increasing Tr increases the rise time	Increasing Tw increases the rise time	Increasing Tc increas the rise time
	Peak overshoot (Percentage from the nominal value)	Increasing Ti slightly decrease the peak overshoot	Increasing Ta decrease the peak overshoot	Increasing Tr increases the peak overshoot	Increasing Tw slightly increases the peak overshoot	Increasing Tc slightly increases the peak overshoot
	Duration of overshoot (Percentage from the desired value)	Increasing Ti slightly increases the duration of overshoot	Increasing Ta increases the duration of overshoot	Increasing Tr increases the duration of overshoot	Increasing Tw slightly decreases the duration of overshoot	Increasing Tc slightly decreases the duratior of overshoot

Table 6.2: Performance index and associated dynamic behaviour for the Skill Pool Model (APSKPM)

Performance index at the design Parameters		Automated Pipeline Skill Pool Model (APSKPM) Design parameters									
		Ti=1, Ta=2, Tr=1 Tw=7	Ti=2 Ta=4, Tr=2 Tw=7	Ti=1, Ta=4, Tr=4 Tw=7	Ti=2, Ta=2, Tr=2 Tw=7	Ti=4, Ta=8, Tr=8 Tw=7	Ti=4 Ta=8 Tr=4 Tw=7	Ti=3, Ta=6, Tr=3 Tw=7	Ti=2, Ta=4, Tr=8 Tw=7	Ti=3, Ta=4, Tr=4 Tw=7	Ti=3, Ta=4, Tr=8 Tw=7
Recruitment completion rate measurements	Rise Time (Months)	4	3	3	3	7	5	5	5	4	7
	Peak overshoot	21.6%	6.08%	18.9%	7.4%	31.7%	15.5%	10.8%	42.5%	23%	37%
	Duration of overshoot (Months)	4	5	4	7	20	15	14	13	10	16
Staff level measurements	Initial staff level droop	1.5%	1.8%	2.5%	1.65%	21.4%	9.45%	5.2%	17.15%	2.55%	19.5%
	Duration of staff inventory deficit	4	5	4	9	20	16	15	13	10	16
	Peak staff inventory overshoot	0.75%	0.25%	0.35%	0.8%	6.6%	1.3%	0.8%	8.65%	7.6%	8%
Recruit staff in process measurements	Rise Time (Months)	4	4	3	5	8	6	5	6	4	7
	Peak overshoot	21.6%	0.35%	1.3%	0.45%	2.2%	1.05%	0.7%	3.05%	1.6%	2.65%
	Duration of overshoot (Months)	4	6	4	7	17	14	10	12	10	15

Table 6.3: Performance index and associated dynamic behaviour for the Automated Pipeline Skill Pool Model (APSKPM), in case study A, where the shaded region shown the optimum response

Model output	APSKPM Model Case Study A		
	X	MSE	ITAE
Recruitment completion rate	147	8	1124
Actual staff level	1998	80	5924
Recruit staff in process	2016	325	5924

Table 6.4: Descriptive statistical characteristics for APSKPM for case study A for optimal behaviour

6.7 Dynamic Analysis of the APSKPM model for case study B

For data in case study B, figure 6.9 shows the dynamic response in the staff recruitment completion rate, actual staff level and recruit staff in process for the range values of Ti. Figure 6.9(a), shows that we have an under-damped system, but that increasing Ti would reduce the peak overshoot. To achieve a good level of control, large overshoots are to be avoided. A small overshoot has to be balanced against a moderate staff recovery rise time.

Figure 6.9(b) concentrates on the effect of Ti on the actual staff level behaviour. Present staff leaving rate decreases cause an initial deficit because staff losses are met from the existing staff level. The response then shows a moderate overshoot before settling to its steady state value. At Ti less than 3 months this may be attributable to the staff shortage in the company due to staff turnover. This is due to the initial staff loss being met from the actual staff pool whilst extra staff is being recruited. As Ti increases, the duration of staff pool deficit would increase, and the peak staff pool overshoot would decrease as well . Figure 6.9(c) shows the behaviour of recruit staff in process. The response of recruit staff in process shows similar properties to that of the recruitment completion rate, but with the actual values multiplied by Tr.

Figure 6.10 examines the response of the staff recruitment completion rate, actual staff level and recruit staff in process for varying values of Ta, where Ta is gradually varied between 1 month to 30 months for fixed values of Ti, Tr, Tw, and Tc. As shown in Figure 6.10(a) the largest value of Ta gives less of an oscillatory response for the recruitment completion rate, and as Ta decrease the recruitment completion rate overshoot increases, but the settling time decreases. Also, it shows that the maximum recruitment completion rate overshoot is 50% of the initial value and there is no peak overshoot. Figure 6.10(b) shows that large values of Ta give a slow actual staff level recovery. Decreasing Ta would decrease staff level drop as well as settling time. Smaller values of Ta would induce instability in a real system. Figure 6.10(c) represents the recruit staffs in process response, which is similar to the recruitment completion rate with the multiplied factor of Tr.

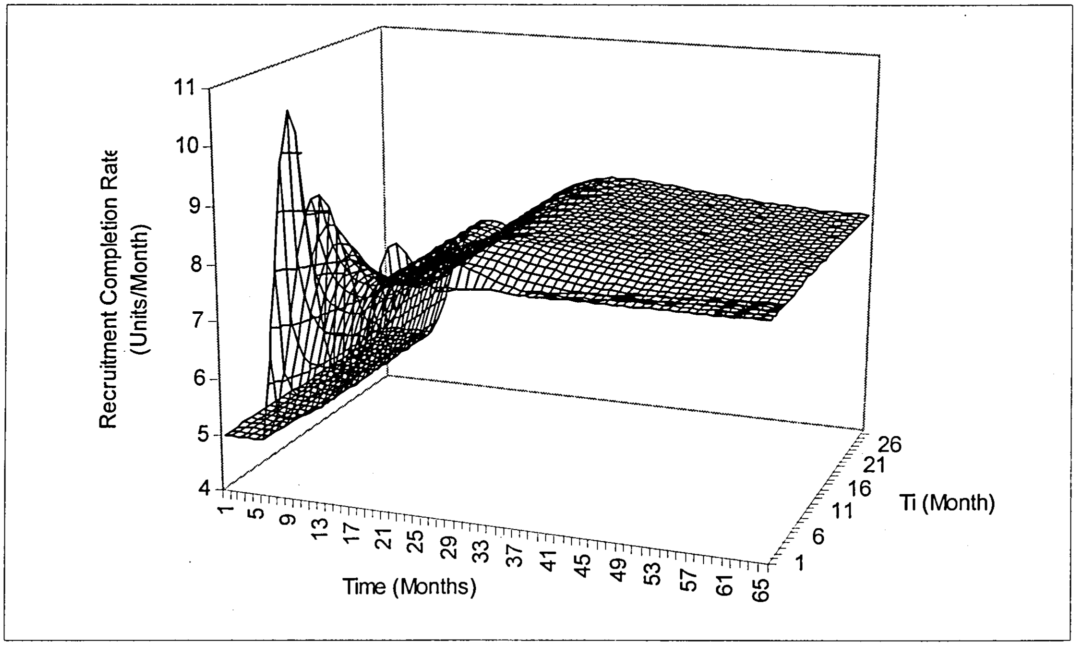
Figure 6.11 concentrates on the behaviour of the three controllers namely, staff recruitment completion rate, actual staff level and recruit staff in process, where Tr varies between 1 and 30 month. Figure 6.11(a) illustrates that the behaviour of the recruitment completion rate. The simulation shows that at Tr =3 months the behaviour of recruitment completion rate approaches the optimum response. As Tr increases to more than 6 months, the system response shows a permanent overshoot.

At values of Tr < 3 months the recruitment completion rate starts with overshoot values, which increase for increasing Tr. Figure 6.11(b) illustrates the system behaviour for actual staff level, as Tr increases over 6 months the response is under the nominal value and it doesn't recover completely. Figure 6.11(c) shows the response of recruit staff in process for various value of Tr. As Tr increases the oscillatory response increases, and for Tr less than 2 months the recruit staff in process is under the initial value, and for Tr greater than 6 months the responses are a pronounced overshoot. Obviously at Tr =3 months and 4 months the recruit staff in process has a good response.

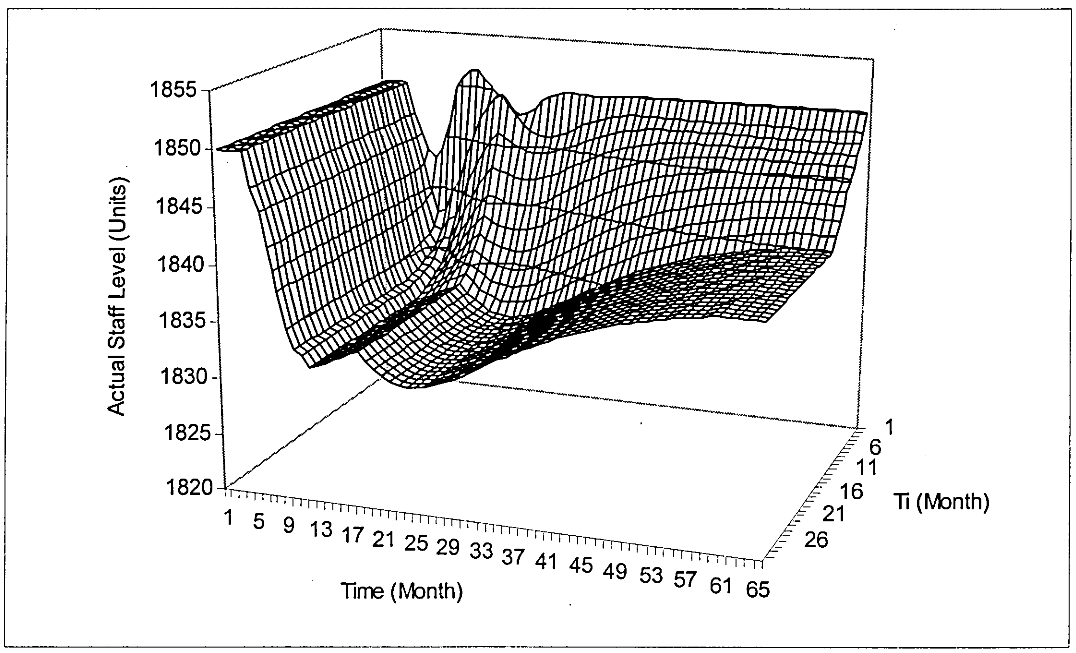
Figures 6.12 show the recruitment completion rate, actual staff level and recruit staff in process at different values of staff pipeline control parameter Tw. The aim is to observe how the system recovers from input changes. Figure 6.12(a) shows the recruitment completion rate behaviour. As Tw decreases, the recruitment completion rate overshoots decreases. However, the time it take the system to reach steady state value slightly increases and, as Tw decreases, the dynamic recovery to the input improves. Figure 6.12(b) indicates that, as Tw less than 3 months is less peak overshoot but the duration of overshoot is longer. For Tw greater than 4 months the actual staff level overshoot increase, the actual staff level response indicates that as Tw decrease, the overshoot damps down, at the same time the initial staff pool deficit increases slightly for smaller values of Tw. Specifically at Tw < 10 months the actual staff level fall even below then the negative value after (32) months. This is due to the extra damping introduced by increasing the recruit staff in process feed back gain. The recruit staff in process has the similar behaviour as the training completion rate but with multiplying factor of Tr as shown in Figure 6.12 (c).

Figure 6.13 illustrates the behaviour of the parameter Tc on the three controllers, staff recruitment completion rate, actual staff level and recruit staff in process. This parameter is used to estimate the recruitment lead time to control the desired value of recruit staff in process. Figure 6.13(a) shows that at Tc less than 8 months the starting value is less than the initial values. As Tc increases the peak overshoot increases as well as the duration of overshoot increase. Indeed for all Tc values the recruitment completion rate is completely recovered to the nominal value. Figure 6.13(b) shows that at Tc less than 8 months the actual staff level decrease below the nominal value. The staff level pool has satisfactory behaviour fro Tc between 9 and 13 months and the actual staff level drop and the duration of the staff deficit are small comparing by other values, for Tc grater than 12 months the actual staff level increase and doesn't get to steady state value.

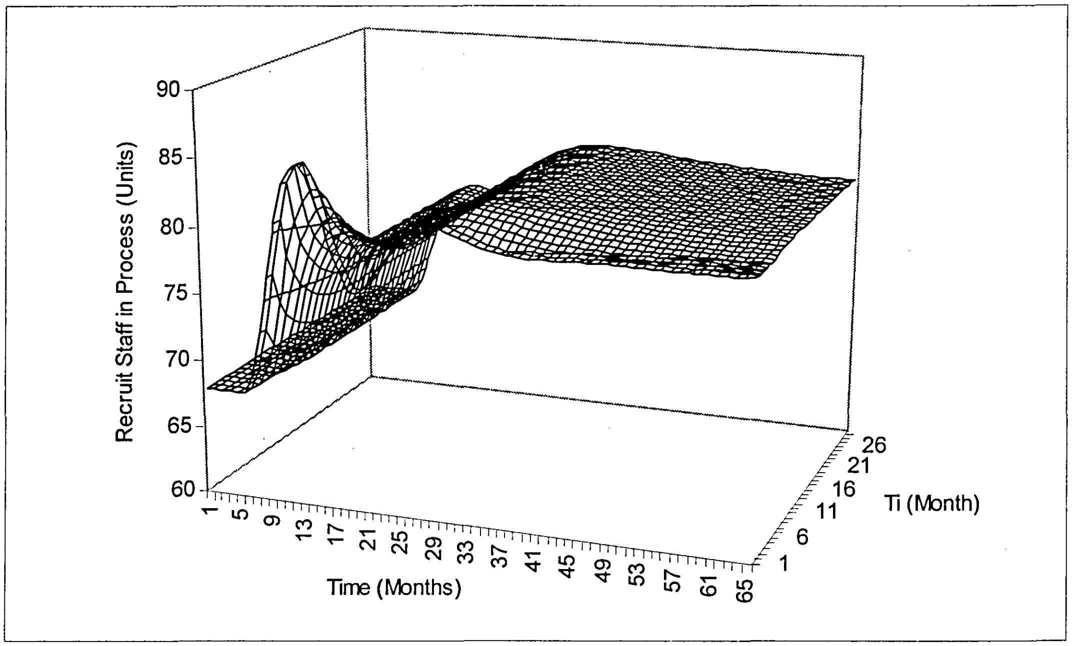
Figure 6.13(c) shows the recruit staff in process response for different value of Tc. By inspection on Figure 6.13(c) at Tc= 9 months it is acceptable behaviour, as Tc decrease less than 8 months the initial recruit staff in process level drop increase and as Tc increase above 13 months the recruit staff in process level overshoot increase permanently. The result shown in Figure 6.13(c) indicated that Tc should be equal 9 months. Table 6.5 gives the overall summary of the effect of varying Ti, Ta , Tr and Tw on human resource policies. Table 6.6 describes the descriptive statistical characteristics for recruitment and actual staff level at optimum design parameters. The optimum parameters in this case where determined in the way described in Chapter 5, by minimising the values of MSE and ITAE and determining those X values closest to the target values.



(a) Recruitment completion rate

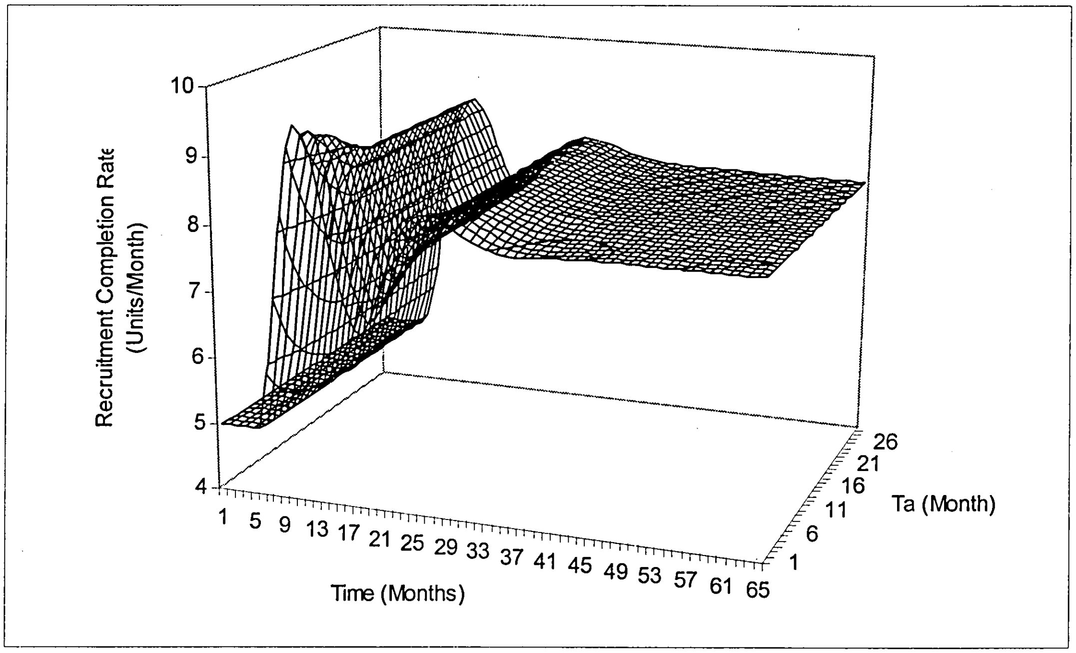


(b) Actual staff level

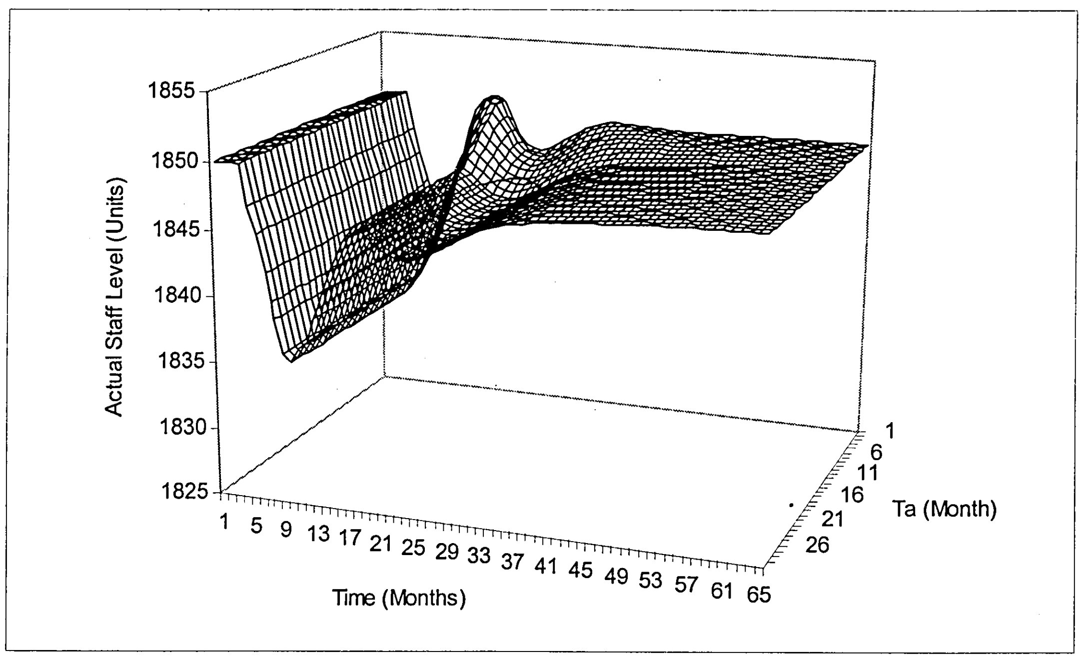


(c) Recruit staff in process

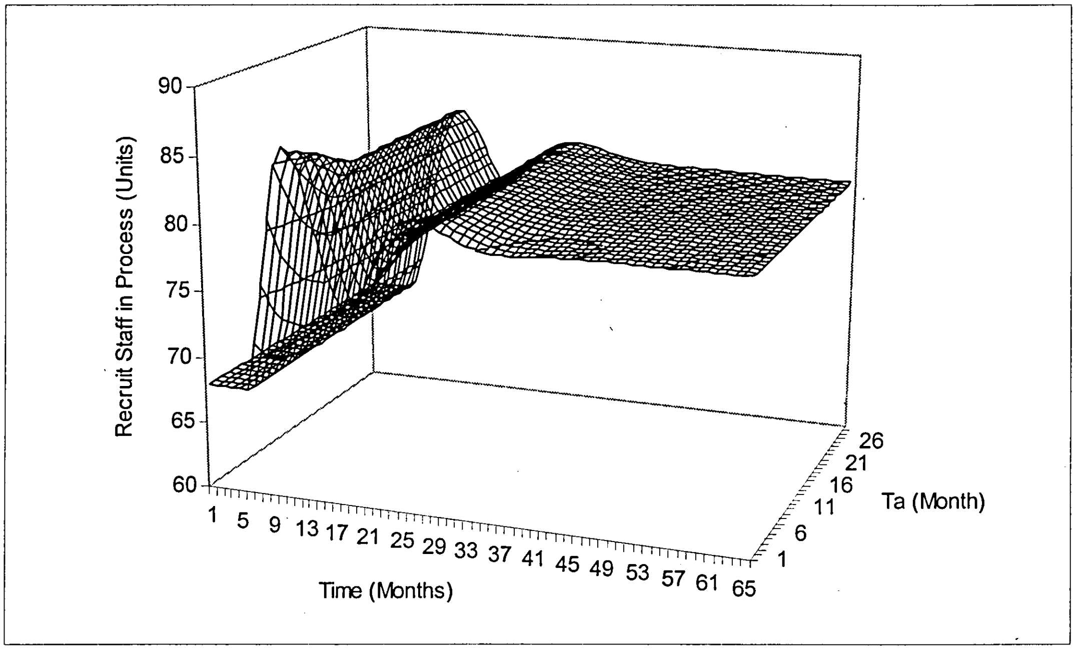
Figure 6.9: Response of APSKPM for (Ti=Ta=Tw=4 months) and varying values of Ti



(a) Recruitment completion rate

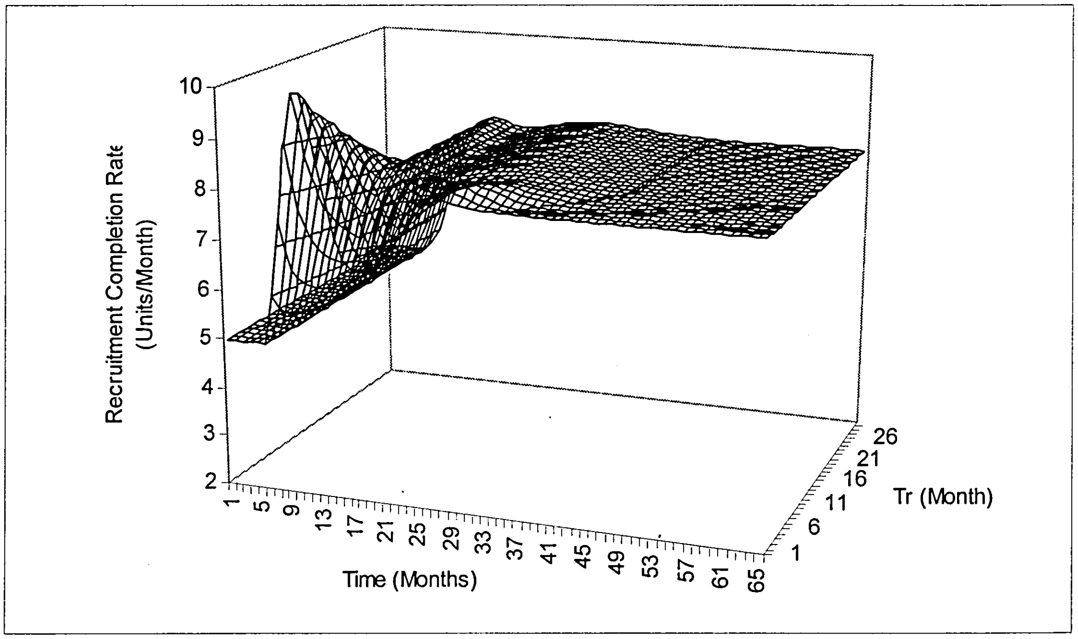


(b) Actual staff level

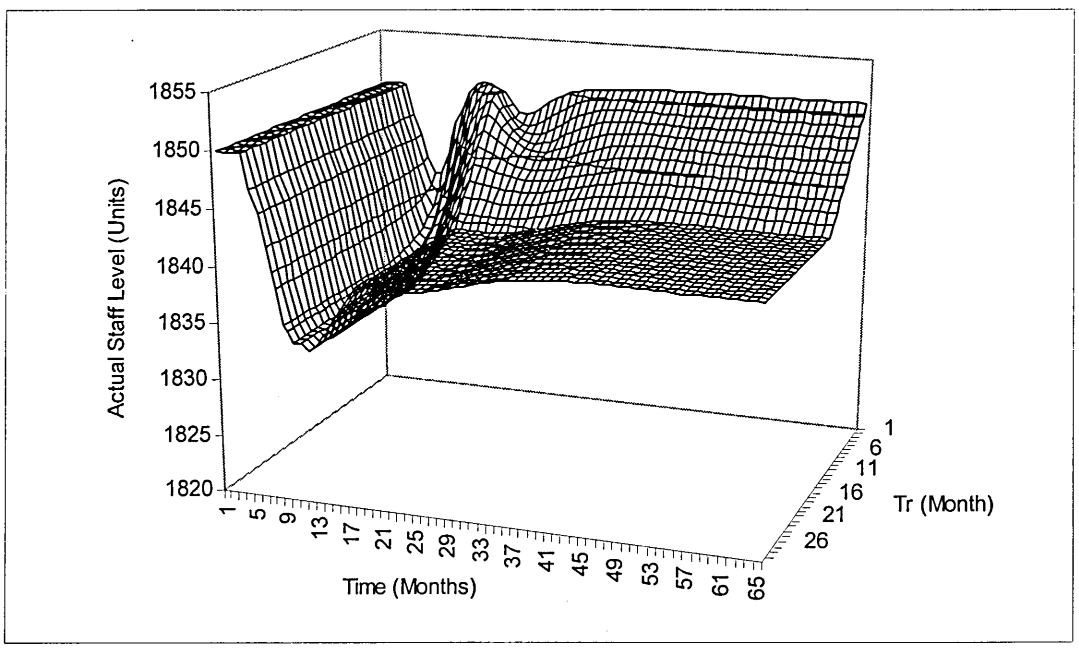


(c) Recruit staff in process

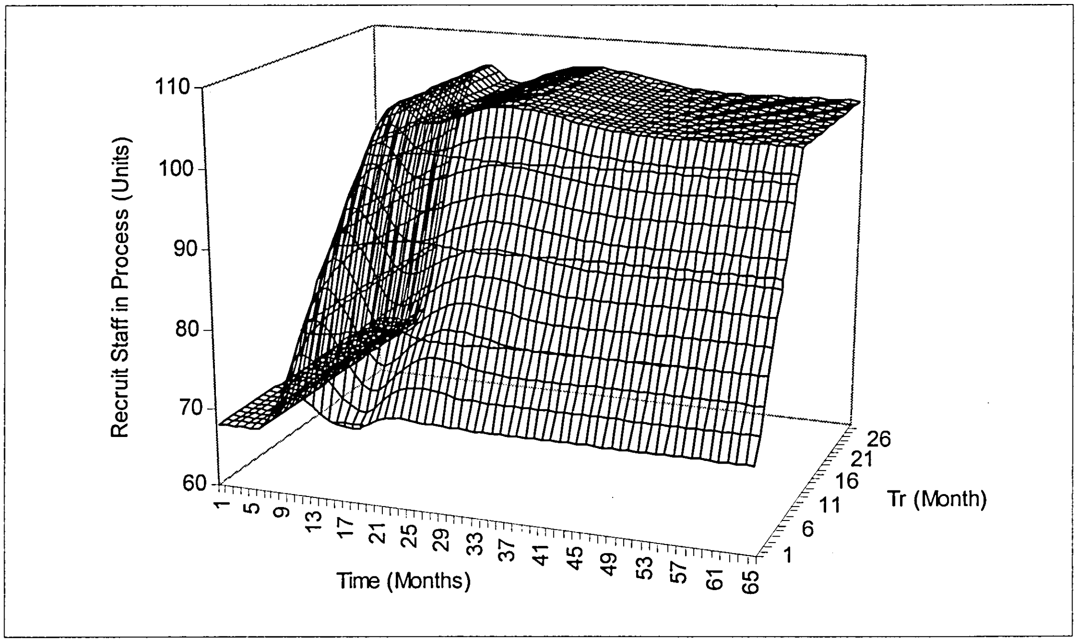
Figure 6.10: Response of APSKPM for (Ti=Ta=Tw=4 months) and varying values of Ta



(a) Recruitment completion rate

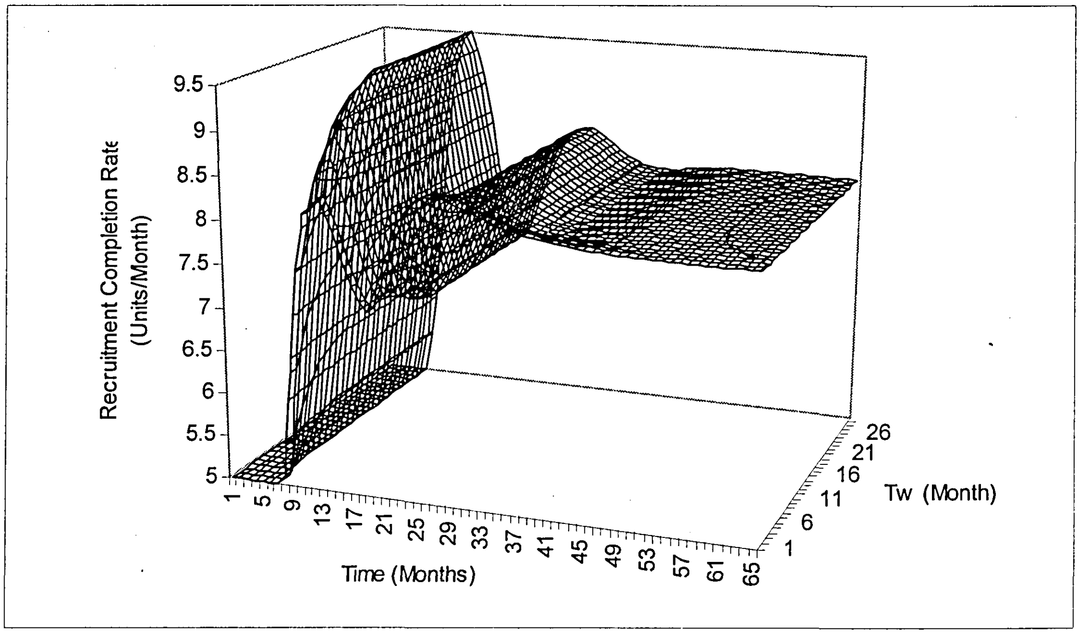


(b) Actual staff level

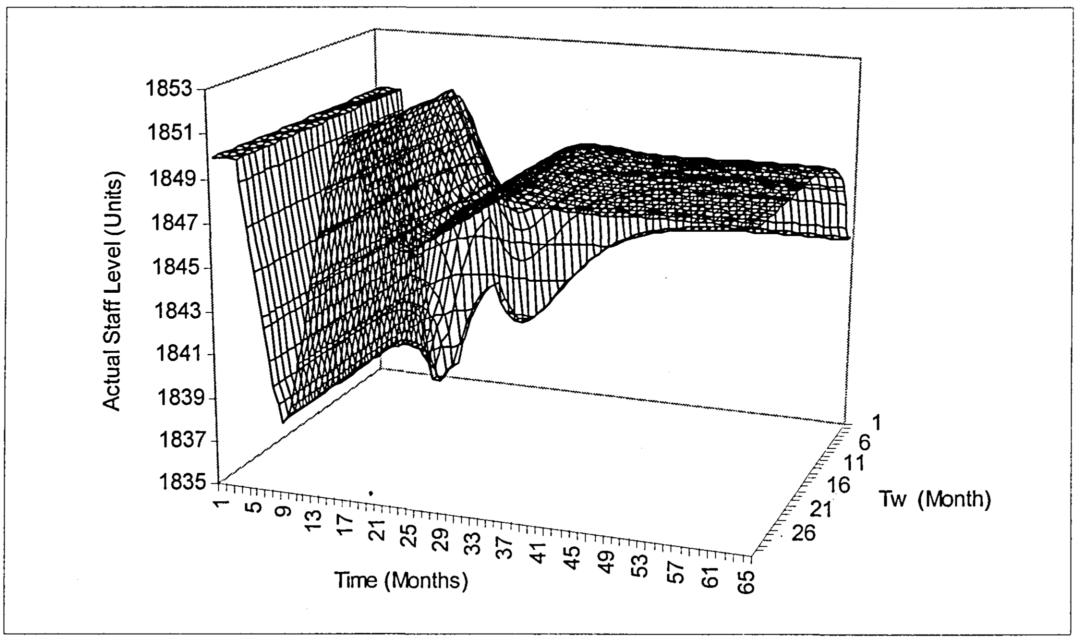


(c) Recruit staff in process

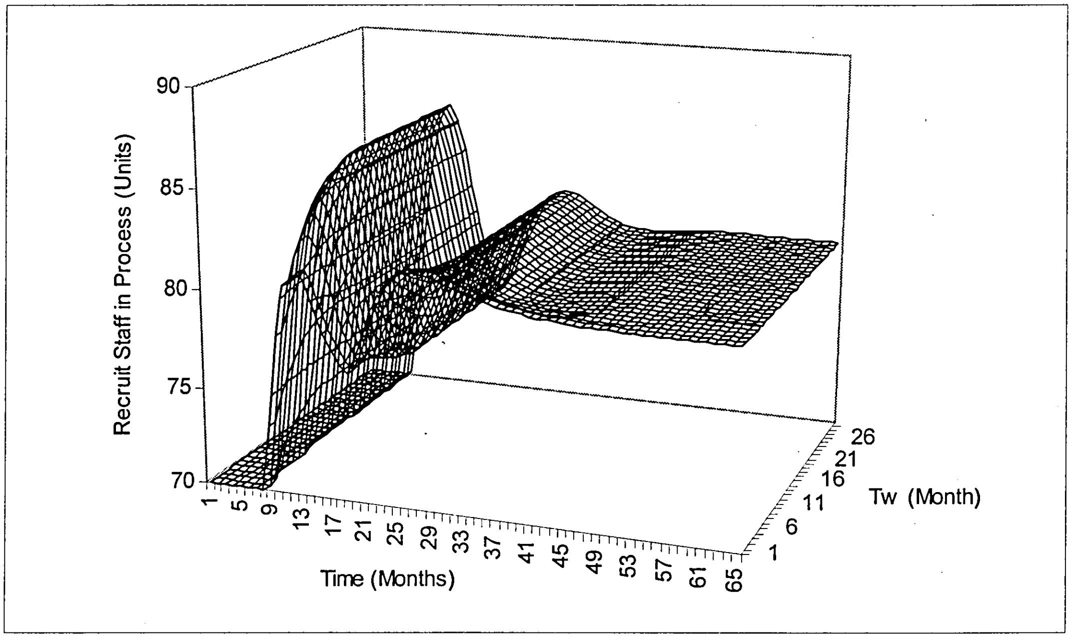
Figure 6.11: Response of APSKPM for (Ti=Ta=Tw=4 months) and varying values of Tr



(a)Recruitment completion rate

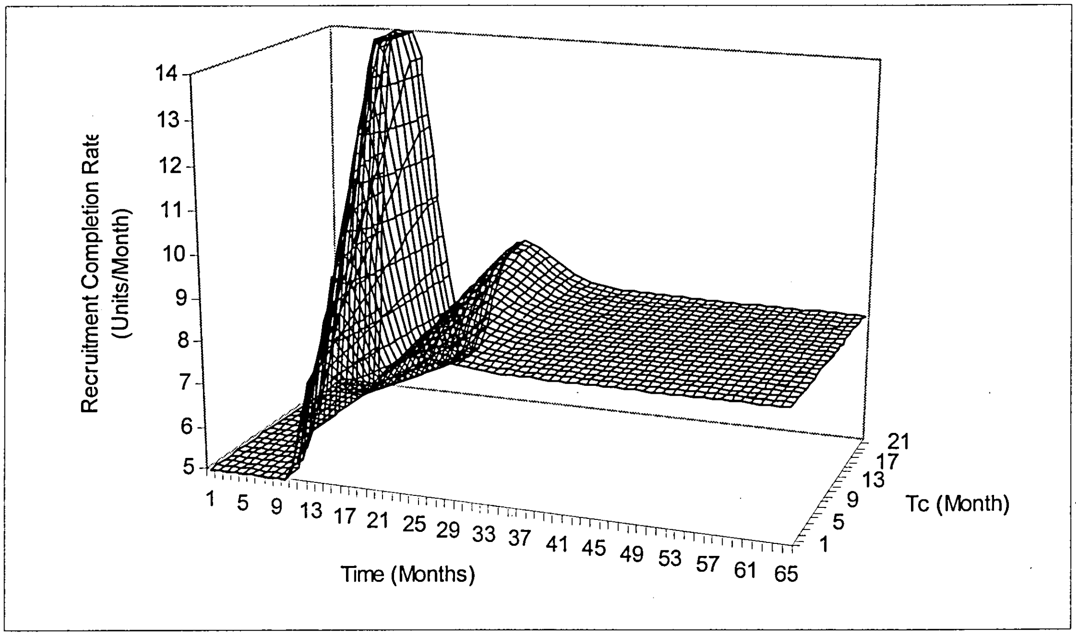


(b) Actual staff level

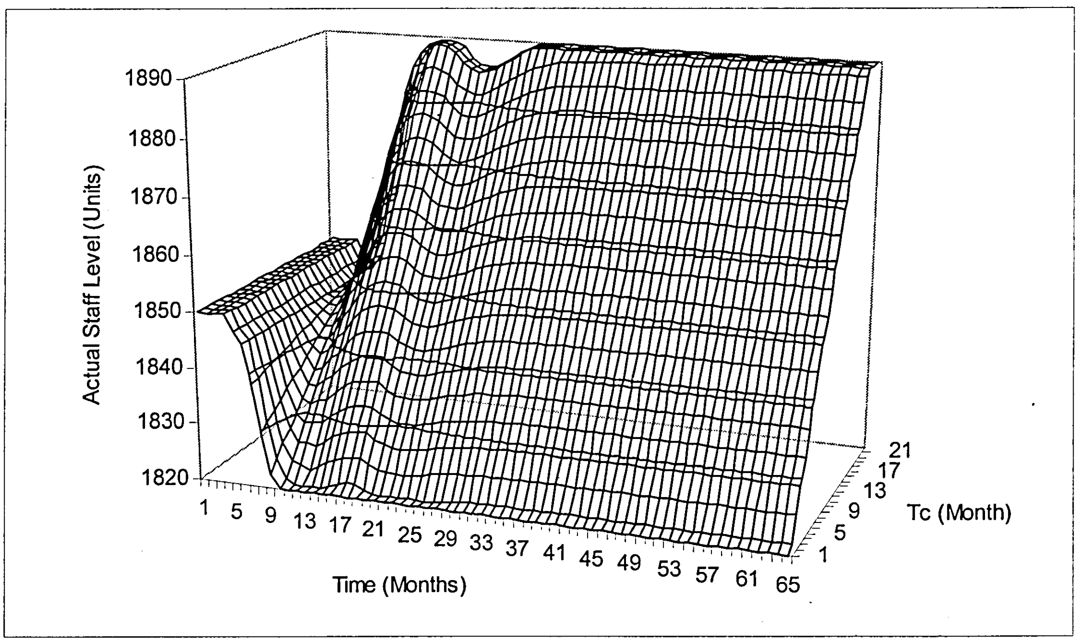


(c) Recruit staff in process

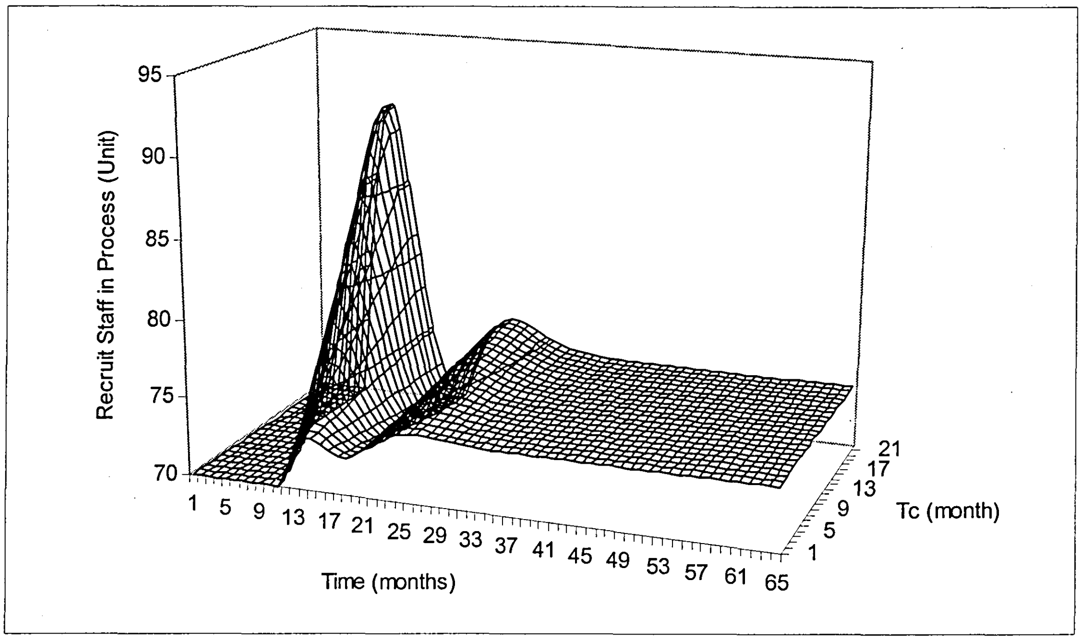
Figure 6.12: Response of APSKPM for (Ti = Ta = Tr = 4 months) and varying values of Tw



(a) Recruitment completion rate



(b) Actual staff level



(c) Recruit staff in process

Figure 6.13: Response of APSKPM for (Ti=Ta=Tw=4 months) and varying values of Tc

Performance index at the design Parameters		Automated Pipeline Skill Pool Model (APSKPM) Design parameters (B)									
		Ti=1, Ta=2, Tr=1 Tw=7	Ti=2 Ta=4, Tr=2 Tw=7	Ti=1, Ta=4, Tr=4 Tw=7	Ti=2, Ta=2, Tr=2 Tw=7	Ti=4, Ta=8, Tr=8 Tw=7	Ti=4 Ta=8 Tr=4 Tw=7	Ti=3, Ta=6, Tr=3 Tw=7	Ti=2, Ta=4, Tr=8 Tw=7	Ti=3, Ta=4, Tr=4 Tw=7	Ti=3, Ta=4, Tr=8 Tw=7
Recruitment completion rate measurements	Rise Time (Months)	3	3	3	4	8	6	4	7	5	7
	Peak overshoot	37.5%	25%	25%	25%	37.5%	25%	12.5%	50%	37.5%	50%
	Duration of overshoot (Months)	4	9	4	8	20	16	9	14	11	17
Staff level measurements	Initial staff level droop	0.13%	0.21%	0.21%	0.16%	1.3%	0.59%	0.27%	0.97%	0.5%	1.1%
	Duration of staff inventory deficit	5	6	6	6	15	14	8	14	10	14
	Peak staff inventory overshoot	0.21%	0.32%	0.16%	0.37%	0.97%	0.5%	0%	0.86%	0.48%	0.97%
Recruit staff in process measurements	Rise Time (Months)	2	2	3	2	8	6	5	7	5	8
	Peak overshoot	5%	3.3%	3.3%	3.3%	5%	3.4%	3.1%	6.4%	5%	8%
	Duration of overshoot (Months)	2	9	5	8	19	16	10	13	12	15

Table 6.5: Performance index and associated dynamic behaviour for the Automated Pipeline Skill Pool Model (APSKPM), in case study B, where shaded region shown the optimum response

Model output	APSKPM Model Case Study B		
	X	MSE	ITAE
Recruitment completion rate	8	0.897	158
Actual staff level	1848	5.03	2484.5
Recruit staff in process	79	3.2	788

Table 6.6: Descriptive statistical characteristics for APSKPM for case study B for optimal behaviour

6.9 Summary

This chapter started by looking at the APSKPM and the rationale behind the basic principles of the model. Transfer functions were derived for the principal model outputs under investigation. A simulation model was written in the *ithink* software package and tested in Excel to investigate the basic transient behaviour of the key model outputs to changes in staff leaving rate. The chapter illustrated typical lead-time performance and ways in which system behaviour could be improved. Also the chapter established performance criteria, key to describing the system behaviour and to understanding how to improve the system response. Results have shown that for the optimal parameter values the system has a very good response, and confirm the parameter choice made by John (1992), for example, for optimal system behaviour. The APSKPM model has shown how the addition of extra feedback has improved the system behaviour as detailed by John (1994) and Cheema (1994).

6.10 References

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CHAPTER 7

Optimising Dynamic Behaviour of Automated Pipeline Policy using Integral controller [APSKPM+ (P+I)]

7.1 Chapter overview

This chapter presents an overview of a basic analysis of a new model which we have called the Automated Pipeline Skill Pool Model plus proportional and integral controller, or (APSKPM + (P + I)) for short. The aim of using such a model is to improve the performance of the APSKPM model by rducing any steady state error, i.e. the staff gap, more quickly. This will be achieved by adding a new control term, Ki, which is the integral controller. We will see that the ratio of the proportional controller to the integral term specifies how quickly the system attempts to achieve zero error. This chapter starts by looking at influence and block diagrams as in the previous chapters. Transfer functions are derived and dynamic analysis of our case study data is carried out to improve our understanding of the dynamics of staff turnover in a company. Optimum policy parameters are once again derived for the case study areas considered.

7.2 Introduction

The Automated pipeline skill pool model introduced in the previous chapter of this thesis is now addressed with the addition of a proportional plus integral controller. Much work in dynamic analysis of the APIOBPCS + (P+I) model has been carried out by Cheema *et al* (1997), and Diseny and Towill (2002), in connection with production control. The term, 1/Ti, in the staff gap, when added to the integral controller term, Ki, and the result multiplied by the staff gap, will feed to the recruitment demand rate (as shown in the block diagram 7.2 below). The new APSKPM + (P+I) model is derived from the generic IOBPCS model base of (Towil, 1982), but includes the Work In Progress (WIP) feedback with addition of a proportional plus integral controller. The main aim of using an integral controller in the feedback path generally is to remove any steady state error and the ratio of the proportional controller to the integral term specifies how quickly the system attempts to achieve zero error as described by Dejonckheere *et al* 2003.

7.3 Influence diagram representation of APSKPM + (P+I)

The model in Figure (7.1) is a time varying extension of the baseline SKPM with integral and proportional controller, and is adapted from the simplified Work In Progress (WIP) feedback and automated Pipeline SKPM as detailed by Cheema (1994).

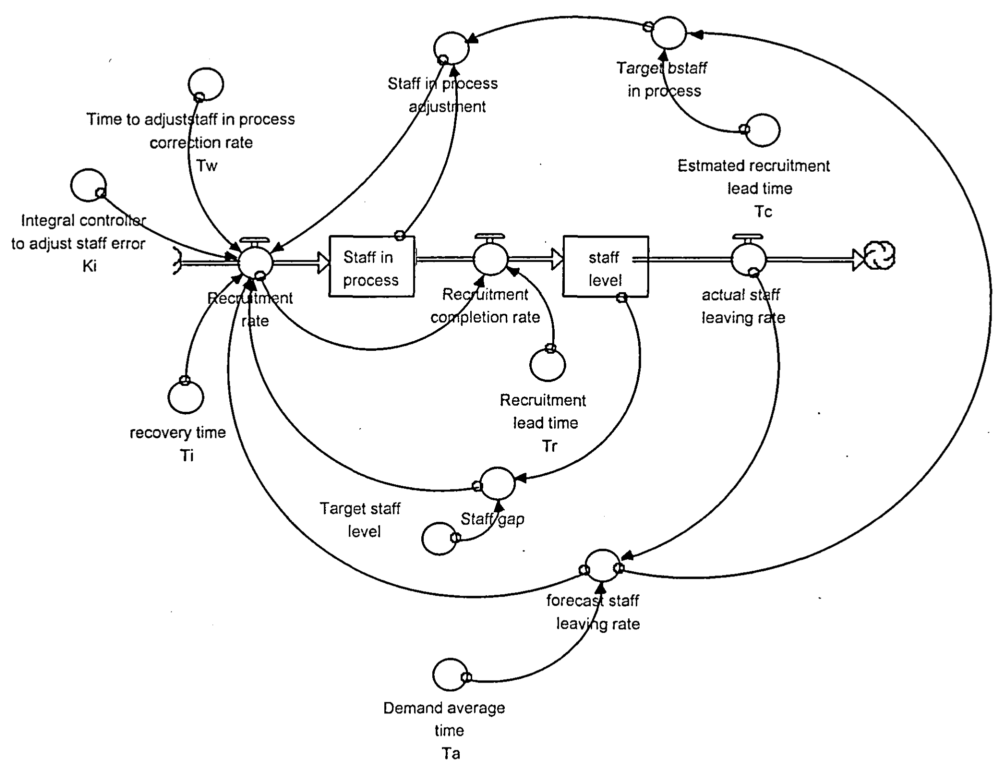


Figure 7.1: Influence diagram of APSKPM + (P + I)

The model shows how the new proportional plus integral controller fits into the APSKPM model where (Ki/S) is the integral term. Therefore the purpose of APSKPM+(P+I) simulation would be to show how these controllers affect the staff recruitment requirement, how they interact with each other, and how optimum control can be achieved by altering the values of Ti, Ta, Tw and Ki. The APSKPM + (P + I) is set up to take into account the recruit staff in process term as well as reducing the staff inventory error.

7.4 APSKPM + (P+I) Block diagram

Figure 7.2 shows the generalized form of the Automated Pipeline Skill Pool Model with Integral Controller [APSKPM+ (P+I)], which incorporates staff in process feedback. The structure and methodology of the design of this model are derived as a function of the present staff leaving rate, actual staff level and recruit staff in process. The staff gap is calculated as a difference between target staff level and actual staff level. The staff gap is carried over a period specified by the proportional controller (1/Ti) and integral controller (Ki/S), (the quantity Ki it is simply mathematical device to improve overall system behaviour. The recruit staff in process adjustment is calculated as a difference between desired recruit staff in process and actual recruit staff in process, where the desired recruit staff in process equals the forecast staff leaving rate multiplied by the gain Tc (the theoretical value of the recruitment lead time). The recruit staff in process is recovered over a period specified by the proportional controller (1/Tw); using an integral controller will reduce the staff gap quicker, thus removing any steady state error more quickly.

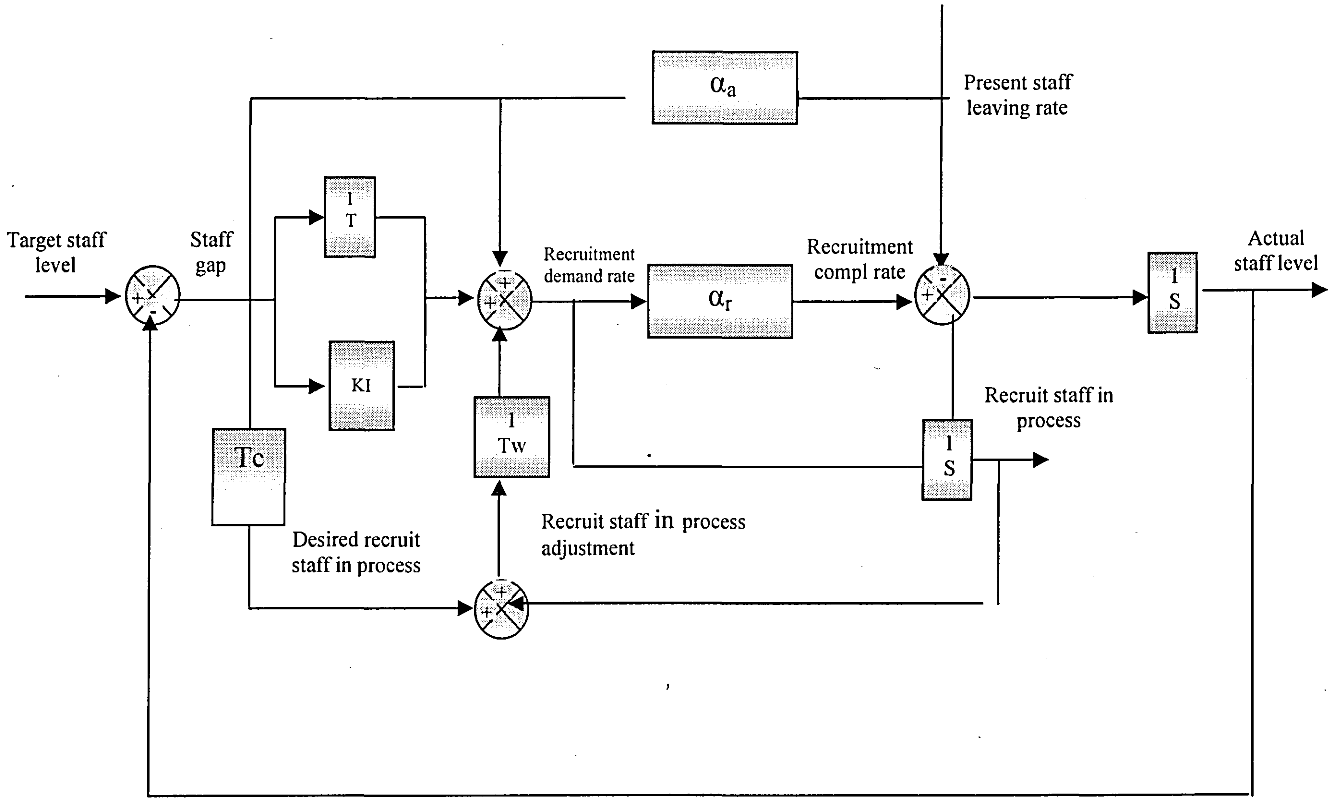


Figure 7.2: A block diagram representation of APSKPM + (P + I)

The main blocks of the APSKPM+(P+I) block diagram, as shown in Figure 7.2, are:

1/Ti: This is the proportional constant to deal with the discrepancy between the target staff level and the actual value of the staff level.

1/S: This represent the integration process whereby both the actual staff level and the recruit staff in process are accumulated over time.

α_r: It is the multiplier used in the simulation to take account of Tr, the recruitment delay time.

α_a It is the multiplier used in the simulation to take account of Ta, the time over which the staff leaving rates over are averaged.

1/Tw: This is the proportional constant to deal with the recruit staff in process adjustment.

Tw is used in the control algorithm and refers to the time to adjust staff in process.

Tc: It is the proportional constant to deal with the desired recruit staff in process.

7.5 Transfer Functions

The transfer function of APSKPM+(P+I) can be derived using the block diagram analysis as shown in Figure (7.2). A detailed analysis is presented in Appendix (4).

$$\frac{recruitment.completion.rate}{present.staff.leaving.rate}=\frac{TS^2(Tc+Tw)+Tw(1+TaS)(TiKi+S)}{(1+TaS)(TwTiS^2(1+TrS)+S(Tw+TiTrS)+TwTiKi)}$$

$$\frac{acual.staff.level}{present.staff.leaving.rate}=\frac{TiS[(Tc+Tw)+(1+TaS)[Tw(1+TrS)+Tr]]}{(1+TaS)(TwTiS^2(1+TrS)+S(Tw+TiTrS)+TwTiKi)}$$

$$\frac{recrui.staff.in.process}{present.staff.leaving.rate}=\frac{TiS[\ TS^2(Tc+Tw)+Tw(1+TaS)(TiKi+S)\ ]}{(1+TaS)(TwTiS^2(1+TrS)+S(Tw+TiTrS)+TwTiKi)}$$

Equation A, B and C are derived in Appendix 4 and, as before, enable us to see the dependency on the parameters T_i, T_a, T_r,T_w, T_c and K that are to be set by the decision maker when determining optimal HRP policy.

7.6 Dynamic Analysis of the [APSKPM+ (P+I)] model for case study A

As discussed earlier, the addition of an extra feedback term and proportional integral controller to the original SKPM model would improve the system performance and reduce any staff vacancies. However, the introduction of a proportional and integral controller in the feedback path generally removes any steady state error. The system behaviour for recruitment completion rate, actual staff level and recruit staff in process for the APSKPM+(P+I) is produced by varying all the design parameters, Ti, Ta, Tr, Tw, Tc and Ki, where Ki varies only between 0 and 1. As before, this will allow us to determine the optimum mix of control parameters. Once again, the simulation is implemented using the *ithink* simulation package.

Figure (7.3) shows the effect of Ti on the recruitment completion rate, actual staff level and recruit staff in process. Figure 7.3(a) shows that increasing Ti values will damp the recruitment completion rate overshoot, but it takes longer for the company to recover the staff vacancies. For Ti values of less than 6 months, the system response is one of staff overshoot resulting in over staffing. Figure 7.3(b) shows that decreasing Ti would reduce the maximum staff pool deficit and reduce the offset value to recover. For Ti < 2 there are some oscillations but the peak value is still under the initial value of the actual staff level. As Ti increases, to be over 8 months, the actual staff level pool deficit increases correspondingly. Figure 7.3(c) shows similar behaviour to that for Figure 7.3(a).

Figure (7.4) shows the results of varying Ta for three controllers, namely: recruitment completion rate, actual staff level, and recruit staff in process. Figure 7.4(a) illustrates that as Ta decreases less than three months, the recruitment completion rate overshoot increases, but the settling time decreases. On the other hand, large values of Ta give less oscillatory response for the recruitment completion rate. However, if we increase Ta beyond 7 months, the overshoot decreases and the settling time increases. Figure 7.4(b) shows that large values of Ta give less oscillatory response of the actual staff level, and increasing Ta beyond 7 months leads to overshoot decrease and the settling time increases. Values of Ta less than 3 months would lead to instability in the real system. Figure 7.4(c) presents the recruit staff in process response, which shows similar results to recruitment completion rate.

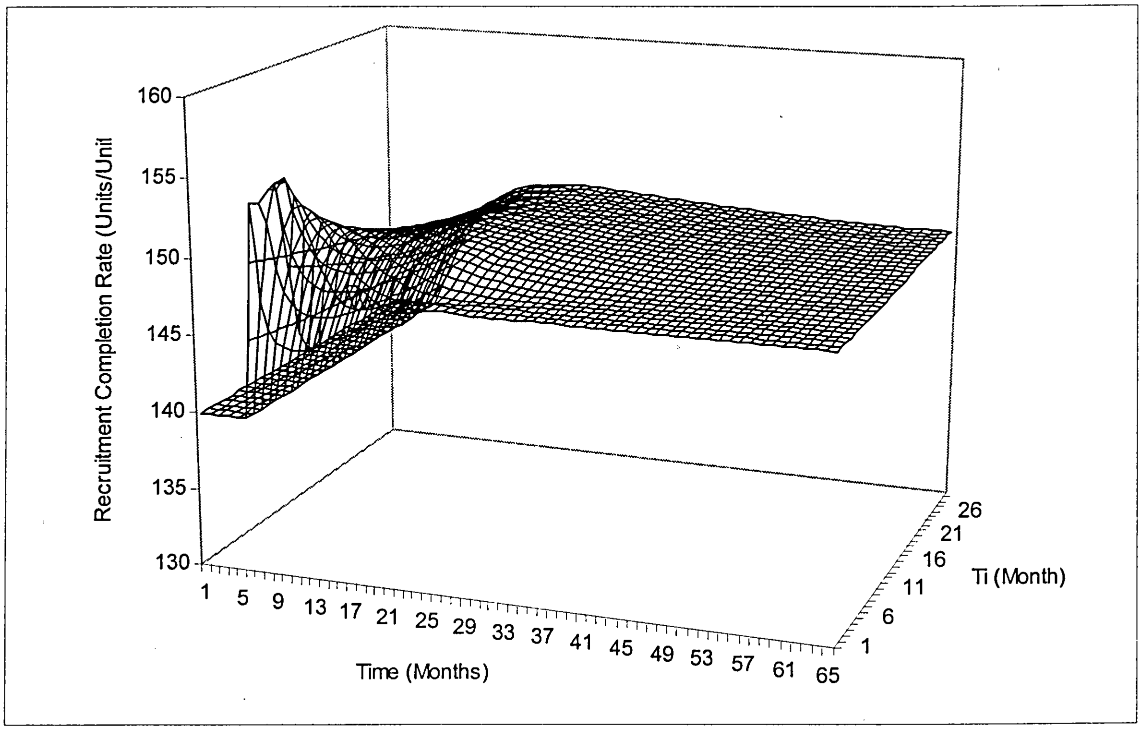
Figure 7.5 illustrates the behaviour of the three controllers, namely: recruitment completion rate, actual staff level and recruit staff in process, at varying values of Tr. As shown in Figure 7.5(a) increasing Tr leads to increases in the recruitment completion rate overshoot, and the time it takes the system to reach its steady state also increases. We observe that the best response would be at the values of $3 \geq Tr \geq 7$, for the recruitment completion rate. Figure 7.5(b) shows that increasing Tr would increase the duration of staff pool deficit. This duration gives an indication of the speed of recovery from the staff pool deficit. As Tr increases the peak staff pool overshoot reduces as well. Figure 7.5(c) shows that as Tr increases the oscillatory response increases. For Tr < 2 months the recruit staff in process level is under the initial value and for Tr > 7 months the response is a pronounced overshoot. Obviously at Tr = Ti = 2 months the recruit staff in process has a good response with the rise time equal to 2 months. The peak overshoot is 1.25% of its initial value and the duration of overshoot equals 5 months.

Figure 7.6 shows the behaviour of the three controllers: recruitment completion rate, actual staff level and recruit staff in process at varying values of Tw. As shown in Figure 7.6(a) increasing Tw leads to decreasing recruitment completion rate overshoot in magnitude, and as Tw increases the duration of overshoot decreases. Obviously, Tw = 8 months is a good design so the recruitment completion rate has a good response with rise time 2 months and the peak overshoot 1.23% of its initial value and the duration of overshoot equal 5 months. Figure 7.6(b) shows that smaller value of Tw would induce instability in a real system and as Tw increases the staff pool overshoot increases, and for Tw $\leq$ 6 months there is no overshoot. Figure 7.6(c) shows there is a similar impact to the recruitment completion rate on the recruit staff response. Tw = 7 months is a good design: the recruit staff in process has a good response with rise time 2 months and the peak overshoot 1.23% of its initial value, and the duration of overshoot equals 5 months.

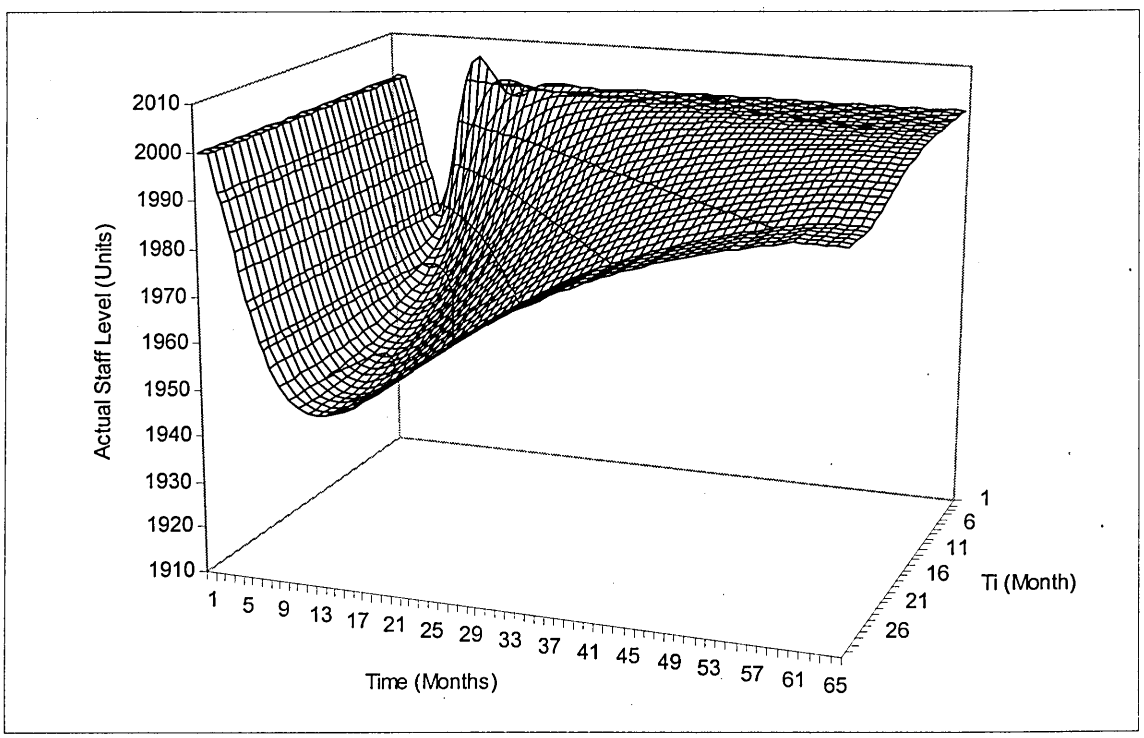
Figure 7.7 illustrates the influence of parameter Tc on the same three controller above. This parameter is used to estimate the recruitment lead time to control the target recruit staff in process. Figure 7.7(a) shows the recruitment completion rate. Tc = 14 months is a good design. Figure 7.7(b) shows that for Tc $\leq$ 12 months the actual staff level pool drops below initial values; the actual staff level has satisfactory behaviour for Tc between 13 and 15 months, Therefore at Tc = 14 months the actual staff-level drop and the duration of staff deficit are small and it is an acceptable design. Figure 7.7(c) shows there is a small overshoot at Tc=14 months. For Tc > 15months the recruit staff in process level drop becomes less than the initial value and the staff pool never recovers. As Tc increases, the peak overshoot in recruit staff in process will increase and the duration of overshoot will increase as well.

Figure 7.8 shows the results of *Ki* varying between 0 and 1 for the three controllers: recruitment completion rate, actual staff level and recruit staff in process. Figure 7.8(a) shows that as Ki increases the peak overshoot increases and the duration of overshoot increases. By inspecting the figure we suggest that Ki = 0.7 is a good design because unnecessary fluctuation in recruitment completion rate has been avoided and the time to recruit new staff is not too long. Figure 7.8(b) shows that with Ki = 0 we have the same behaviour as APSKPM. As Ki increases the staff pool deficit increases and the duration of the staff pool deficit increases. Ki = 0.8 months is a good design parameter as the actual staff level has a good response and the system does not take too long a time to reach the steady state condition with the staff gap approaching zero. The response of recruit staff in process shows similar properties to that of recruitment completion rate as shown in Figure 7.8(c).

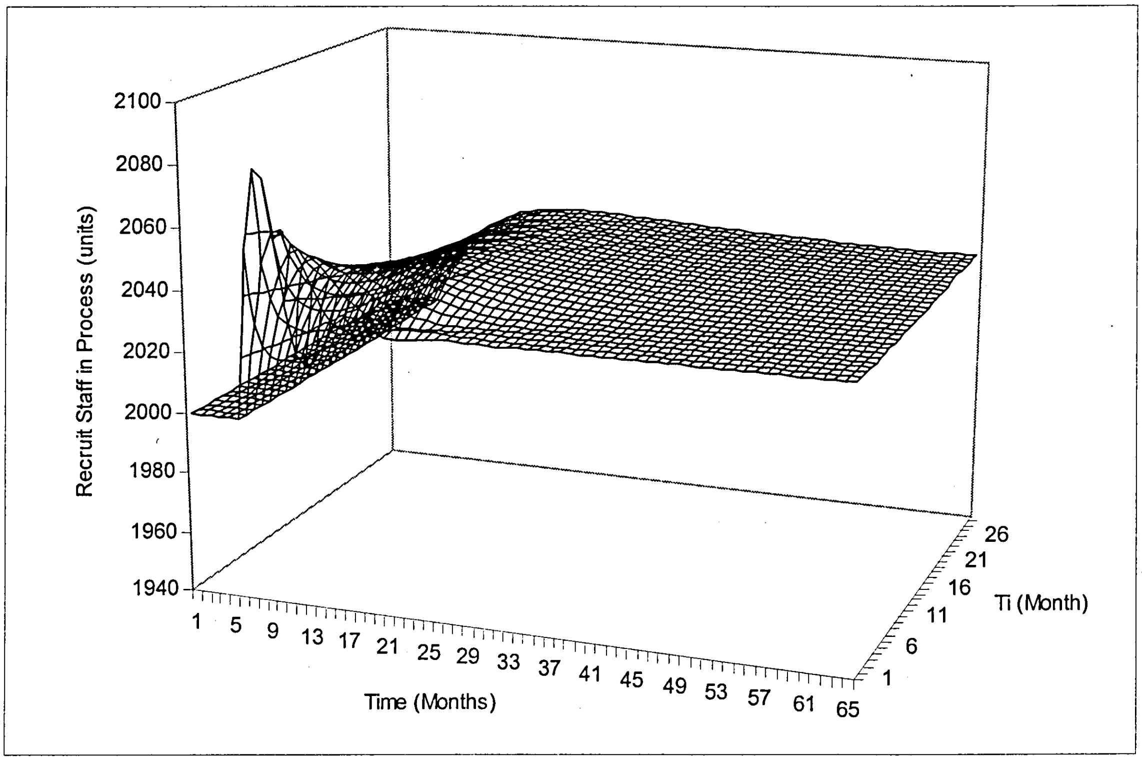
Therefore it can be seen that for Ti > 10 months the value of the damping ratio, ζ, (see Appendix 3) is greater than one, which means the system is over damped implying that the design parameter Ti must be set in the range $0 < Ti < 10$. However, the parameter setting of Tw, ranging between $0 < Tw < 16$, gives rise to ideal values of the damping ratio, μ. Therefore these parameter settings give values of $\zeta = 0.75$, which is within the standard acceptable system design criteria. Table 7.1 gives the overall summary of the effect of varying Ti, Ta , Tr, Tw and Ki on human resource policies for APSKPM +(P+I). Table 7.2 describes the descriptive statistical characteristics for recruitment and actual staff level at optimum design parameters. The optimum parameters in this case where determined in the way described in Chapter 5, by minimising the values of MSE and ITAE and determining those X values closest to the target values.



(a) Staff recruitment completion rate behaviour

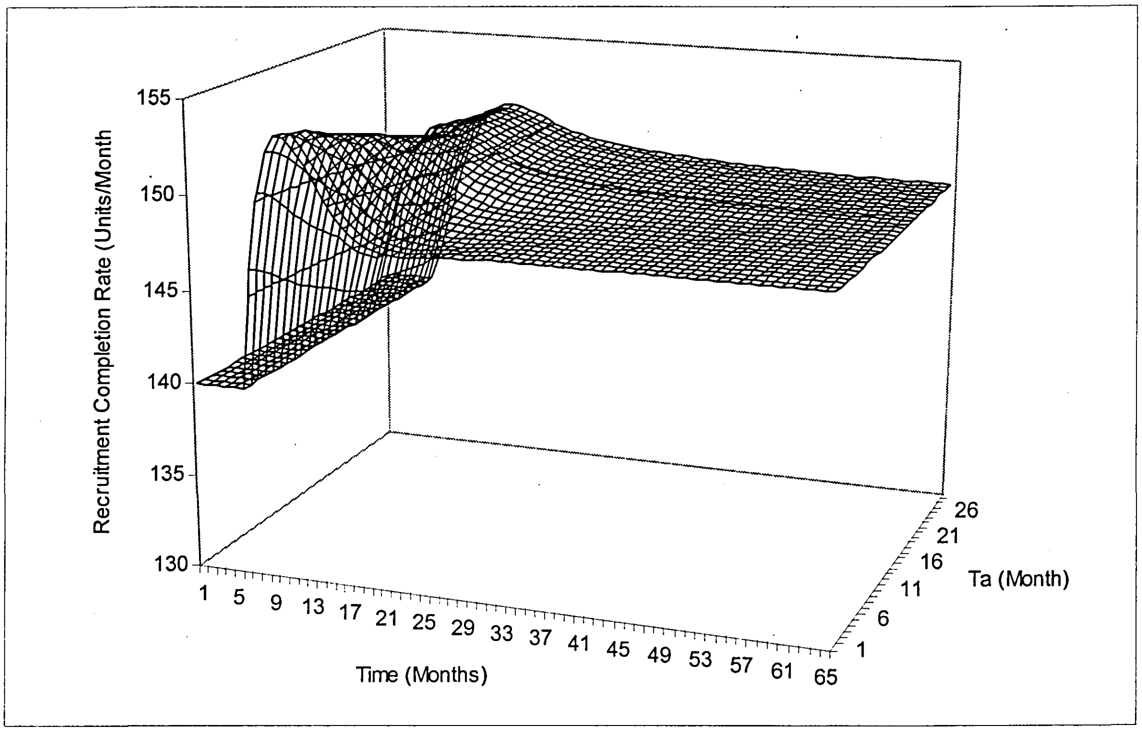


(b) Staff level behaviour

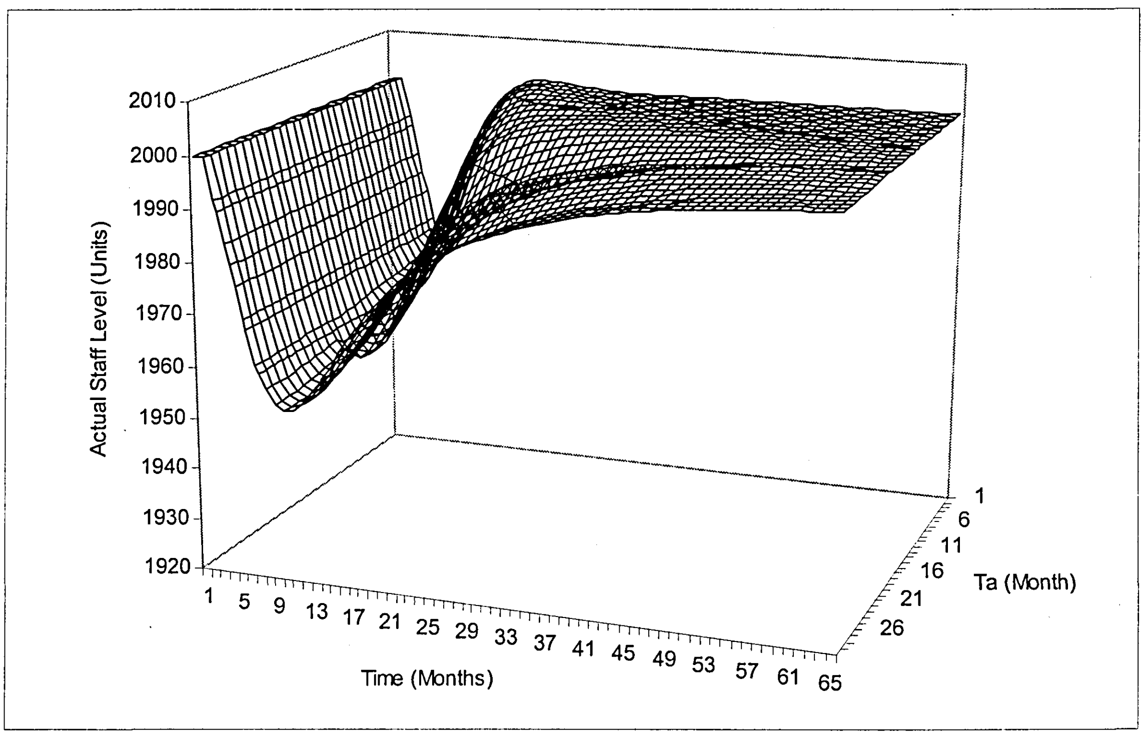


(c) Recruit staff in process behaviour

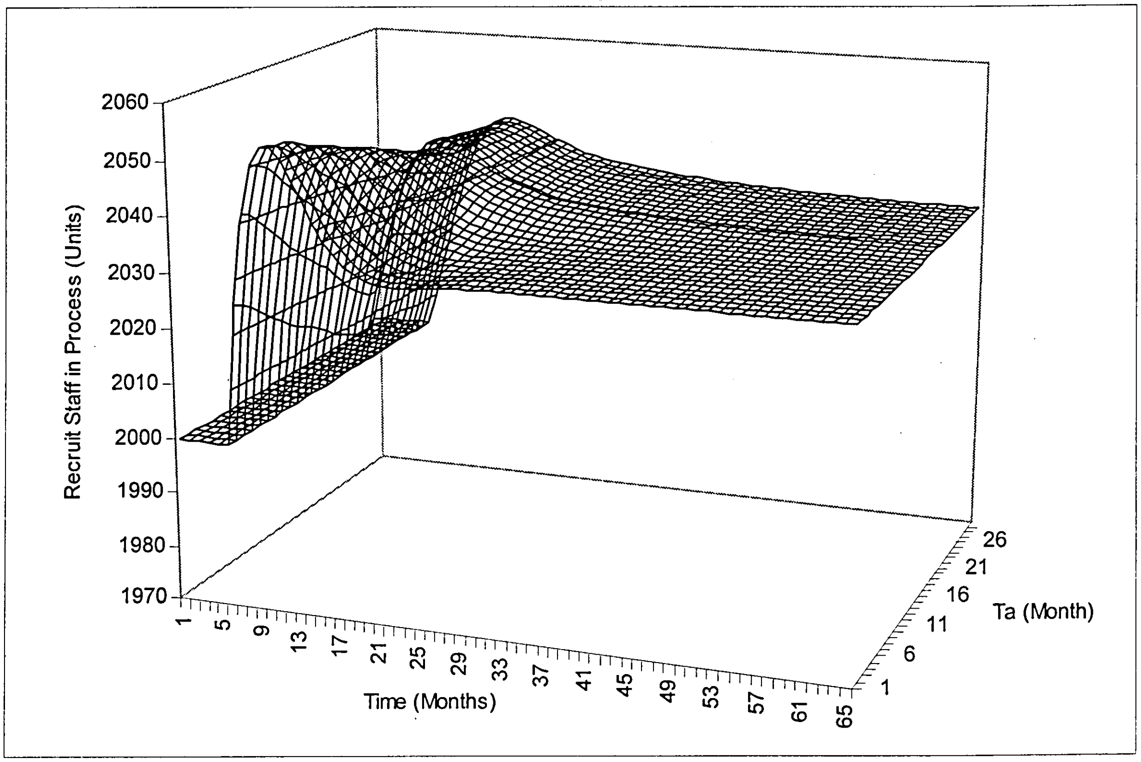
Figure 7.3: Response of APSKPM+(P+I) for (Tr=Ta=Tw=4 months) and varying values of Ti



(a) Staff recruitment completion rate behaviour

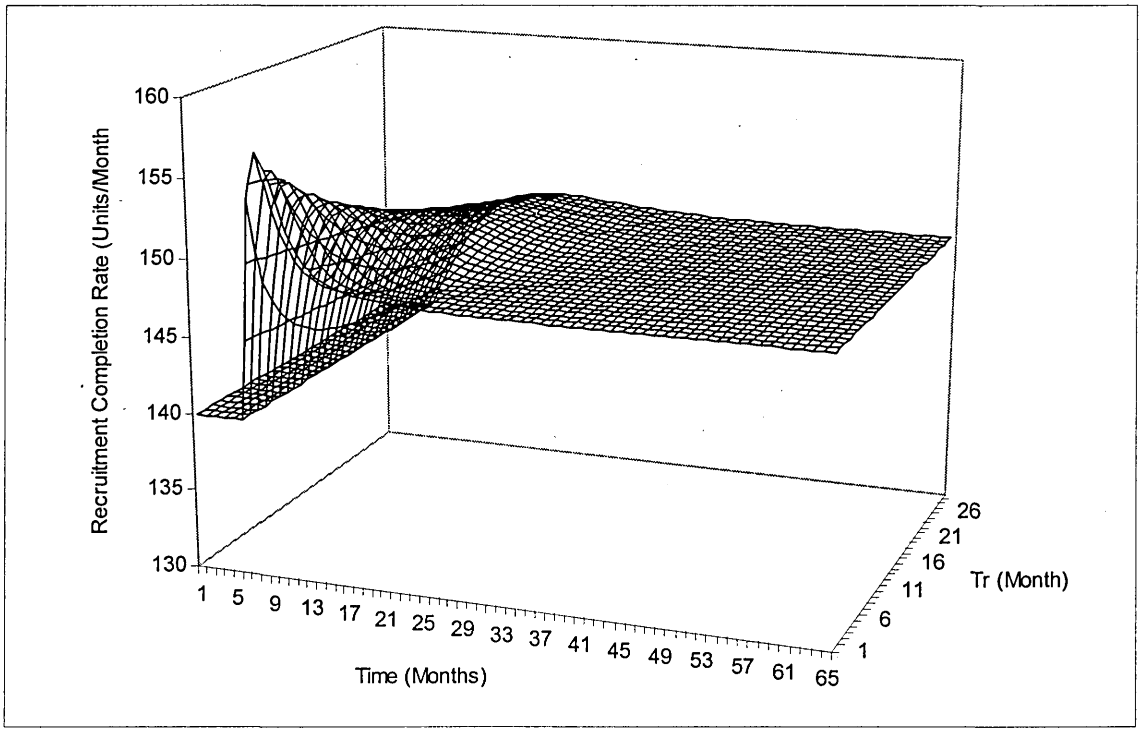


(b) Staff level behaviour

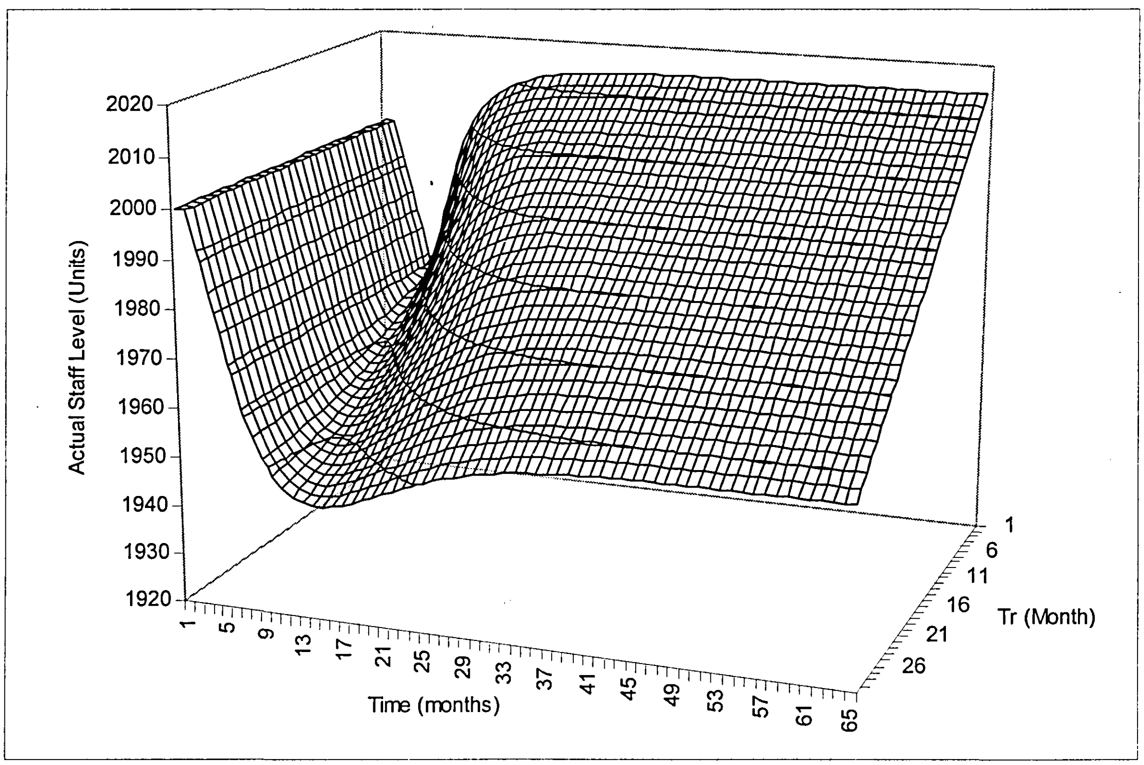


(c) Recruit staff in process behaviour

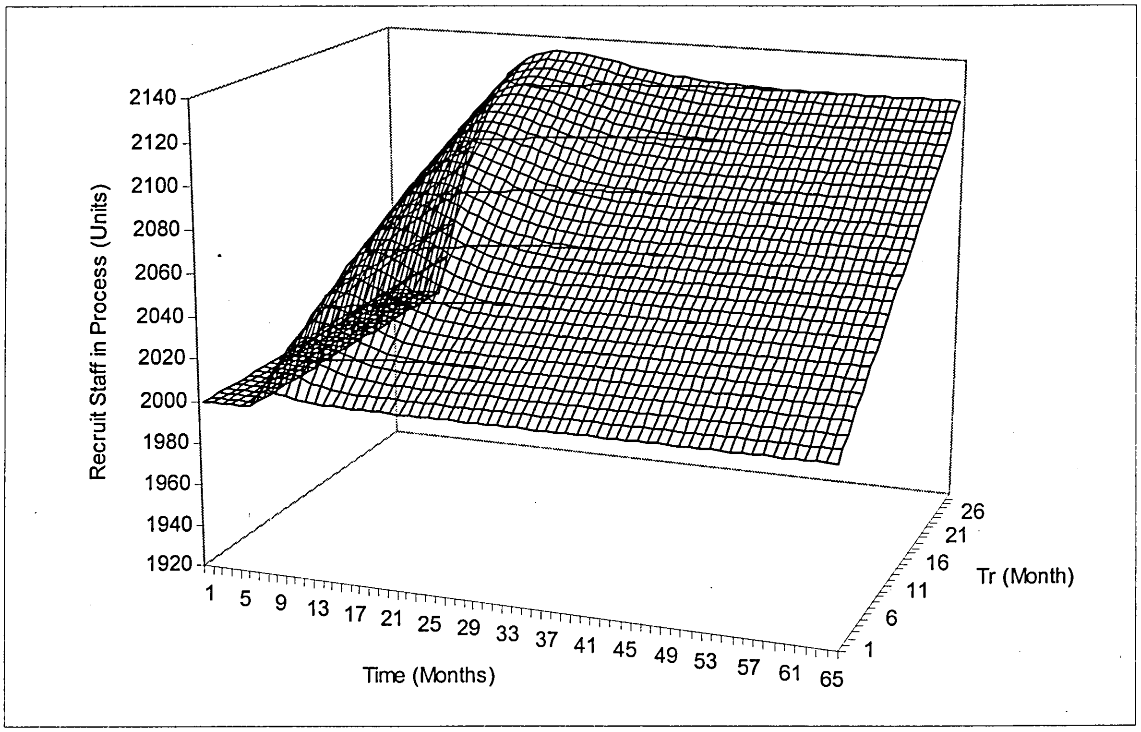
Figure 7.4: Response of SKPM+(P+I) for (Ti=Tr=Tw=4 and Tc=13 months) and varying values of Ta



(a) Staff recruitment completion rate behaviour

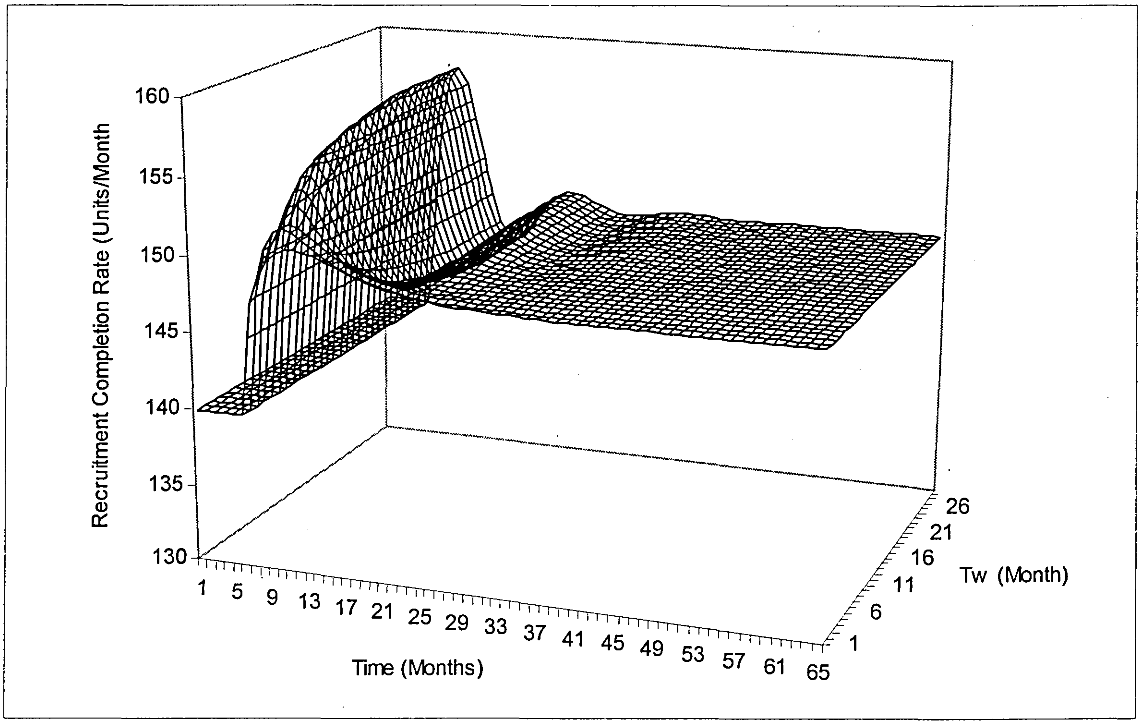


(b) Staff level behaviour

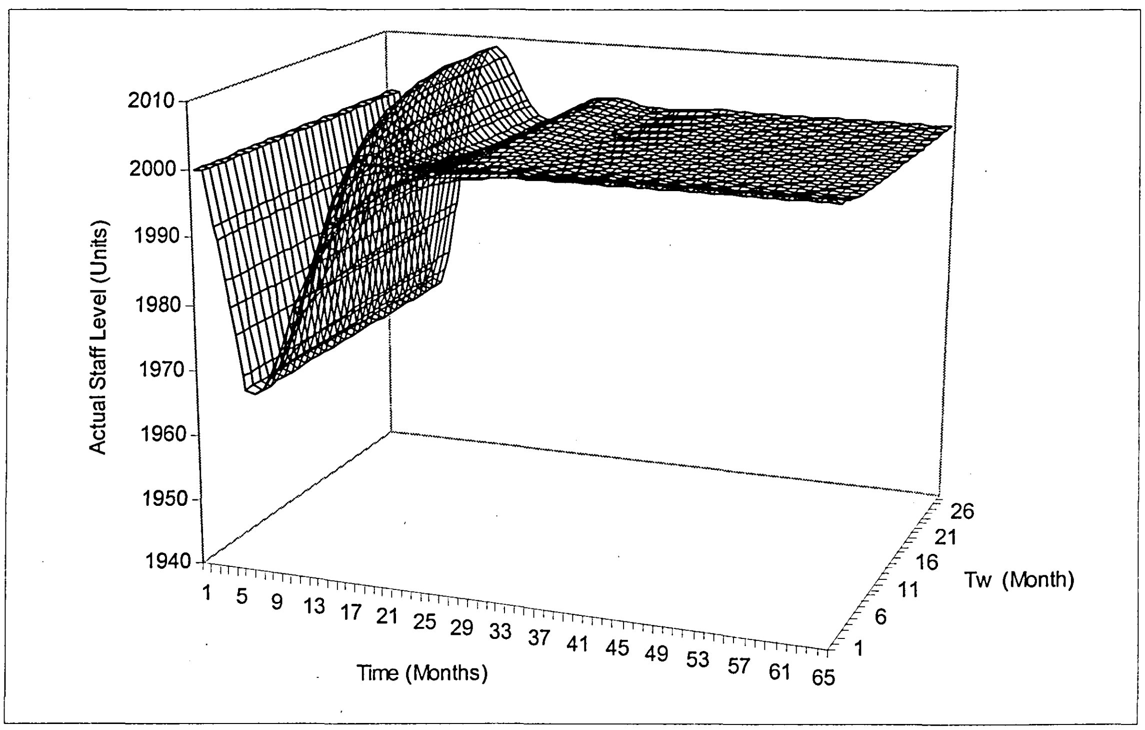


(c) Recruit staff in process behaviour

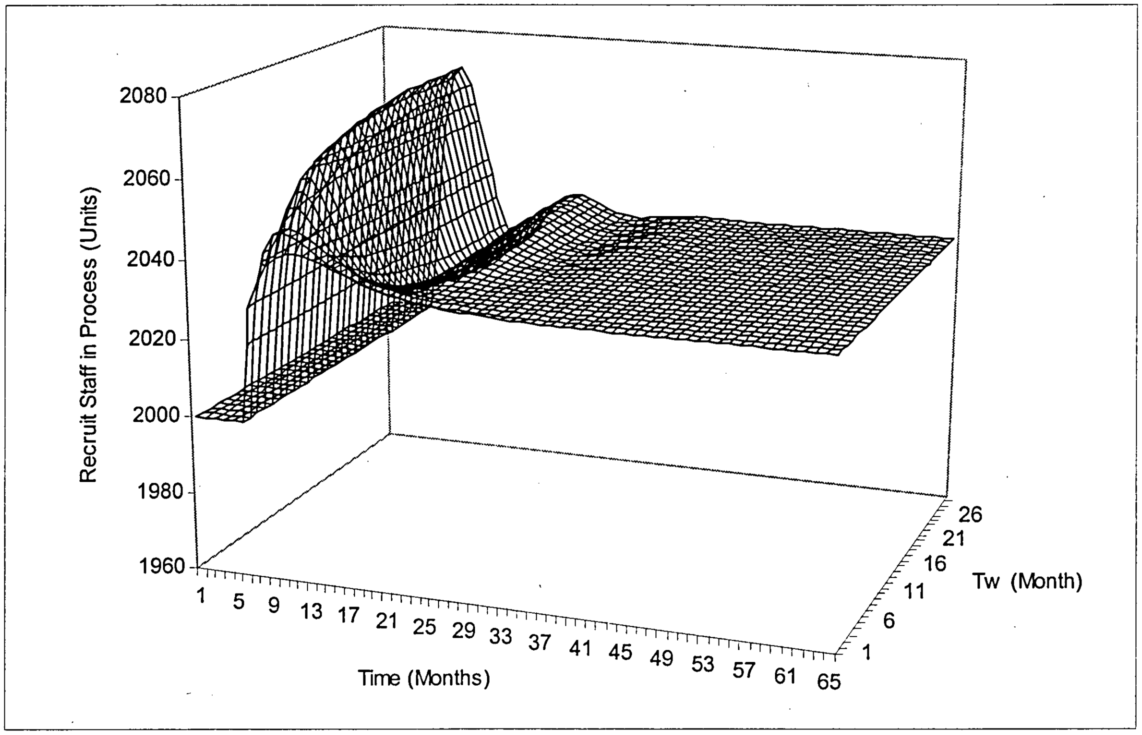
Figure 7.5: Response of APSKPM +(P+I) for (Ti=Ta=Tw=4 and Tc =13 months) and varying values of Tr



(a) Staff recruitment completion rate behaviour

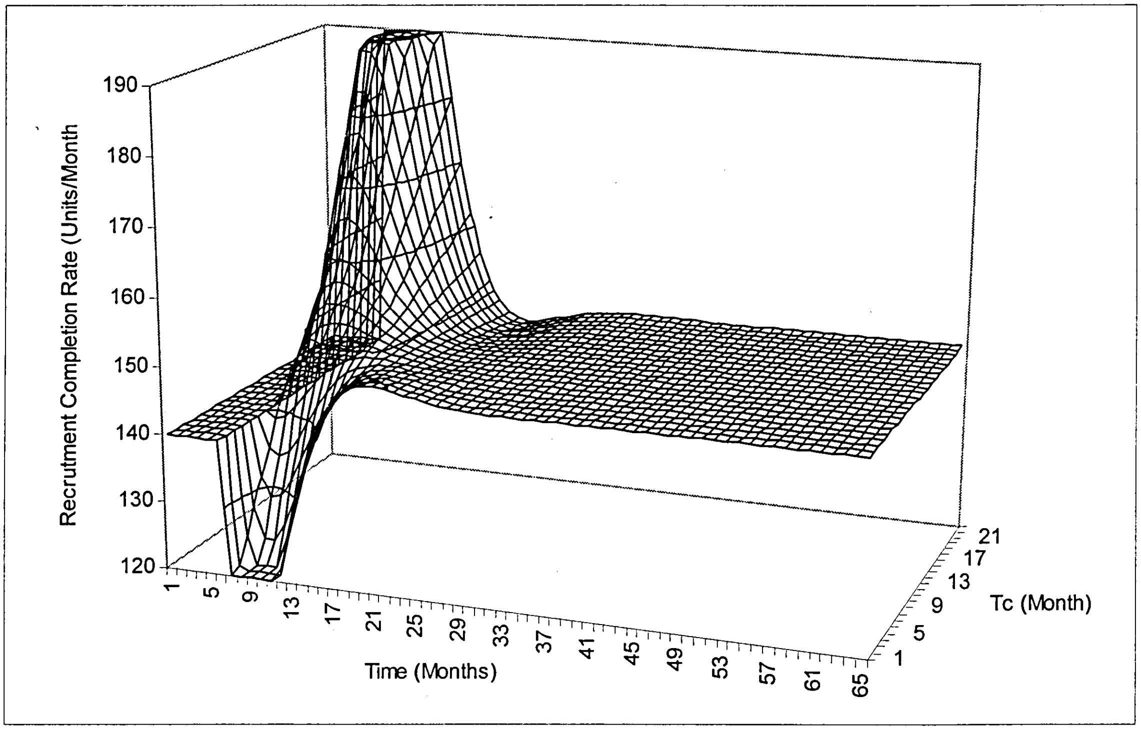


(b) Staff level behaviour

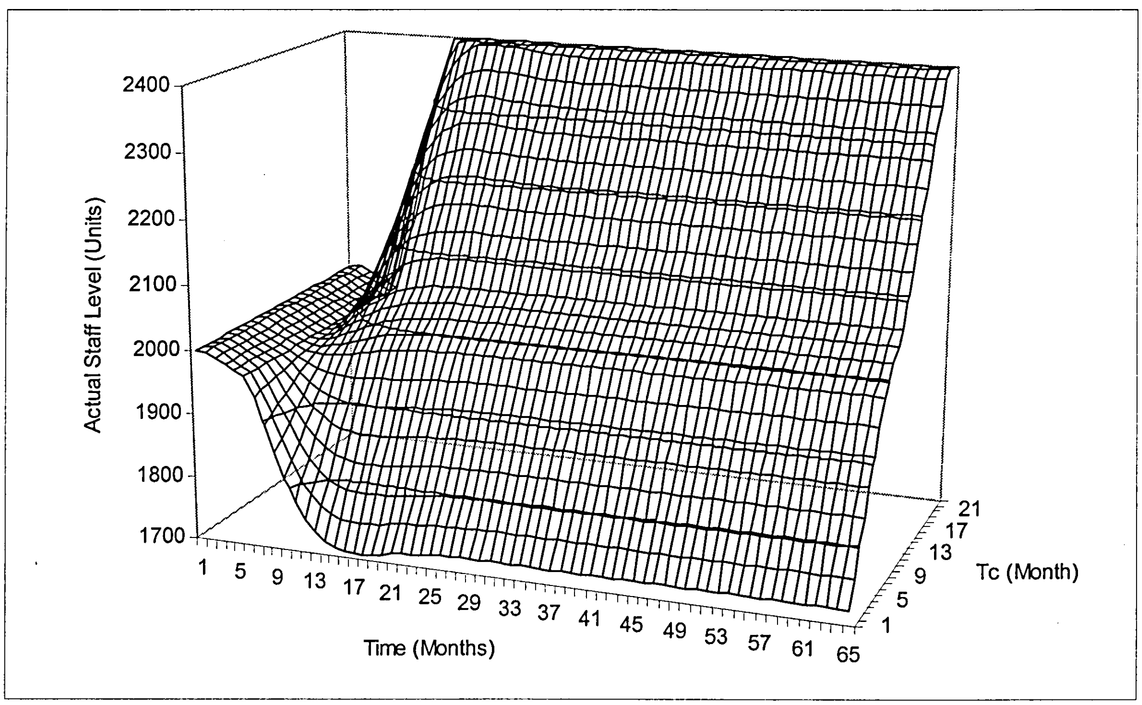


(c) Recruit staff in process behaviour

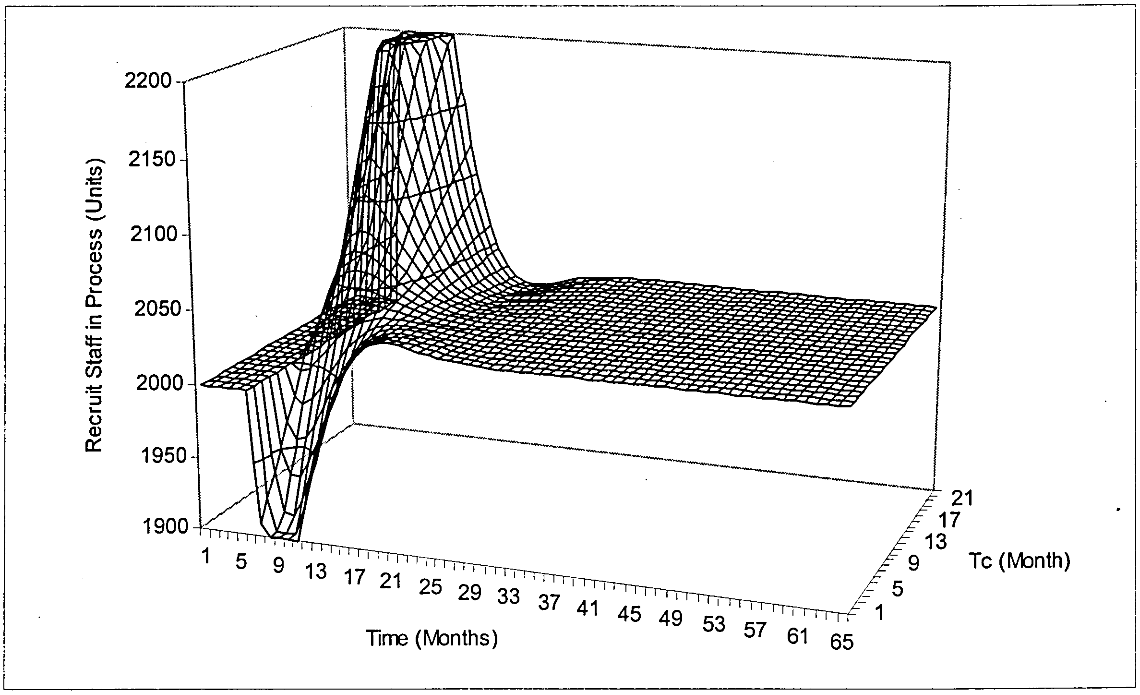
Figure 7.6: Response of APSKPM+(P+I) for (Ti=Ta=Tr=4 and Tc =13 months) and varying values of Tw



(a) Staff recruitment completion rate behaviour

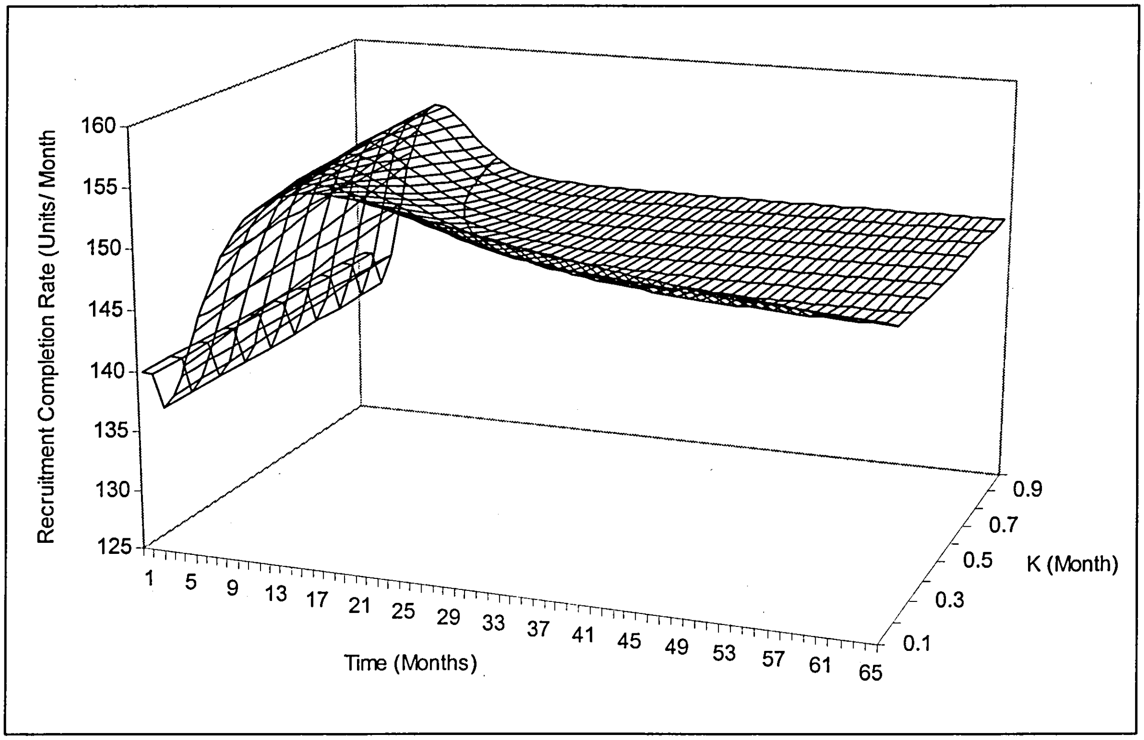


(b) Staff level behaviour

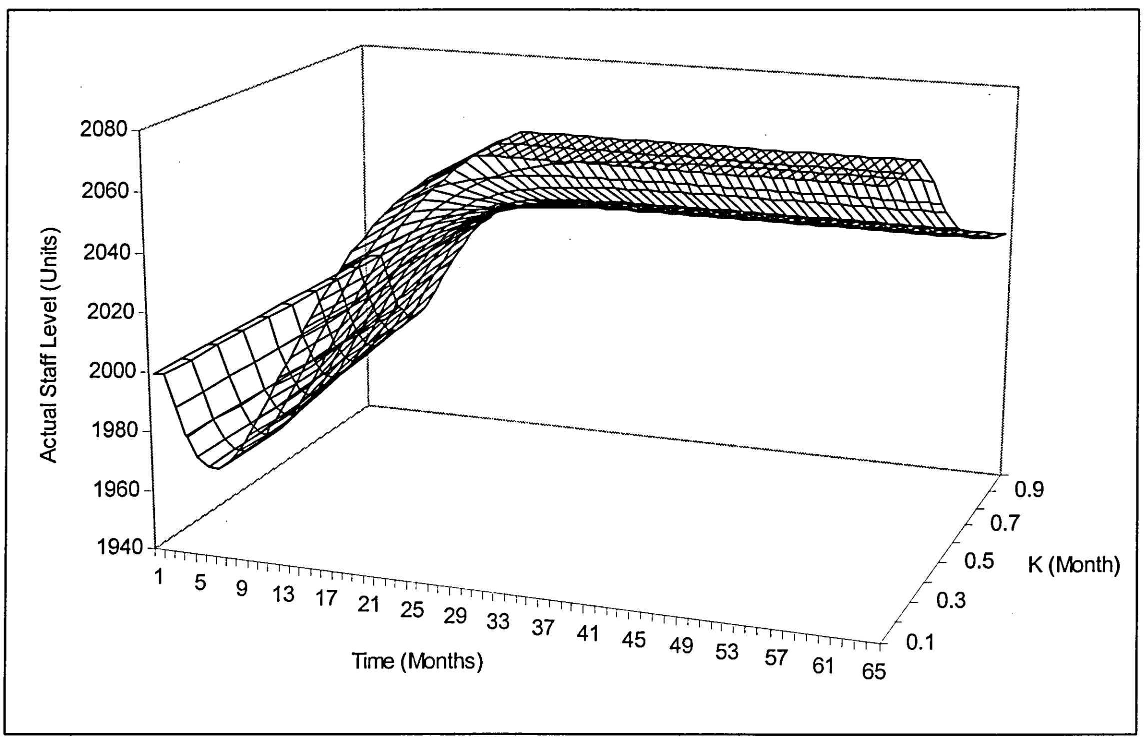


(c) Recruit staff in process behaviour

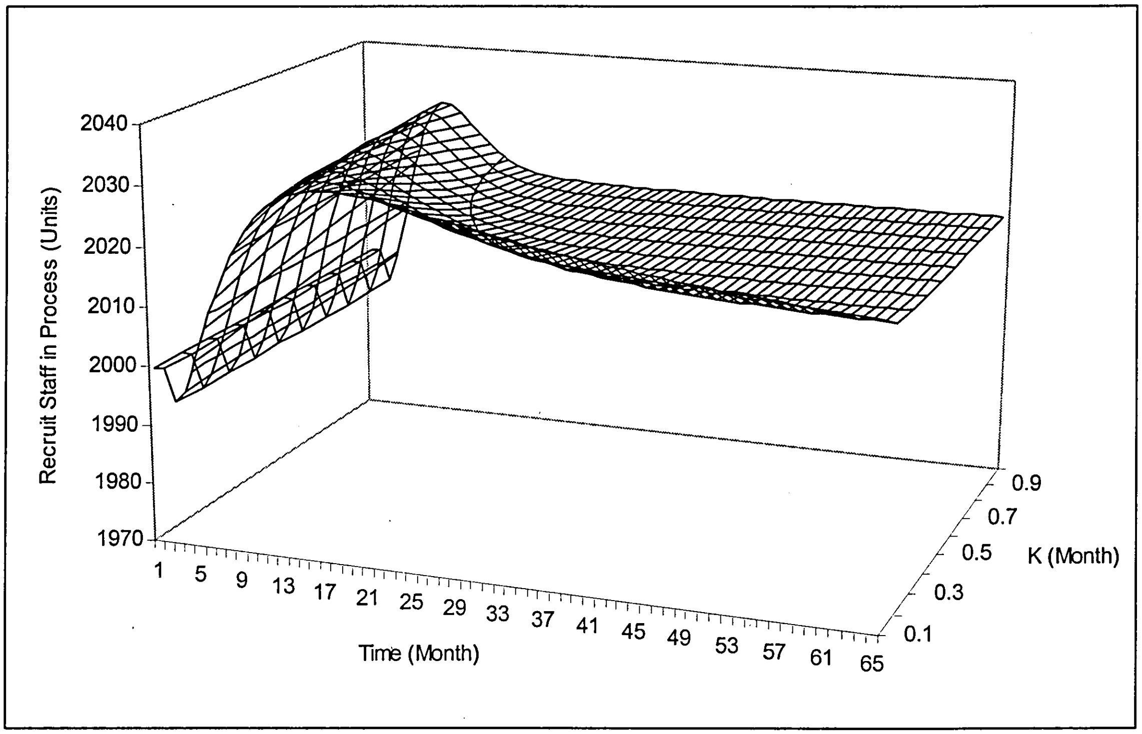
Figure 7.7: Response of APSKPM +(P+I) for (Ti=Ta=Tw=Tr=4 months) and varying values of Tc



(a) Staff recruitment completion rate behaviour



(b) Staff level behaviour



(c) Recruit staff in process behaviour

Figure 7.8: Response of APSKPM + (P+I) for (Ti=Ta=Tr=Tw=4 and Tc =13 months) and varying values of Ki

Performance index at the design Parameters		Automated Pipeline Skill Pool Model plus Integral Controller (APSKPM+(P+I)) Design parameters (A)									
		Ti=1, Ta=2, Tr=1 Tw=7	Ti=2 Ta=4, Tr=2 Tw=7	Ti=1, Ta=4, Tr=4 Tw=7	Ti=2, Ta=2, Tr=2 Tw=7	Ti=4, Ta=8, Tr=8 Tw=7	Ti=4 Ta=8 Tr=4 Tw=7	Ti=3, Ta=6, Tr=3 Tw=7	Ti=2, Ta=4, Tr=8 Tw=7	Ti=3, Ta=4, Tr=4 Tw=7	Ti=3, Ta=4, Tr=8 Tw=7
Recruitment completion rate measurements	Rise Time (Months)	4	3	3	4	8	6	7	6	4	7
	Peak overshoot	20.2	3.4	18.9	7.4	31	14.1	25	41	22.2	35
	Duration of overshoot (Months)	4	5	4	8	20	17	12	13	10	15
Staff level measurements	Initial staff level droop	2.75%	2.4	2.8	2.2	22	10.5	0.65	17.8	8	20.2%
	Duration of staff inventory deficit	5	5	5	10	20	20	19	13	11	17
	Peak staff inventory overshoot	0.45	0.02	0.05	0.3	5.3	0.15	0	8.05	2	7
Recruit staff in process measurements	Rise Time (Months)	3	3	3	5	8	6	7	6	4	7
	Peak overshoot	0.4%	0.34	1.2	0.45	2.15	0.95	2	3	1.55	2.5
	Duration of overshoot (Months)	4	6	5	8	19	17	13	14	10	16

Table 7.1: Performance index and associated dynamic behaviour for the Automated Pipeline Skill Pool Model (APSKPM + P+I), in case study A, where shaded region shown the optimum response

Model output	(APSKPM (P + I)) Model Case Study A		
	X	MSE	ITAE
Recruitment completion rate	148	5.01	380
Actual staff level	2012	214	5905
Recruit staff in process	2016	276	4346

Table 7.2: Descriptive statistical characteristics for APSKPM + (P+I) for case study A

7.7 Dynamic Analysis of the [APSKPM+ (P+I)] model for case study B

Figure 7.10 shows the dynamic response in the staff recruitment completion rate, actual staff level and recruit staff in process for a range of Ti values. Figure 7.10(a), shows that increasing Ti would reduce the peak overshoot. Whilst large overshoots are to be avoided, a small overshoot has to be balanced against a moderate staff recovery rise time.

Figure 7.10(b) concentrates on the effect of Ti on the actual staff level behaviour. A decrease in the present staff leaving rate causes the initial deficit in staff level as staff losses are met from the existing staff level. At Ti = 1 and 2 months this may be attributable to the staff shortage in the company due to staff turnover. This is due to the initial staff loss being met from the actual staff pool whilst extra staff are being recruited. As Ti increases, the duration of staff pool deficit would increase, and the peak staff pool overshoot would decrease. Figure 7.10(c) shows the behaviour of recruit staff in process. The response of recruit staff in process shows similar properties to that of recruitment completion rate, but with the actual values multiplied by Tr.

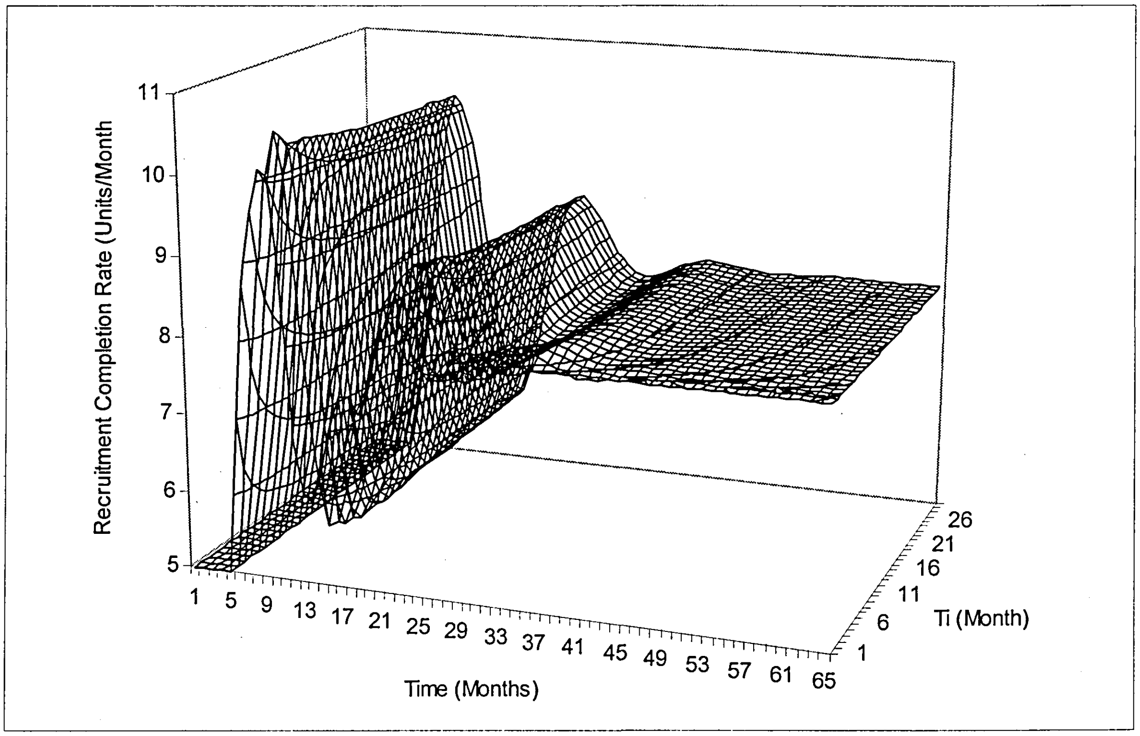
Figure 7.11 examines the response of the staff recruitment completion rate, actual staff level and recruit staff in process for varying values of Ta. As shown in Figure 7.11(a) large values of Ta gives less oscillatory behaviour for the training completion rate, and as Ta decreases the recruitment completion rate overshoot increases, but the settling time decreases. Figure 7.11(b) shows that large values of Ta give a slow actual staff level recovery. Decrease in Ta would lead to a staff level drop decrease as well as a dcrease in settling time. Smaller values of Ta would induce instability in a real system. The analysis also shows that for the best value of Ta the organization would recover only up to 80% of the initial value of the actual staff level. Figure 7.11(c) represents the recruit staffs in process response, which is similar to the recruitment completion rate with the multiplied factor of Tr.

Figure 7.12 illustrates the behaviour of the three controllers namely, recruitment completion rate, actual staff level and recruit staff in process at varying values of Tr. As shown in Figure 7.12(a) increase in Tr leads to increase in the recruitment completion rate overshoot, and the time it takes the system to reach its steady state increase, and we observed that the best response would be at the values of $3 \geq Tr \geq 7$, for the recruitment completion rate. Figure 7.12(b) shows that increasing Tr would increase the duration of staff pool deficit. This duration gives an indication of the speed of recovery from the staff pool deficit. As Tr increases the peak staff pool overshoot reduces as well. Figure 7.12(c) shows that as Tr increases, the oscillatory response increases. For Tr < 3 months the recruit staff in process level is under the initial value and for Tr > 7 months the response is a pronounced overshoot. At Tr = Ti = 2 months the recruit staff in process has a good response with the rise time equal to 2 months.

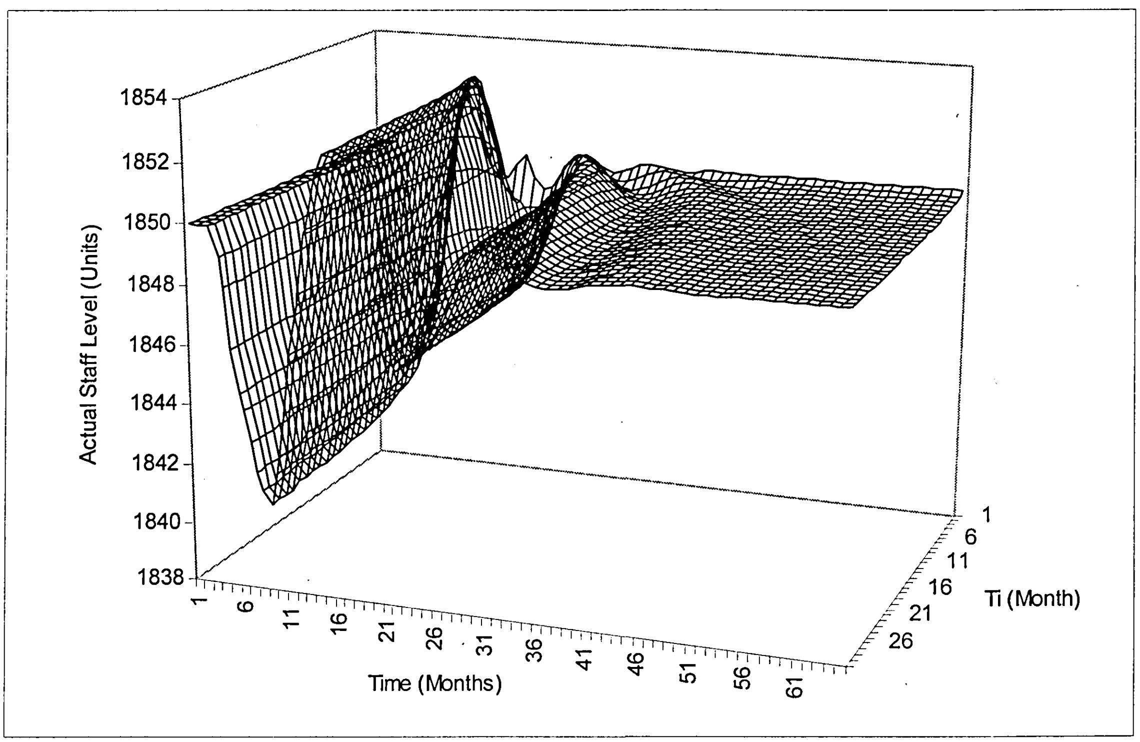
Figures 7.13 show the recruitment completion rate, actual staff level and recruit staff in process at different values of staff pipeline control parameter Tw. The aim is to observe how the system recovers from input changes. Figure 6.13(a) shows the recruitment completion rate behaviour. As Tw decreases, the recruitment completion rate overshoots decreases. Figure 6.13(b) indicates that, as Tw less than 4 months is less peak overshoot but the duration of overshoot is longer. For Tw greater than 4 months the actual staff level overshoot increase, the actual staff level response indicates that as Tw decrease, the overshoot damps down, at the same time the initial staff pool deficit increases slightly for smaller values of Tw. The recruit staff in process has the similar behaviour as the training completion rate but with multiplying factor of Tr as shown in Figure 6.13(c).

Figure 7.14 illustrates the behaviour of the parameter Tc on the three controllers, staff recruitment completion rate, actual staff level and recruit staff in process. This parameter is used to estimate the recruitment lead time to control the desired value of recruit staff in process. Figure 7.14(a) shows that for Tc less than 12 months the starting value is less than the initial value. As Tc increases the peak overshoot increases as well as the duration of overshoot. For all Tc values, the recruitment completion rate is completely restored to its initial value. Figure 7.14(b) shows that at Tc less than 12 months the actual staff level decreases below the initial value. The staff level pool has satisfactory behaviour for Tc between 12 and 15 months, and the actual staff level drop and the duration of the staff deficit are small compared to other values. For Tc greater than 15 months the actual staff level increases and doesn't get to its steady state value. Figure 7.14(c) shows the recruit staff in process response for different values of Tc. By inspection, at Tc = 8 months it is acceptable behaviour. As Tc decreases less than 12 months the initial recruit staff in process level drop increases, and as Tc increases above 15 months the recruit staff in process level overshoot increases permanently. The results indicate that Tc should be equal 14 months for optimal behaviour.

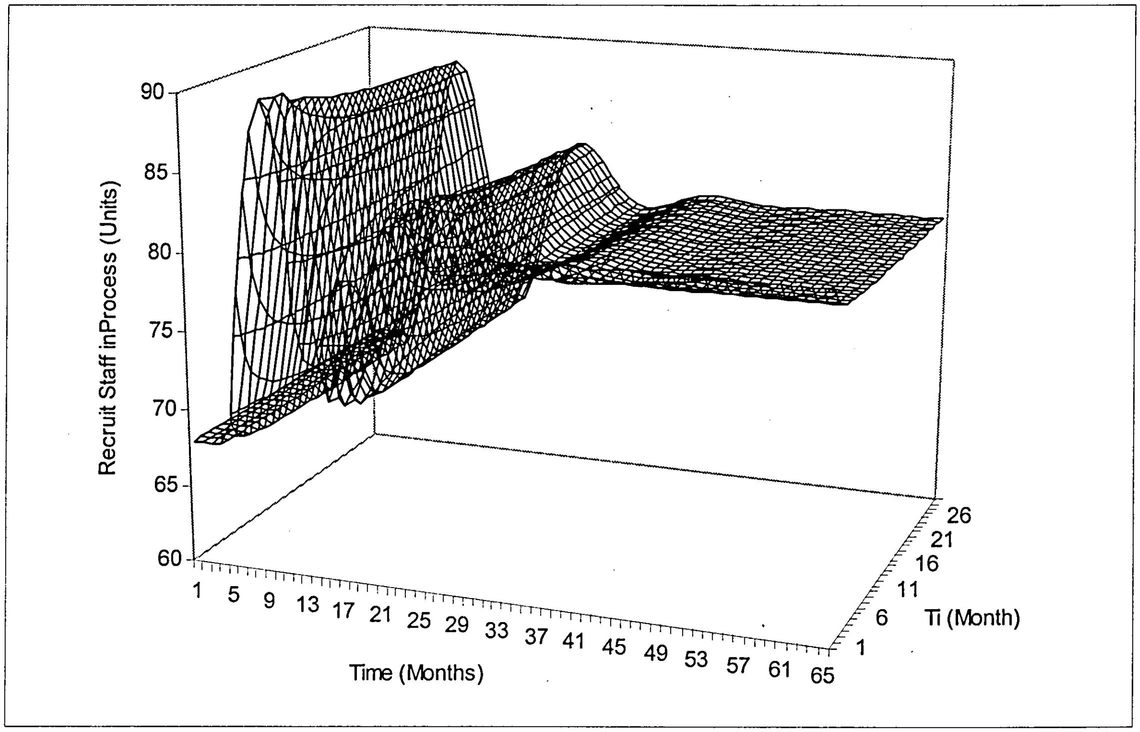
Figure 7.15 shows the results of Ki varying between 0 and 1 for the three controllers: recruitment completion rate, actual staff level and recruit staff in process. Figure 7.15 (a) shows that as Ki increases the peak overshoot increases and the duration of overshoot increases. By inspecting the figure we suggest that Ki = 0.7 is a good design because unnecessary fluctuation in recruitment completion rate has been avoided and the time to recruit new staff is not to long. Figure 7.15 (b) shows that with Ki = 0 we have the same behaviour as APSKPM. As Ki increases the staff pool deficit increases and the duration of staff pool deficit increases. The response of recruit staff in process shows similar properties to that of recruitment completion rate as shown in Figure 7.15 (c). Indeed, when Ki = 0 for APSKPM+(P+I) and APSKPM, the plots for recruitment completion rate, actual staff level and recruit staff in process shows no difference between two models. Table 7.3 gives the overall summary of the effect of varying Ti, Ta , Tr, Tw and Ki on human resource policies for APSKPM +(P+I) model. Table 7.4 describes the descriptive statistical characteristics for recruitment and actual staff level at optimum design parameters for case study B. The optimum parameters in this case where determined in the way described in Chapter 5, by minimising the values of MSE and ITAE and determining those X values closest to the target values.



(a) Recruitment completion rate

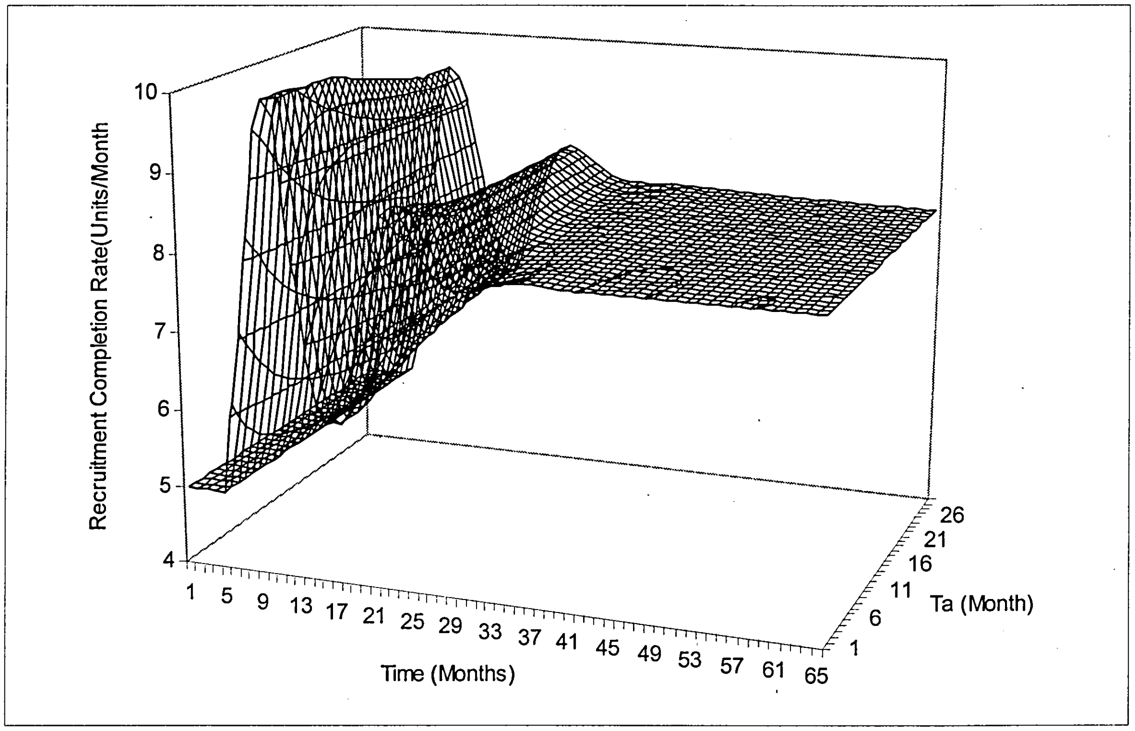


(b) Actual staff level

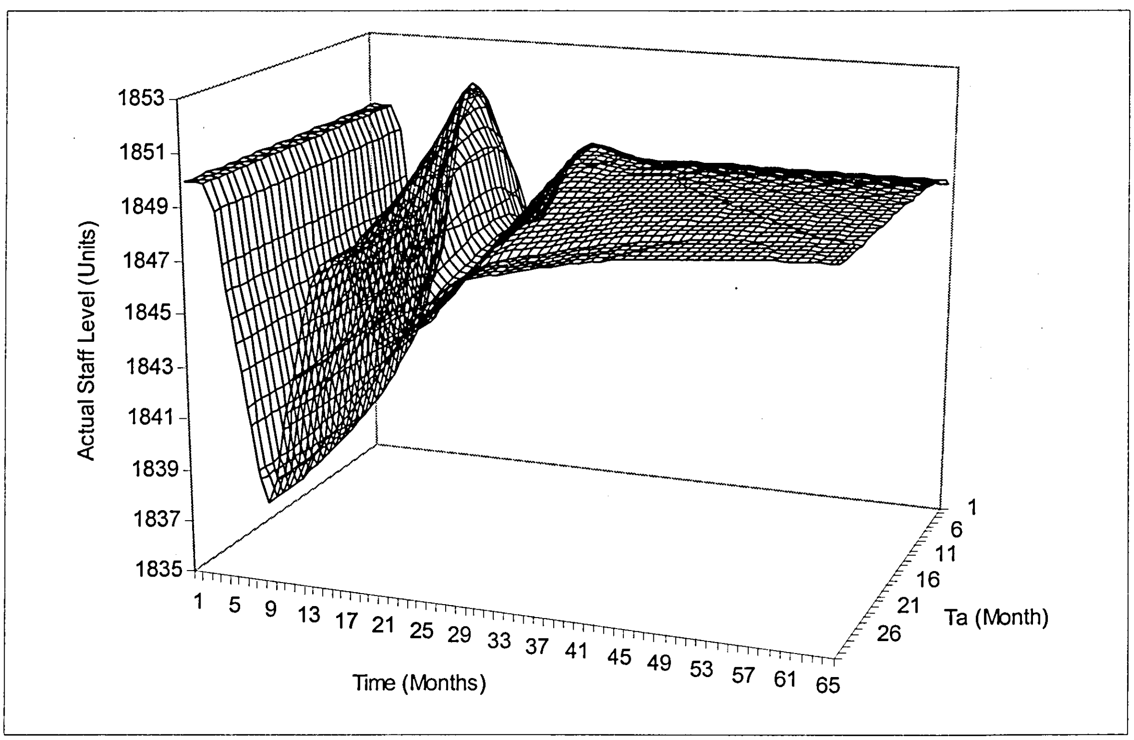


(c) Recruit staff in process

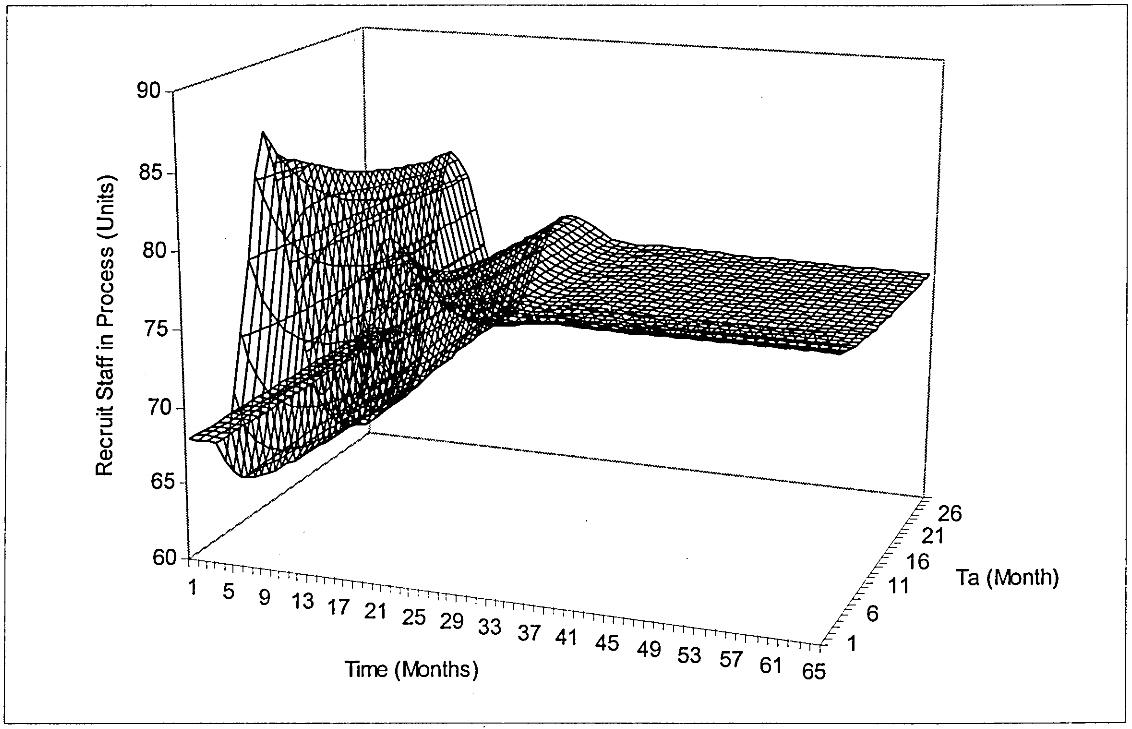
Figure 7.10: Response of APSKPM+(P+I) for varying values of Ti



(a) Recruitment completion rate

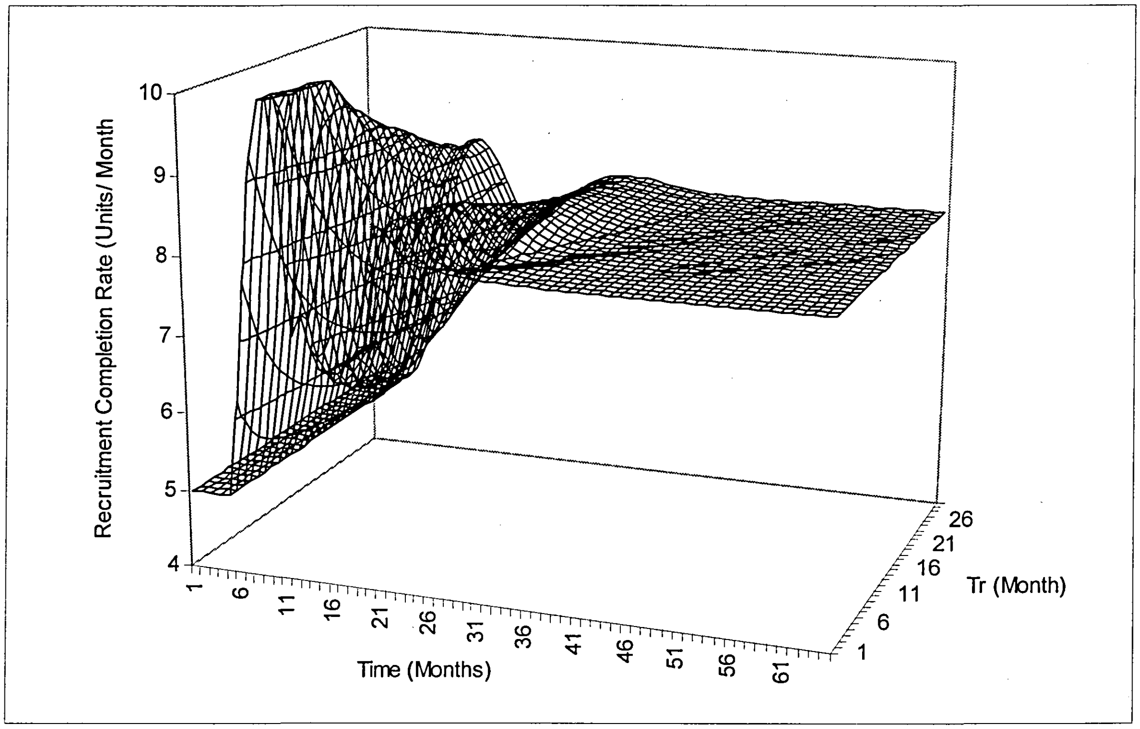


(b) Actual staff level

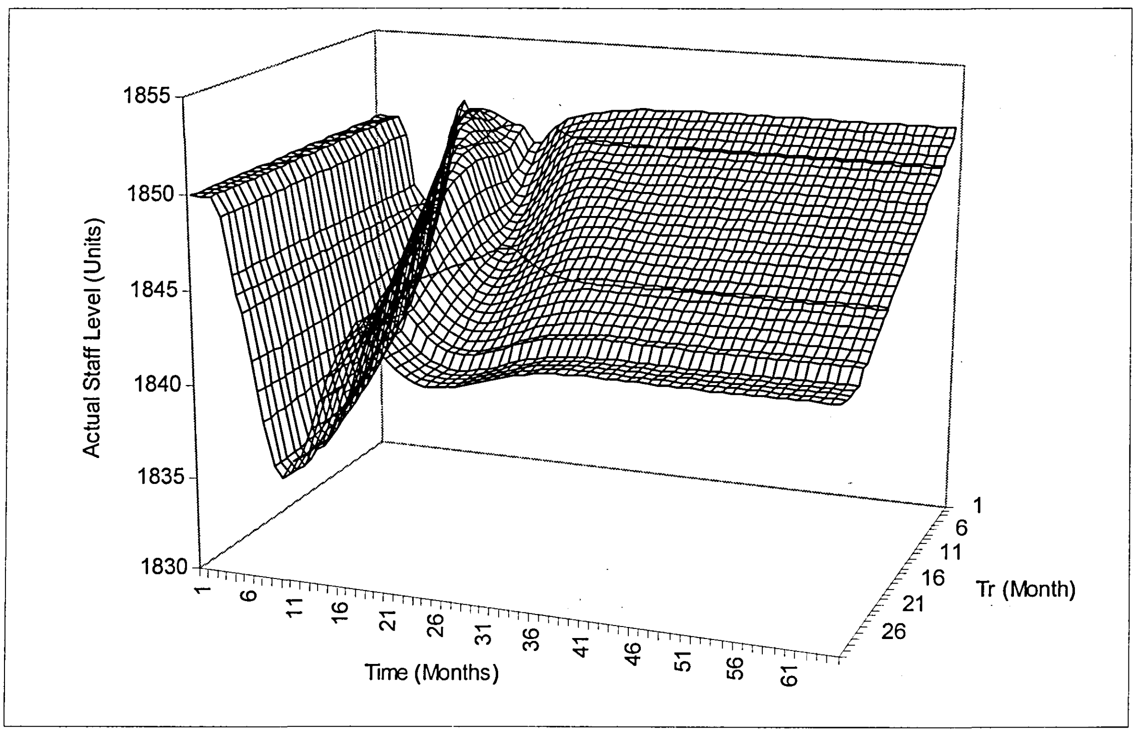


(c) Recruit staff in process

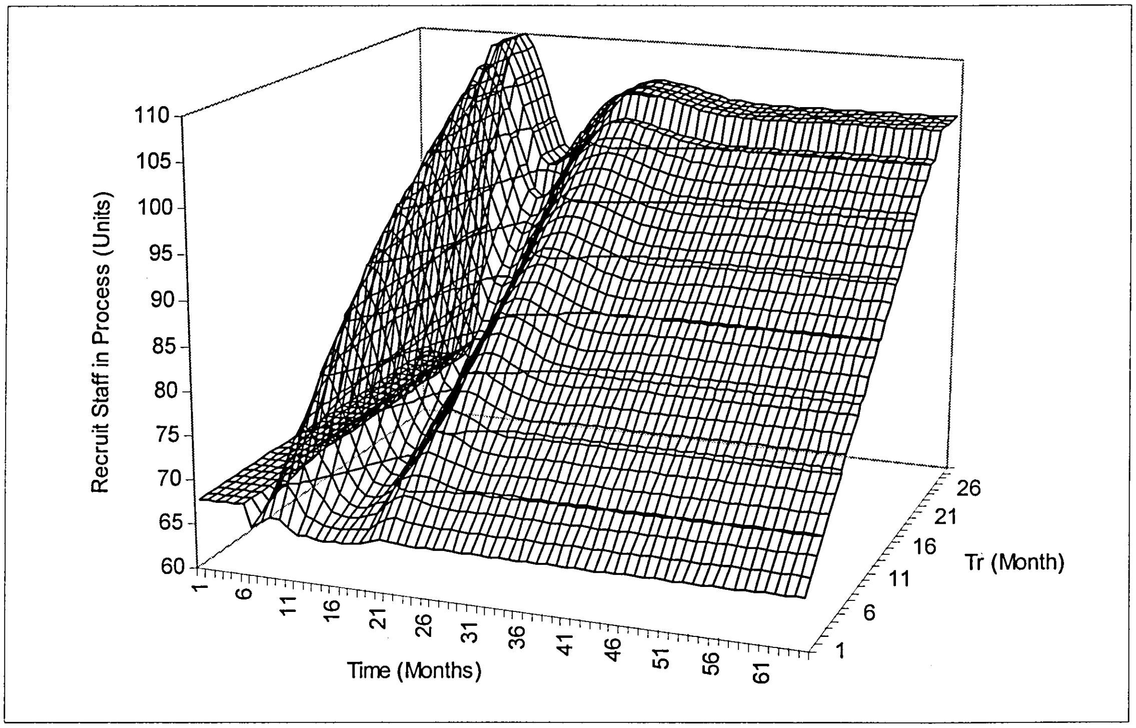
Figure 7.11: Response of APSKPM+(P+I) for varying values of Ta



(a) Recruitment completion rate

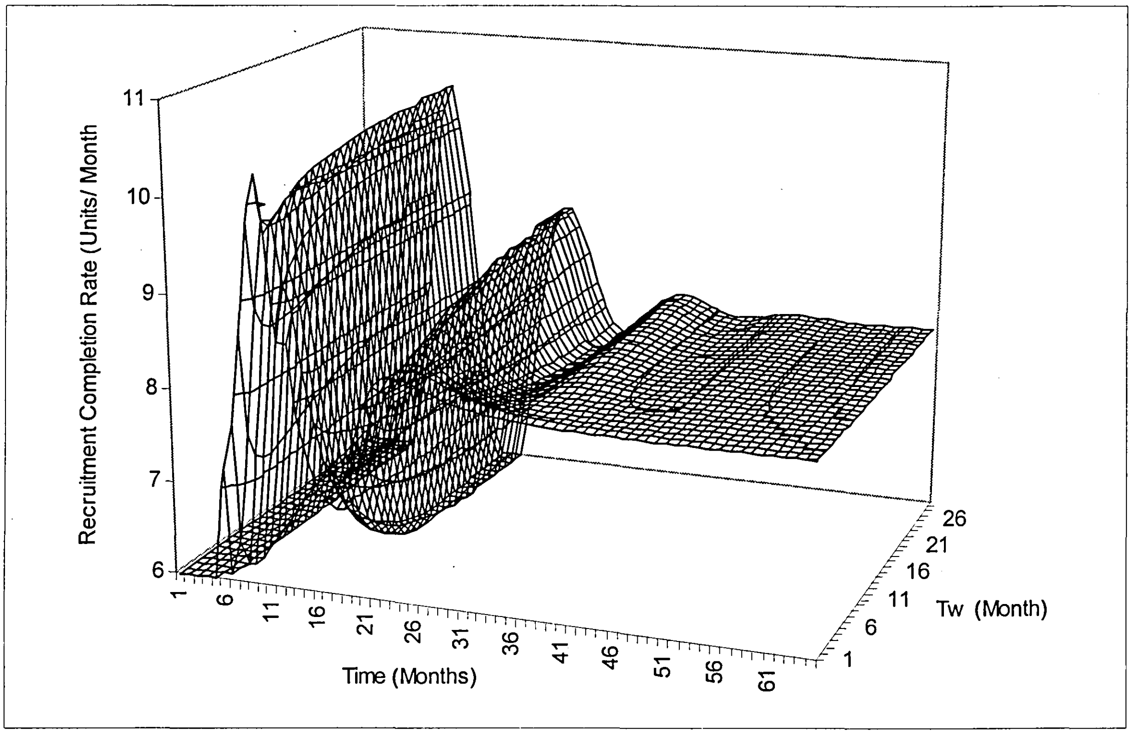


(b) Actual staff level

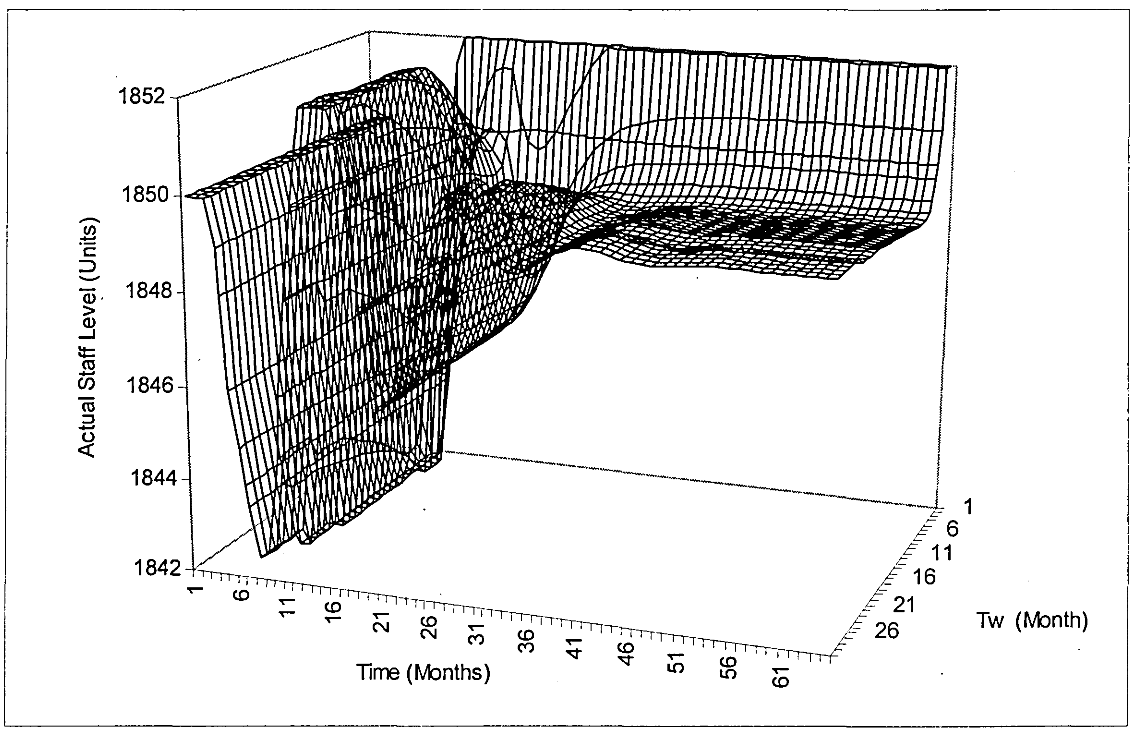


(c) Recruit staff in process

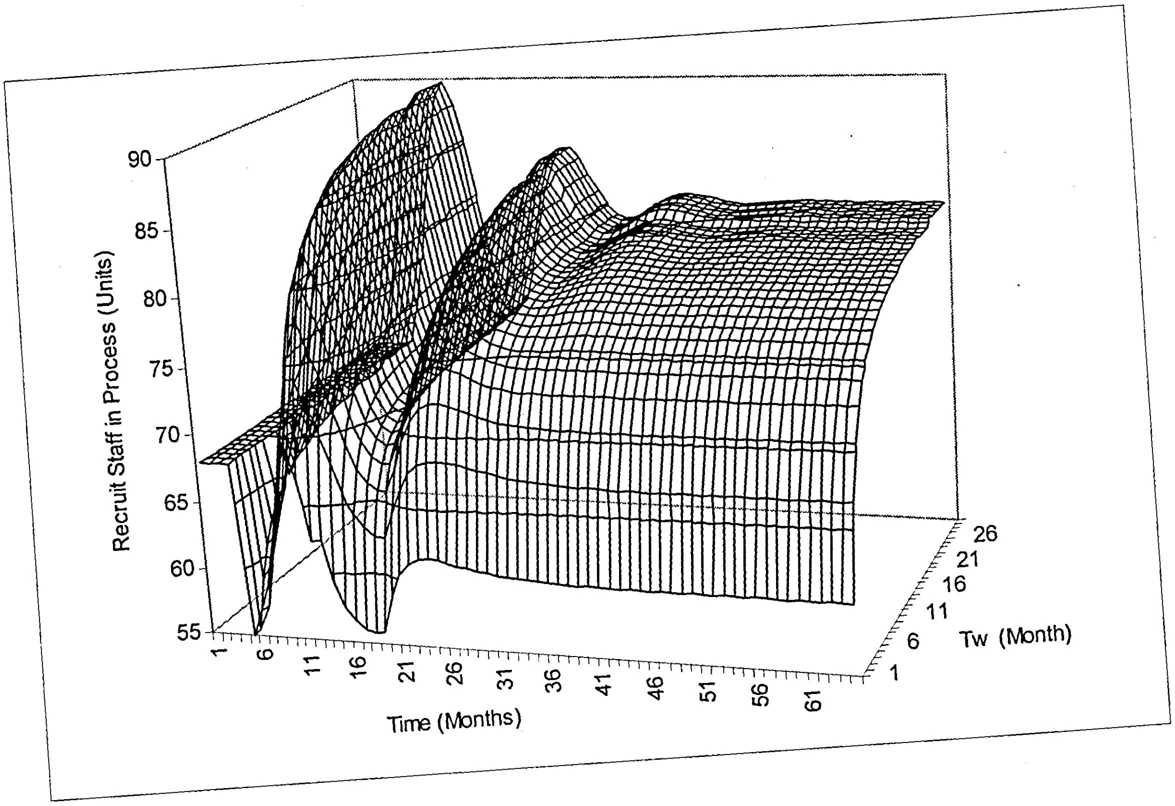
Figure 7.12: Response of APSKPM+(P+I) for varying values of Tr



(a) Recruitment completion rate

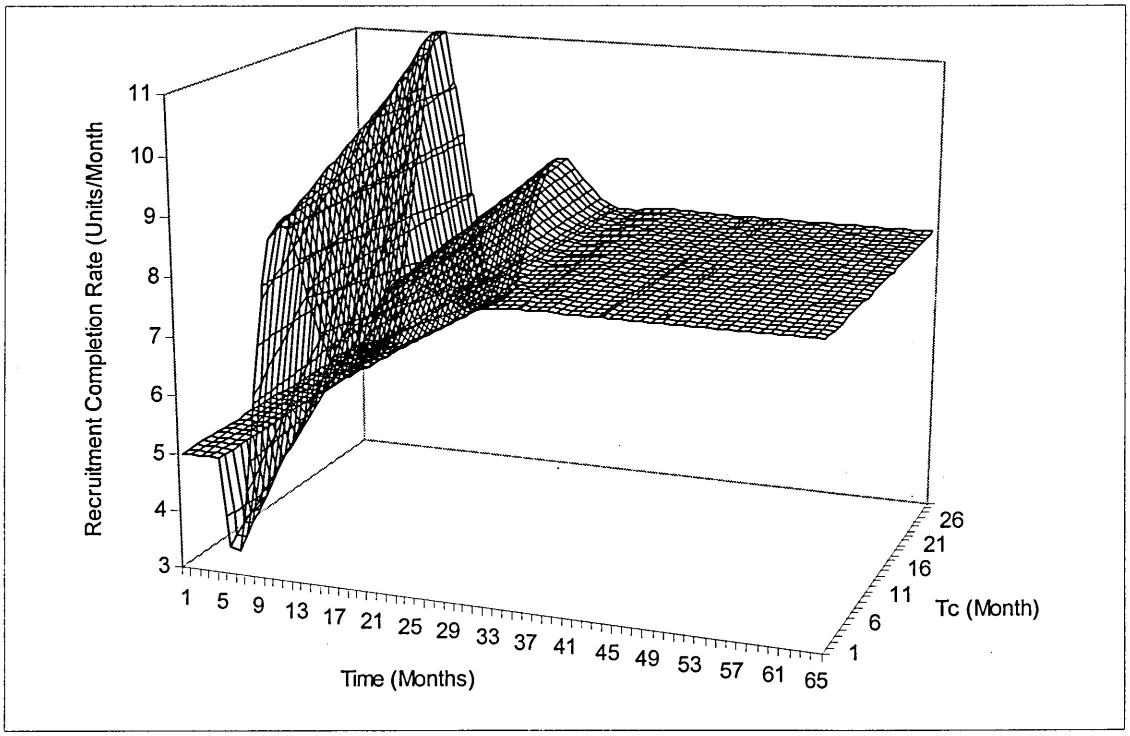


(b) Actual staff level

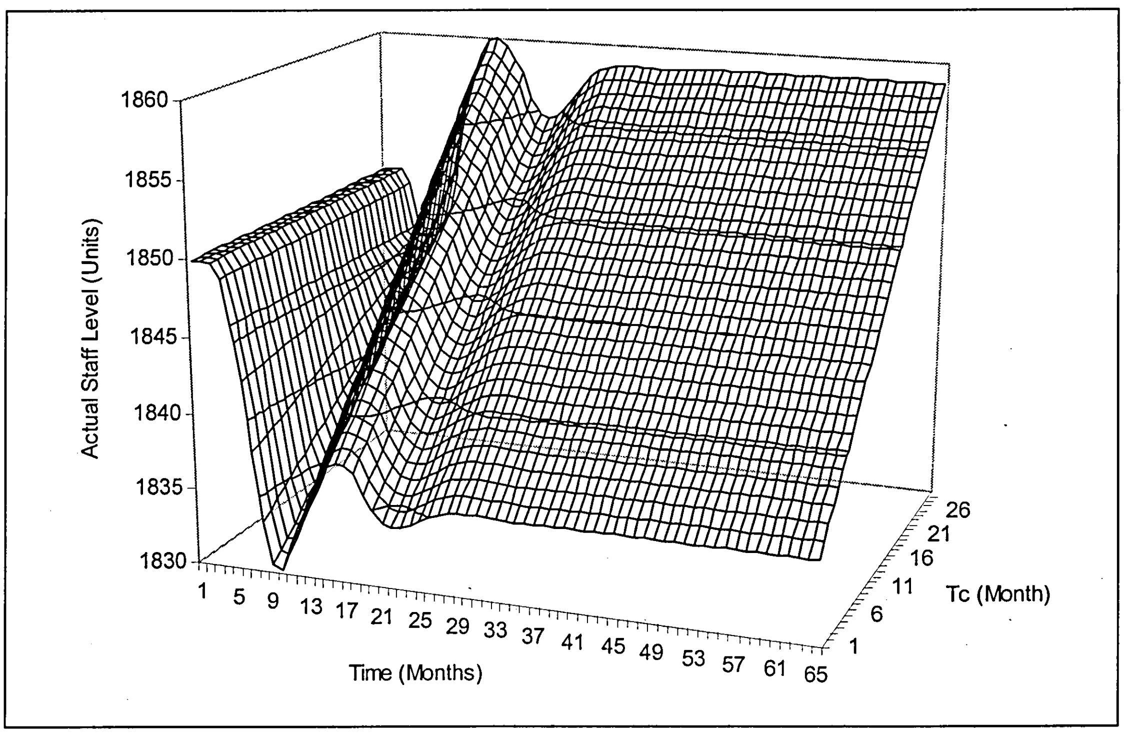


(c) Recruit staff in process

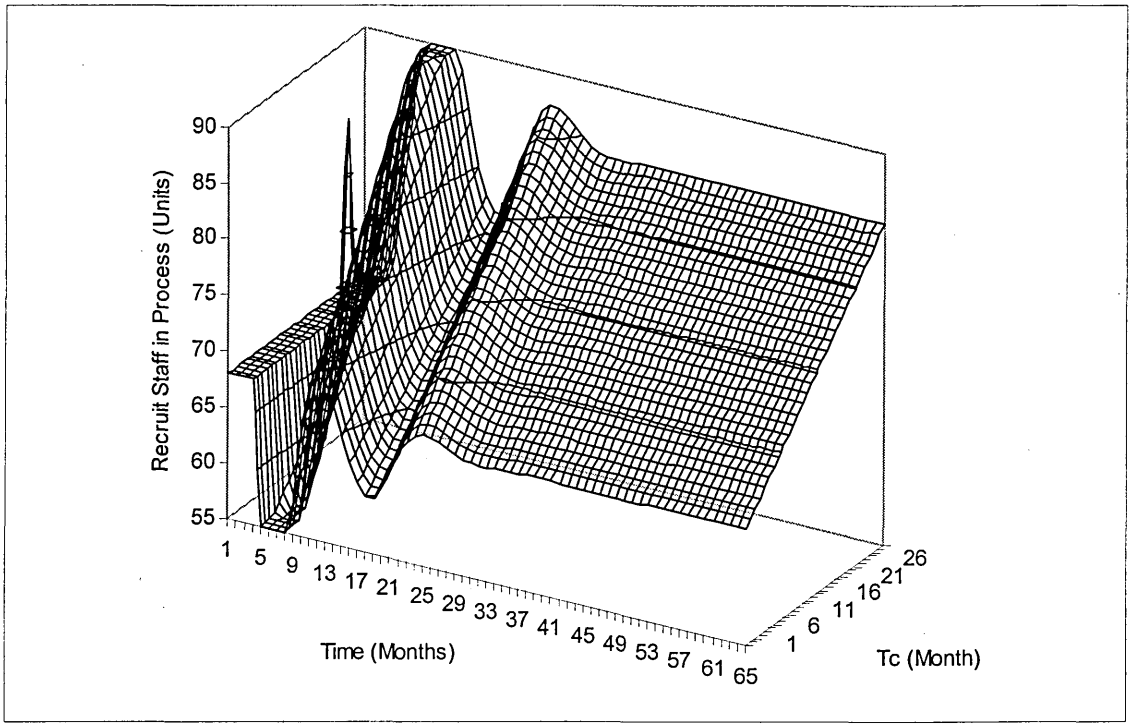
Figure 7.13: Response of APSKPM+(P+I) for varying values of Tw



(a) Recruitment completion rate

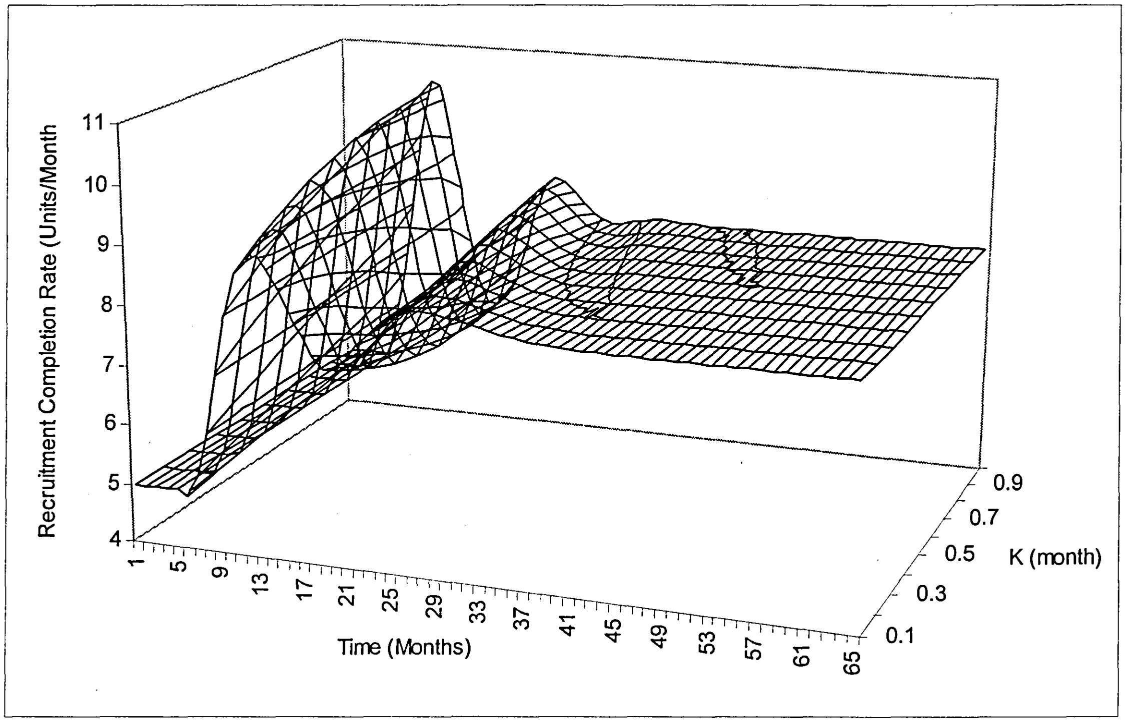


(b) Actual staff level

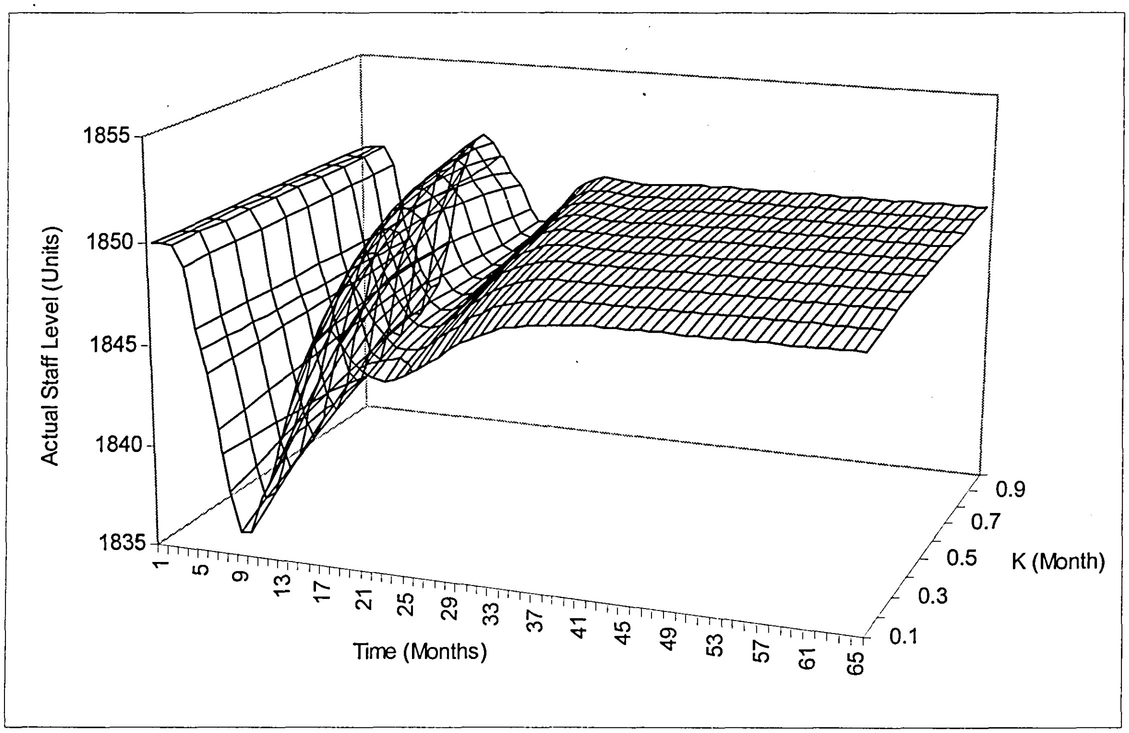


(c) Recruit staff in process

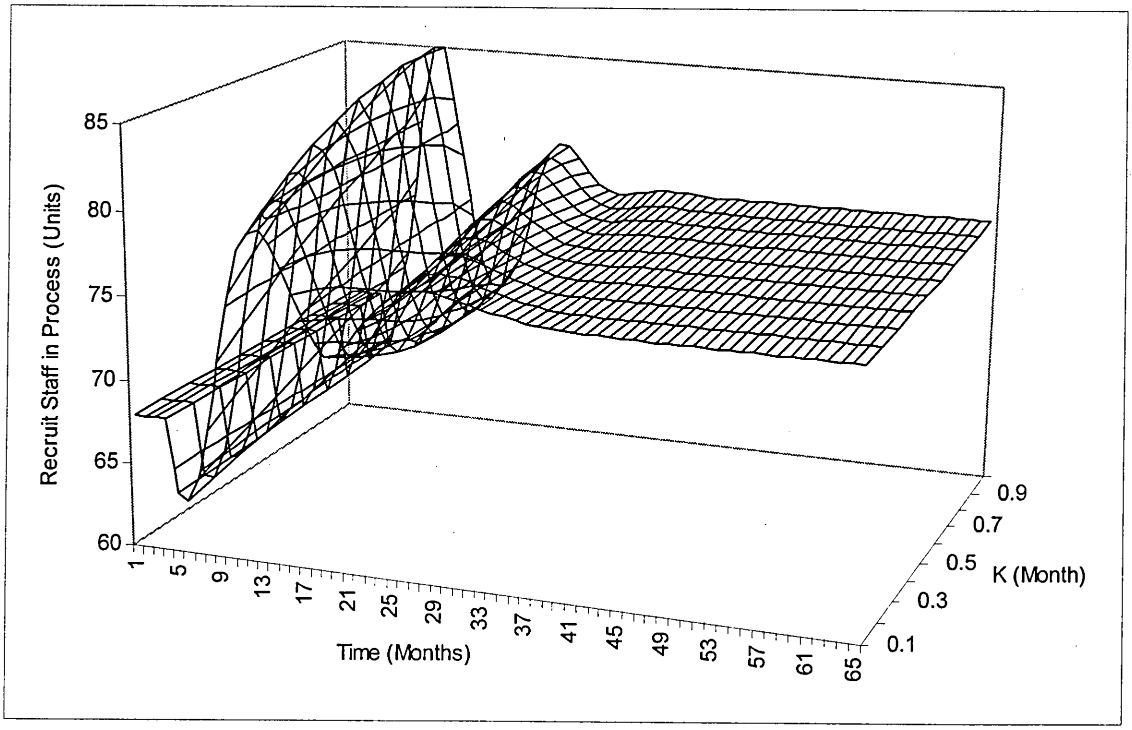
Figure 7.14: Response of APSKPM+(P+I) for varying values of Tc



(a) Recruitment completion rate



(b) Actual staff level



(c) Recruit staff in process

Figure 7.15: Response of APSKPM+(P+I) for varying values of Ki

Performance index at the design Parameters		Automated Pipeline Skill Pool Model plus Integral Controller (APSKPM+(P+I)) Design parameters (B)									
		Ti=1, Ta=2, Tr=1 Tw=7	Ti=2 Ta=4, Tr=2 Tw=7	Ti=1, Ta=4, Tr=4 Tw=7	Ti=2, Ta=2, Tr=2 Tw=7	Ti=4, Ta=8, Tr=8 Tw=7	Ti=4 Ta=8 Tr=4 Tw=7	Ti=3, Ta=6, Tr=3 Tw=7	Ti=2, Ta=4, Tr=8 Tw=7	Ti=3, Ta=4, Tr=4 Tw=7	Ti=3, Ta=4, Tr=8 Tw=7
Recruitment completion rate measurements	Rise Time (Months)	4	3	3	5	6	6	3	4	3	5
	Peak overshoot	37%	12.5%	37%	12.5%	25%	12.5%	12.5%	37%	25%	37%
	Duration of overshoot (Months)	5	6	4	8	18	14	9	13	9	16
Staff level measurements	Initial staff level droop	0.27%	0.37%	0.32%	0.27%	0.75%	0.76%	0.25%	1.02%	0.49%	1.18%
	Duration of staff inventory deficit	5	9	5	7	20	24	16	14	11	17
	Peak staff inventory overshoot	0.05%	0%	0.05%	0.05%	0.1%	0.05%	0%	0.48%	0.1%	0.43%
Recruit staff in process measurements	Rise Time (Months)	5	4	3	3	6	7	5	4	4	5
	Peak overshoot	5.1%	1.7%	5.3%	1.7%	5.3%	1.7%	1.7%	5.1%	3.4%	5.1%
	Duration of overshoot (Months)	4	7	5	6	13	16	12	13	10	16

Table 7.3: Performance index and associated dynamic behaviour for the Automated Pipeline Skill Pool Model (APSKPM +P+I), in case study B

Model output	APSKPM + (P + I) Model Case Study B		
	X	MSE	ITAE
Recruitment completion rate	8	0.89	156
Actual staff level	1849	6.21	2791
Recruit staff in process	75	3.99	583.1

Table 7.4: Descriptive statistical characteristics for APSKPM +(P+I) for case study B

7.8 Summary

This chapter has highlighted the importance of using the automated pipe line skill pool model with proportional and integral controller. It started by looking at the Automated Pipeline Skill Pool Model plus proportional and integral controller (APSKPM + (P+I)) and the rationale behind the basic principles of the model analysis. Transfer functions were derived for the principal model outputs under investigation. A simulation model was written in the *ithink* software package and tested to investigate the basic transient behaviour of the key model outputs to changes in staff leaving rate. The chapter highlights typical lead-time performance and potential scope for improvement. Also the chapter has described the advantage of the introduction of an integral controller in the feedback path which generally speeds up the removal of any steady state error. The model had shown how the system attempts to achieve staff gap zero error. The results have shown that for the various set of conditions the system has a very good response, and confirms the parameter choice made by John et al

(1994). The APSKPM +(P+I) model has shown how the addition of extra feedback can be used to improve the system behaviour as detailed by Cheema (1994).

7.9 References

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CHAPTER 8

Analysing Grading and Promotion using System Dynamics Modelling

8.1 Chapter overview

This chapter starts with definitions and terms relating to promotion and progression between different salary grades within an organization. A basic variant of the Skill Pool Model (SKPM), for three salary grade levels, is then presented and analysed for our case company. Subsequently the Automated pipeline Skill Pool Model (APSKPM) for the same situation of three salary grades is considered. These models are presented to help understand the skill requirements for a company where people are promoted to senior levels. Both of these "three-grade" models are presented as a means of enabling companies to improve their total dynamic HRP performance by looking at the consequences for different salary grades of someone leaving or being promoted at a given salary level. Like previous chapters, influence diagrams for the three-grade models are developed and transformed into the relevant block diagram representations. Simulations are carried out to gain a deeper understanding of the system dynamics of these three-level situations for both the SKPM & APSKPM models. Where appropriate we will refer to each of these three-level models as a PPSKPM (Progression and Promotion Skill Pool Model) and as a PPAPSKPM (Progression and Promotion Automated Pipeline Skill Pool Model). The automated pipeline skill pool model is used because as it has been proved that the addition of feedback loops increases the robustness of a system (Horowitz, 1963). This has been confirmed by Towill (1981) and Cheema *et al* (1997), for a number of commonly met practical systems in the context of production and control. As in previous chapters, the analysis is carried out to find the optimum policy parameters by conducting extensive comparisons between the two models.

8.2 Introduction

Most organizations tend to be hierarchical with a finite number of job or salary grades. Within a particular salary grade, individuals can either stay in their existing grade, leave, or be transferred to a higher grade (Kenn, et al, 1999). The situation of someone being demoted is not considered in this research, although in principle it could easily be modelled. The numbers of staff in any grade are known from personnel records, and the probabilities of leaving or transferring to another grade can be estimated reasonably accurately from the past data. For example, the promotion occurs when a Head of Department makes a submission to the Company Chairman through the Director of Personnel and Financial Services to reclassify a staff member. It usually occurs because of vacancy in that grade, or occasionally as a result of individual merit.

Like other organization each employee is recruited for particular salary grade, and this is the basis for both personnel management and the compensation system. It is important to clarify here, what is meant by the grade. Libyan companies are often characterized by a two-structure division, one focusing on vertical and the other focusing on horizontal. Vertical division is associated to specific job positions and entails different levels of authority and responsibility in the hierarchy. For example, general manager, department manager and section manager are three levels of authority. Horizontal divisions are grades used to differentiate between individuals in terms of salary (stay and pay). In this company the salary consists of two parts:

one determined by employee characteristics (education level, marital status, age, number of dependents etc) and the other determined by grade in each division. The second part is relatively more important as the employee moves up the grade level depending on the score achieved in personnel evaluations. On the other hand promotion is the awarding of a post to a member of staff in accordance with the organization's recruitment and selection procedure. The promotion is dependent on the existence of a vacancy within a specified grade.

According to Brian and Cain, (1996), there are three types of promotion systems:

- Push system: in push systems staff are promoted to the next higher grade whether or not there are vacancies in the staff grades. This system will normally produce expansion of the work force over time.
- Pull system: in pull system a staff member is promoted to the next higher grade only if there is a vacancies in higher grade. This system aims to maintain a constant workforce by limiting recruitment and promotion over time.
- Mixed system: some organizations will have a mixture of pull and push systems. In this context there may be some parts of the organization where staff are trained for a fixed period and then automatically promoted to the higher grade, and in other parts of the organization there may well be a fixed establishment of posts.

Chapters 5 and 6 introduced the skill pool model SKPM and the automated pipeline skill pool model APSKPM for one level of salary grade. The purpose of this chapter is to create models that will allow us to look at several grades of staff. For simplicity three grades are selected for further analysis, although there is nothing special about this number. As mentioned previously the aim here is to create models that will allow us to achieve the optimum utilization of staff members' skills and talents within each grade. A comparative study of the three-grades PPSKPM and PPAPSKPM models is conducted to obtain optimal promotion / progression policy parameters. For simplicity, i have chose only to look at the SKPM and APSKPM models, as opposed to the APSKPM + I + P model,. However, consider the APSKPM model as well as the SKPM model because, as the results showed in Chapters 5 and 6, the APSKPM does give a better response to changes in the leaving rate than does the basic SPKM model.

8.3 Basic analysis of Promotion and Progression Skill Pool Model (PPSKPM)

8.3.1 Influence diagram representing three grade PPSKPM

The three grade staff levels include "junior" staff, defined as grade 1, "staff", defined as grade 2, and "senior staff", defined as grade 3. The three grades are linked together in the models via the feed forward flow of staff promotion and feedback flow of information about total staff ("actual staff level") in each grade. Therefore, the number of staff in grade would have an impact on the whole system.

Figure 8.1 shows the influence diagram for the three-grades Skill Pool Model PPSKPM. Each echelon of our model is based on the production control system (IOBPCS) type of constructed, which as mentioned in earlier chapters,. was developed initially in the context of smoothing factory orders.. Three level models have been studied by Del Vecchio and Towill (1992), Wikner et al (1991), and

Mason et al. (1995). Hafeez et al. (1996) has studies two-level production control model for the steel industry supply chain. The emphasis is on understanding the overall behaviour of this complex system in terms of stability, response time, and inventory levels, etc. The cause and effect diagram is a pictorial display of the factors that influence the behaviour of the system and how they are logically connected. The model developed here are three-level skill pool models with hierarchical control.

The model follows a pull system approach. It is assumed that staff leaves the grade or are promoted to the highest grade. A pull requirement is generated by the system to promote some staff to fill gaps in this higher (grade 3). Once staff are promoted to grade 3, this will lead to vacancy in grade 2, therefore grade 2 will send a signal to grade 1 to "pull" some staff from grade 1 to grade 2. This in turn leads to staff shortages in grade 1. At the same time there may well be staff leaving the company from grade 1. To meet the staff shortages in grade 1 the company will need to hire new staff to fill the vacancies in grade 1. Staff could, of course, leave from grade 2. The above scenario, with grade 3 replaced by grade 2, would apply. Also, it will be the case that staff may be recruited directly into grade 3 and grade 2 levels. An influence diagram representing the 3-level staffing system is illustrated in Figure 8.1 using *Ithink* software.

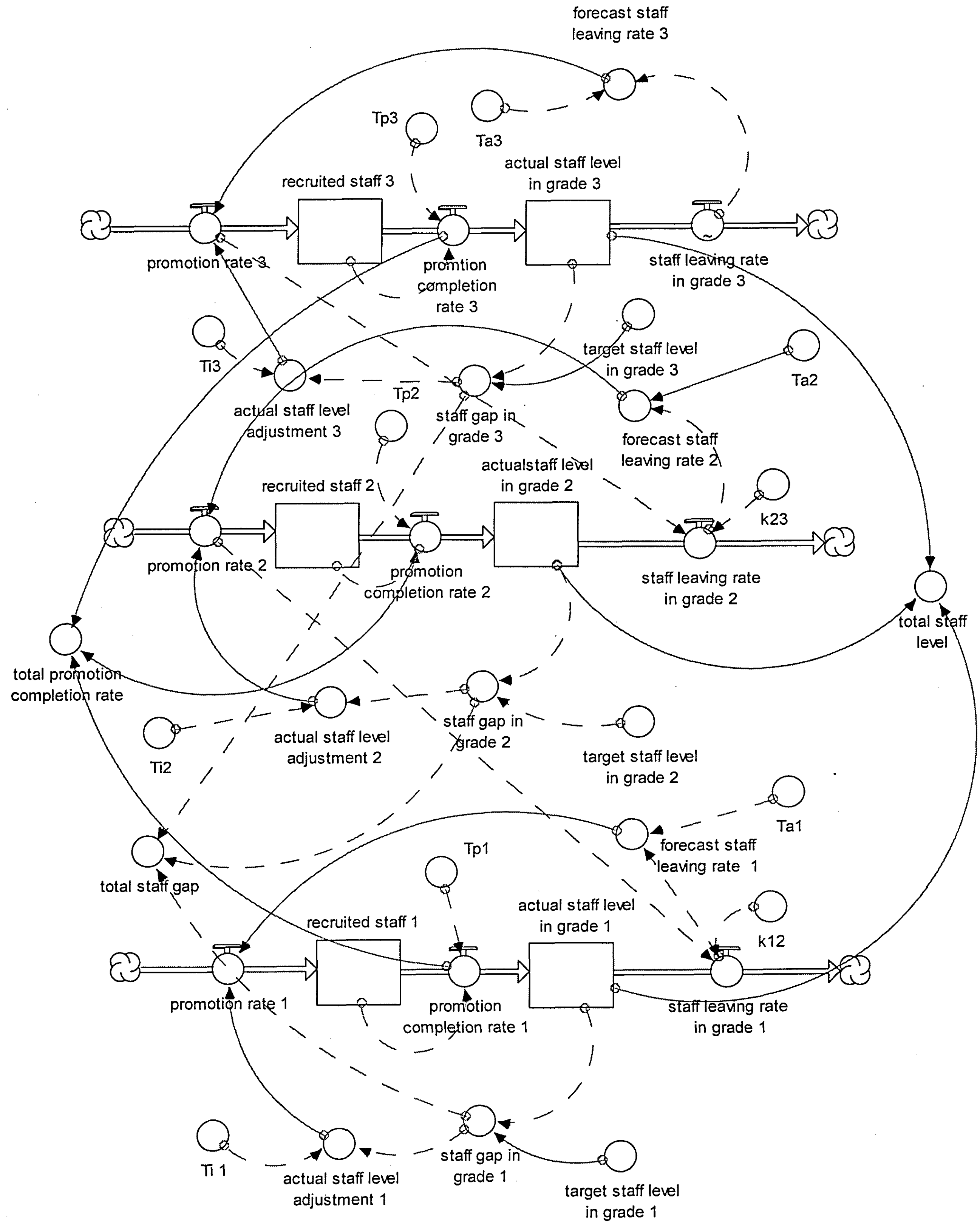

Figure 8.1: Ithink equivalent of influence diagram for three grades PPSKPM model

8.3.2 Three grade PPSKPM block diagram

The 3-grade level influence diagram in Figure 8.1 is transformed into block diagram format as shown in Figure 8.2. The block diagram illustrates that the promotion rates are derived as a function of current staff leaving rate in each grade and the corresponding staff gap. The staff gap is the difference between target staff level and actual staff level in each grade. It is assumed that the error, or staff gap, is recovered over a period of time Ti for each grade. 1/Ti is here acting as a proportional controller which adjusts the time to recover the staff gap error or inventory error over the specified time period. The average staff leaving rate FSLR in each grade is a function of the present staff leaving rate in the same grade and the quantity Ta (the time over which staff leaving rate is averaged). The promotion demand rate will thus be influenced by the forecast staff leaving rate, the staff gap and the (Ti) together with the forecast staff leaving rate over which to reduce this gap. The promotion demand rate influence the promotion completion rate, and involve the control parameter Tp. The actual staff level is calculated by adding to its previous level the net accumulation of staff after promotion, recruitment and leaving has been accounted for.

In the study of system dynamics it is particularly important to summarise further characteristics in the form of transfer functions which are ratios of Laplace polynomials in the Laplace operator. In their derivation the usual laws of linear algebra apply. The transfer function of a system represents the relationship describing the dynamics of the system under consideration. The transfer functions for a single level were described in chapter 5 which algebraically relate system inputs and system outputs.

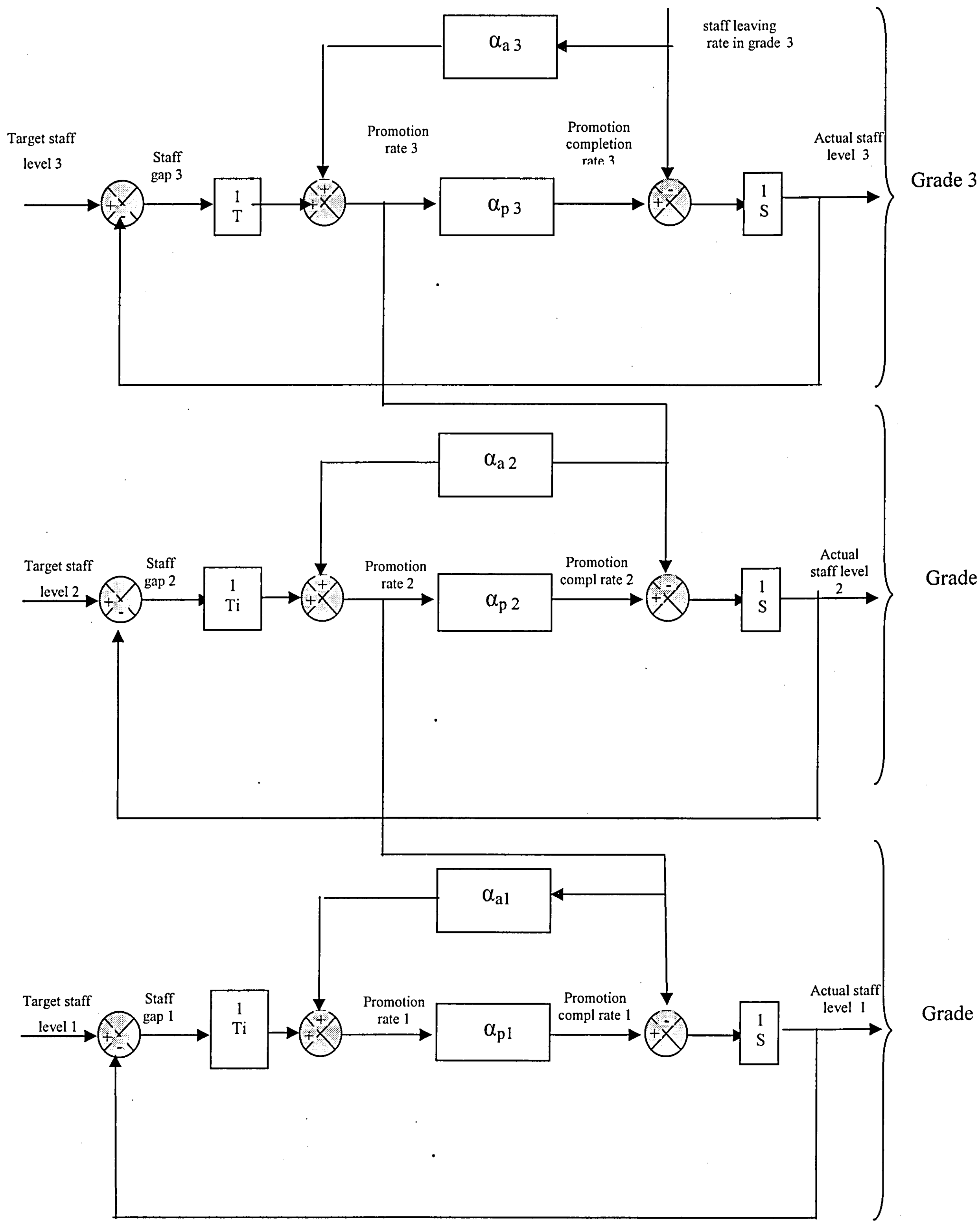

Figure 8.2: Block diagram representation of three staff grades PPSKPM

The equations for the simulation are summarized below:

Forecast staff leaving rate equation

$$FSLR_{k+1} = FSKR_{k} + \alpha_a (PSLR_{k} - FSLR_{k}) \qquad \text{----(1)}$$

$$\alpha_a = 1 / (1 + T_a * S)$$

Staff gap equation

$$SG_{k+1} = DSL_{k+1} - ASL_{k+1} \qquad \text{---(2)}$$

Promotion rate

$$PDR_{k+1} = SG_{k+1} / T_i + FSLR_{k+1} \qquad \text{---(3)}$$

Promotion completion rate

$$PCR_{k+1} = PCR_{k} + \alpha_r (PDR_{k} - PCR_{k}) \qquad \text{---(4)}$$

$$\alpha r = 1 / (1 + T_P * S)$$

Actual staff level

$$ASL_{k+1} = ASL_{k} + PCR_{k+1} - PSLR_{k+1} \qquad \text{---(5)}$$

8.3.3 Analysis of Results for PPSKPM

Figure 8.3 gives a four-year record of monthly staff promotion rates for the company. On average the company is expecting about a 1.75% per month promoted to higher grades. Model simulations are designed to study the system behaviour against the given design parameters Ti, Ta and Tp as explained earlier.

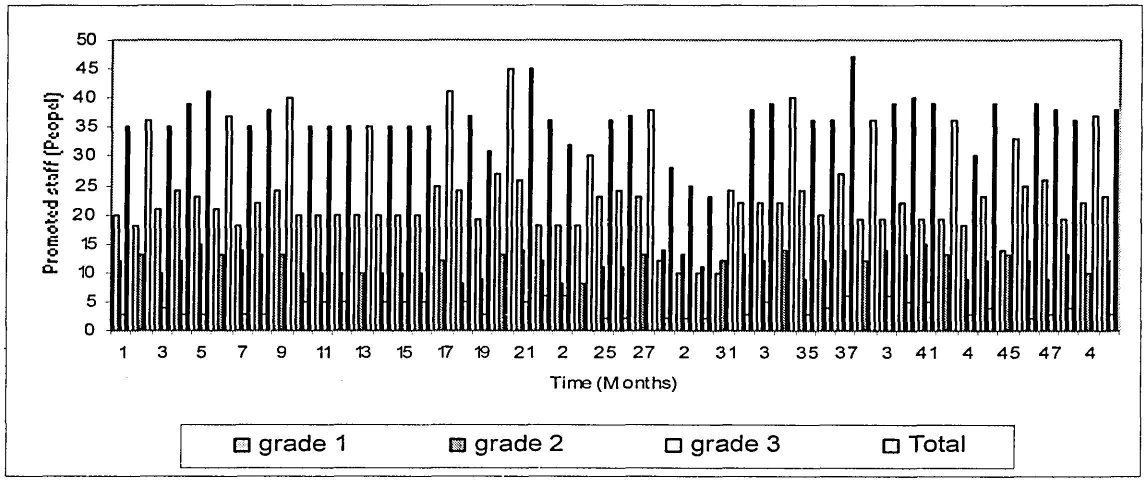

Figure 8.3: Staff promotion rates for company A

The models is simulated and tested for dynamic performance via standard control techniques John *et a.* (1995). Therefore, we need to understand how recruitment or promotion delay time depend on the control parameters in the models and how these affect over and under shoot of grade-level outputs in response to systems disturbances. The main aim of this is to improve system response for optimum use in HR Planning. Therefore, dynamic analysis is conducted to analyse and compare the resulting response of each model in order to test the three level PPSKPM and the effect of hierarchical control.

To do this a core set of parameters Ta, Ti and Tp, were varied from 1 to 12 across all model to observe and record the dynamic response in order to determine their optimum settings. Once selected, the system would determine staff promotion automatically governed by Ta and Ti according to a present staff leaving rate and staff gap in level three and give feed back to lowest levels to promote staff from lower grades - for example from grade 2 to grade 3, and grade 1 to grade 2.

Figure 8.4 examines the response of the promotion completion rate for the three-grades Skill pool Model PPSKPM at optimum values of Ta, Ti and Tp. Figure 8.5 shows the actual staff level for three grades PPSKPM at optimum parameters, and Figure 8.6 shows the response of the staff gap for the three-grades Skill pool Model PPSKPM at optimum values of Ta, Ti and Tp. Tables 8.1, 8.2 and 8.3 gives the overall summary of the effect of varying Ti, Ta and Tr on human resource policies for PPSKPM model. An extensive analysis of simulation results for different (sub-optimal) values of the parameters are given in the figures presented in Appendix 6. The criteria used to select the optimum parameters are analogous to those that were used in previous chapters.

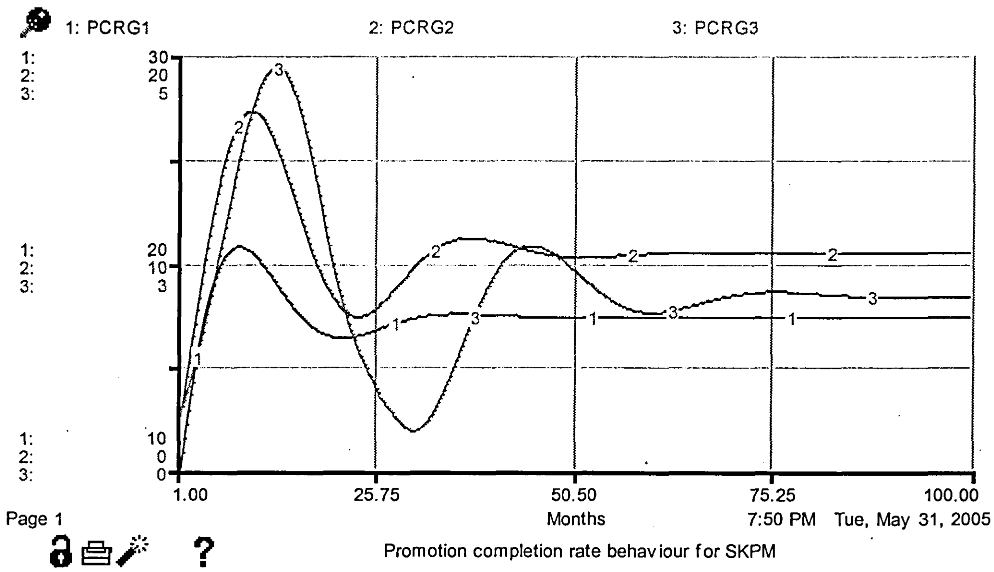

Figure 8.4: Promotion completion rate behaviour for grade 1, grade 2, grade 3 PPSKPM model for Ti = Tp and Ta= 2Tp

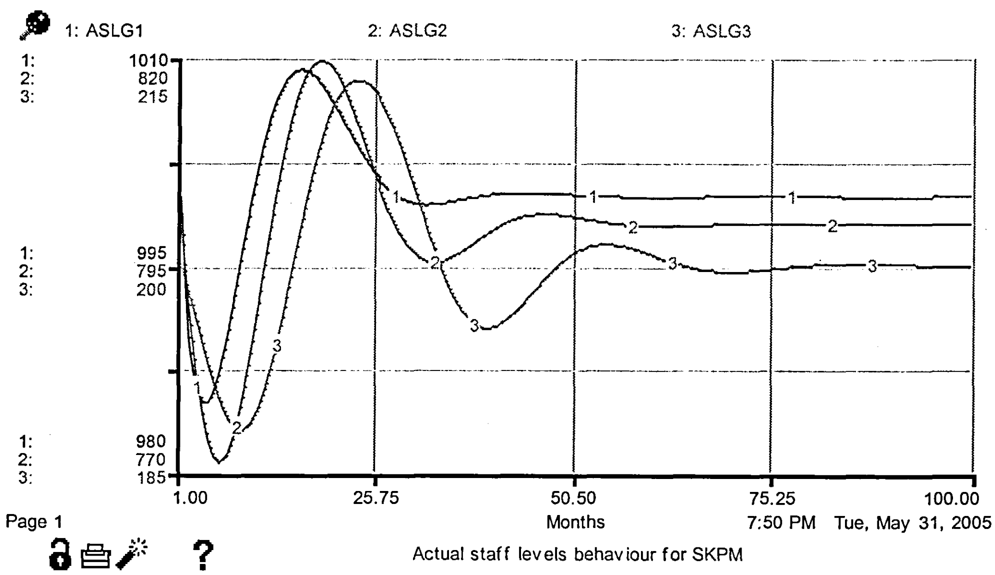

Figure 8.5: Actual staff level behaviour for grade 1, grade 2, grade 3 PPSKPM model for
Ti = Tp and Ta= 2Tp

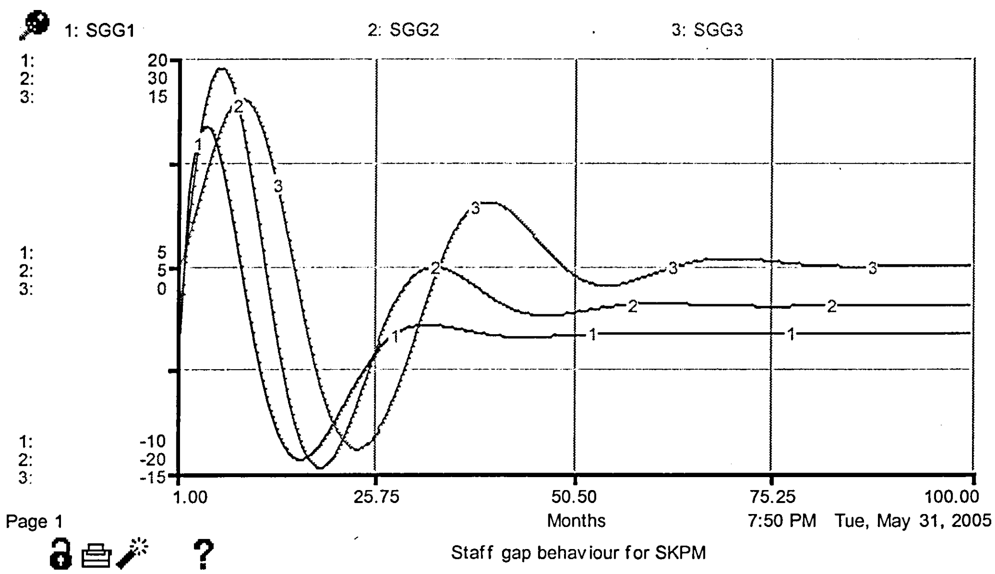

Figure 8.6: Staff gap behaviour grade 1, grade 2, grade 3 PPSKPM model for Ti = Tp and Ta= 2Tp

Performance index at the design Parameters		3 Grades Skill Pool Model (PPSKPM) Design parameters for grade 1						
		Ti=1, Ta=2, Tp=1	Ti=4, Ta=8, Tp=4	Ti=1, Ta=4, Tp=4	Ti=4 Ta=8, Tp=8	Ti=3, Ta=6, Tp=3	Ti=2, Ta=4, Tp=8	Ti=5, Ta=10, Tp=5
Promotion completion rate measurements	Rise Time (Months)	4	6	3	7	3	5	5
	Peak overshoot (Percentage from the nominal value)	13.5%	7%	35%	35%	12.6%	29.5%	27%
	Duration of overshoot (Months)	14	13	6	20	8	8	16
Staff level measurements	Initial staff level droop Percentage from the desired value)	0.35%	1.25%	1.28	4.1%	1.2%	1.4%	23%
	Duration of staff inventory deficit (Month)	14	15	6	16	8	8	13
	Peak staff inventory overshoot (Percentage from the nominal value)	0.29%	0.2%	1.9	1.7%	0.7%	1.3%	1.1%

Table 8.1: Performance index and associated dynamic behaviour for the three grades Promotion and Progression Skill Pool Model (PPSKPM), where the shaded region shown the optimum response

Performance index at the design Parameters		**3 Grades Skill Pool Model (PPSKPM) Design parameters for grade 2**						
		Ti=1, Ta=2, Tp=1	Ti=4, Ta=8, Tp=4	Ti=1, Ta=4, Tp=4	Ti=4 Ta=8, Tp=8	Ti=3, Ta=6, Tp=3	Ti=2, Ta=4, Tp=8	Ti=5, Ta=10, Tp=5
Promotion completion rate measurements	Rise Time (Months)	3	4	3	4	3	5	5
	Peak overshoot (Percentage from the nominal value)	60%	60%	80%	70%	80%	90%	70%
	Duration of overshoot (Months)	13	13	9	14	11	14	15
Staff level measurements	Initial staff level droop Percentage from the desired value)	0.5%	3.65%	2.4%	3.65%	2.65%	5%	4.5%
	Duration of staff inventory deficit (Month)	7	12	7	12	10	12	13
	Peak staff inventory overshoot (Percentage from the nominal value)	0.3%	1.8%	1.9%	2.5%	1.87%	4.125%	2.75%

Table 8.2: Performance index and associated dynamic behaviour for the three grades Promotion and Progression Skill Pool Model (PPSKPM), where the shaded region shown the optimum response

Performance index at the design Parameters		3 Grades Skill Pool Model (PPSKPM) Design parameters for grade 3						
		Ti=1, Ta=2, Tp=1	Ti=4, Ta=8, Tp=4	Ti=1, Ta=4, Tp=4	Ti=4 Ta=8, Tp=6	Ti=3, Ta=6, Tp=3	Ti=2, Ta=4, Tp=8	Ti=5, Ta=10, Tp=5
Promotion completion rate measurements	Rise Time (Months)	4	4	3	3	3	Oscillations continuous for long time	5
	Peak overshoot (Percentage from the nominal value)	80%	75%	75%	65%	75%		75%
	Duration of overshoot (Months)	16	16	10	13	13		15
Staff level measurements	Initial staff level droop Percentage from the desired value)	6%	4.5%	2%	6%	3%		5.5%
	Duration of staff inventory deficit (Month)	15	14	12	13	12		15
	Peak staff inventory overshoot (Percentage from the nominal value)	6.5%	5%	4%	4 %	3.5%		6%

Table 8.3: Performance index and associated dynamic behaviour for the three grades Promotion and Progression Skill Pool Model (PPSKPM), where the shaded region shown the optimum response

8.4 Basic analysis of Promotion and Progression Automated Pipeline Skill Pool Model (PPAPSKPM)

8.4.1 Influence diagram representation of three grades PPAPSKPM model

An Influence diagram is a simple visual representation of a decision problem, and it offers an intuitive way to identify and display the essential elements, including decisions, uncertainties, and objectives, and how they influence each other. Influence diagrams have been important models for decision problems because of their ability to both model a problem rigorously at its mathematical level and depict its high level structure graphically. (Michael and Yacov, 2004).

Figure 8.7 shows the influence diagram for three-grades Automated Pipeline Skill Pool Model (APSKPM). As we mentioned in chapter 5 the influence diagram would allow anyone with elementary control theory knowledge to construct an equivalent model to present time-based dynamics

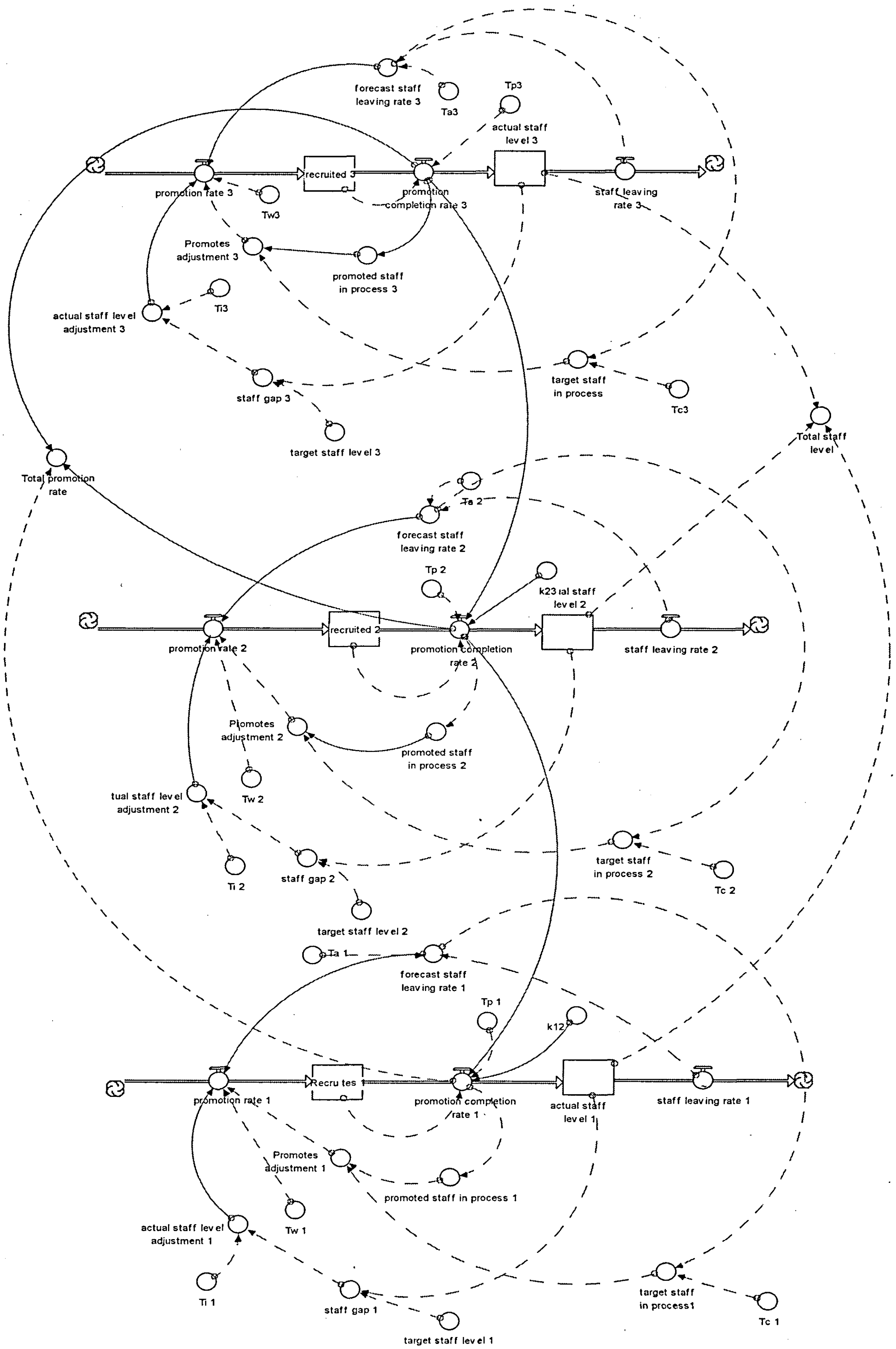

Figure 8.7: Ithink equivalent of influence diagram for three grades PPAPSKPM model

8.4.2Three grade PPAPSKPM block diagram

Figure 8.8 shows the corresponding three levels Automated Pipeline Skill Pool Model (PPAPSKPM) block diagram. The promotion and progression automated pipeline skill pool model is used because as it has been proved that the addition of feedback loops increases the robustness of a system (Horowitz, 1963). Therefore, two individual models within a generic family of designs representative of manufacturing systems (Ferris and Towill, 1993 and John, 1992), were used during the simulation to investigate the effects of hierarchical control. Indeed these models will provide the decision maker with greater insight into the promotion situation which can be carried out without any mathematical knowledge using flowcharting techniques based on principles of system dynamics (Forester 1975).

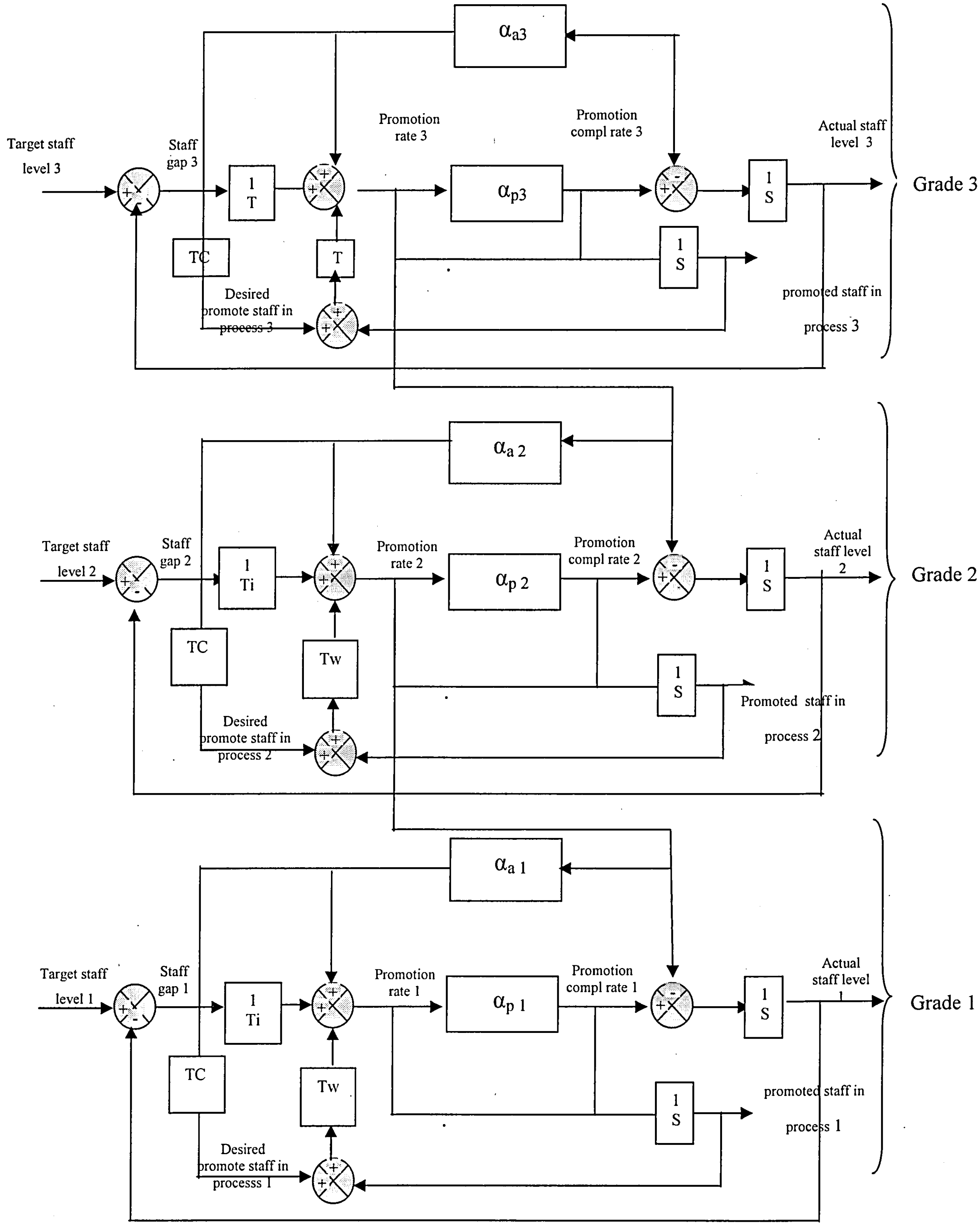

Figure 8.8: Block diagram representation of three staff grades PPAPSKPM

A simulation model was written based on *ithink* software for both models, PPSKPM and PPAPSKPM, (see Appendix 4). The equations for the simulation are summarized below:

Forecast staff leaving rate equation

$$FSLR_{k+1} = FSKR_{k} + \alpha_a (PSLR_{k} - FSLR_{k}) \qquad \text{----(1)}$$

$$\alpha_a = 1 / (1+ T_a * S)$$

Staff gap equation

$$SG_{k+1} = DSL_{k+1} - ASL_{k+1} \qquad \text{---(2)}$$

Promotion demand rate

$$PDR_{k+1} = SG_{k+1} / T_i + FSLR_{k+1} + DPSIP_{k+1} / Tw \qquad \text{--(3)}$$

Promotion completion rate

$$PCR_{k+1} = PCR_{k} + \alpha_r (PDR_{k} - PCR_{k}) \qquad \text{---(4)}$$

$$\alpha r = 1 / (1+ T_P * S)$$

Actual staff level

$$ASL_{k+1} = ASL_{k} + PCR_{k+1} - PSLR_{k+1} \qquad \text{---(5)}$$

Promoted staff in process

$$PSIP_{k+1} = PSIP_{k} + (PCR_{k+1} - PCR_{k+1}) \qquad \text{---(6)}$$

Desired promoted staff in process

$$DPSIP_{k+1} = FSLR_{k+1} *(Tc) \quad \text{---(7)}$$

Promoted staff in process adjustment

$$PSIPA_{k+1} = DPSIP_{k+1} - PSIP_{k+1} \quad \text{---(8)}$$

8.4.3 Analysis of Results for PPAPSKPM

As discussed earlier, as the results showed in Chapters 5 and 6, the PPAPSKPM would over PPSKPM would improve the system performance and reduce any staff vacancies. Therefore, the experiments were designed to set parameters Ti, Ta, Tr, Tw and Tc in a given range to observe and record the dynamic response in order to determine their optimum setting. Once selected, the system would determine staff promotion automatically governed by Ta and Ti according to a present staff leaving rate and staff gap in level three and give feed back to lowest levels to promote staff from lower grades.

Figure 8.9 examines the response of the promotion completion rate for the three-grades PPAPSKPM at optimum values of Ta, Ti, Tp, Tw and Tc. Figure 8.10 shows the actual staff level for three grades PPAPSKPM at optimum parameters, and, Figure 8.11 shows the response of the staff gap for the three-grades Skill pool Model PPAPSKPM at optimum values of Ta, Ti, Tp, Tw and Tc. Tables 8.4, 8.5 and 8.6 gives the overall summary of the effect of varying Ti, Ta, Tp, Tw and Tc on promotion and progression policies for PPAPSKPM model. An extensive analysis of simulation results for different (sub-optimal) values of the parameters are given in the figures presented in Appendix 7. The criteria used to select the optimum parameters are analogous to those that were used in previous chapters.

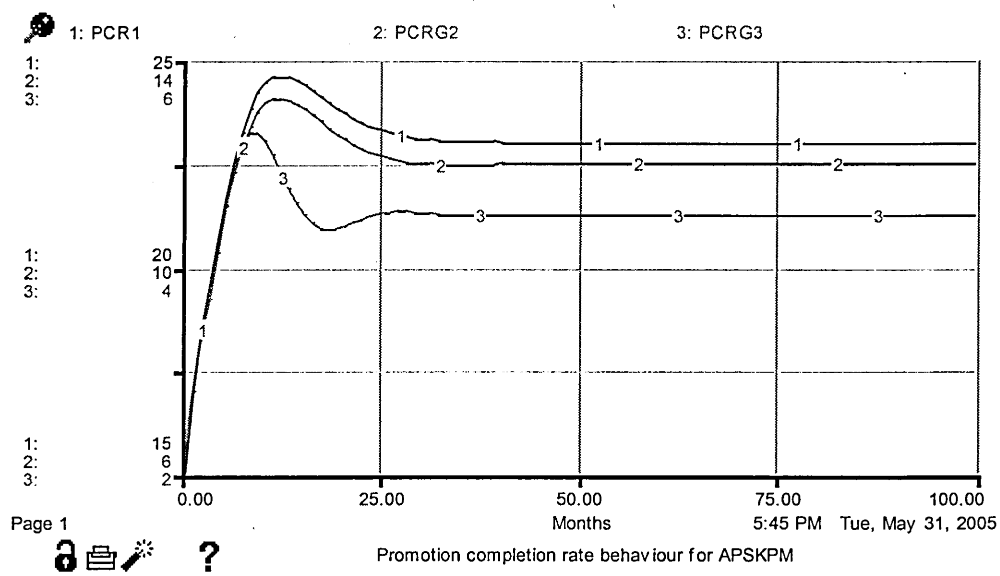

Figure 8.9: Promotion completion rate behaviour for grade 1, grade 2, and grade 3 PPAPSKPM model for Ti = Tp, Ta= 2Tp and Tw = 2Ta

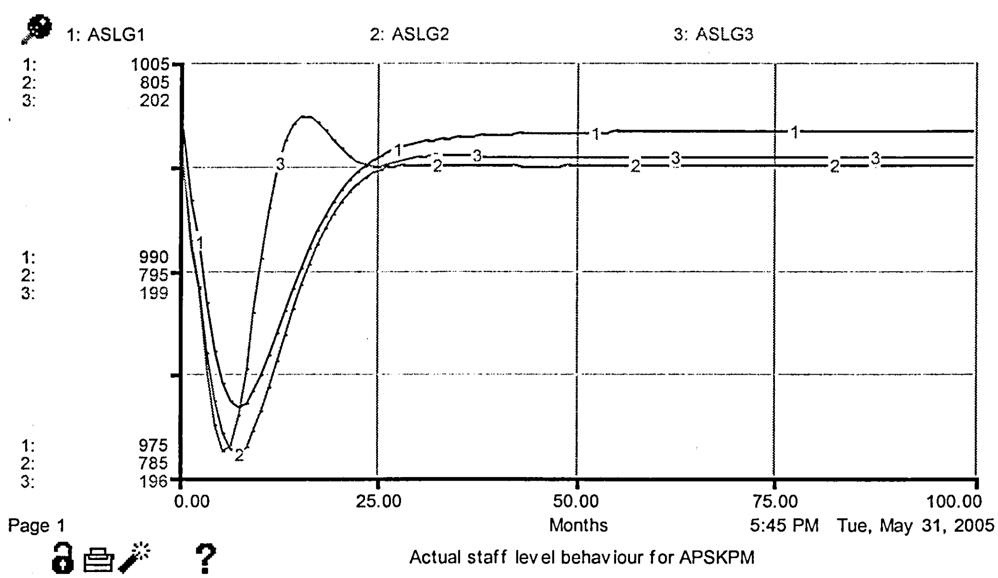

Figure 8.10: actual staff level behaviour for grade 1, grade 2, and grade 3 PPAPSKPM model for Ti = Tp, Ta= 2Tp and Tw = 2Ta

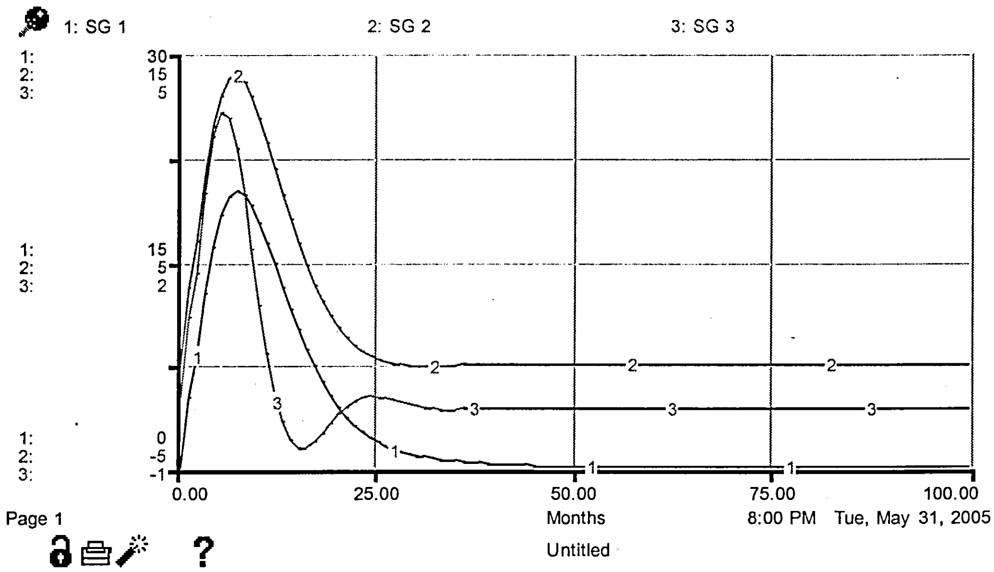

Figure 8.11: Staff gap behaviour for grade 1, grade 2, and grade 3 PPAPSKPM model

For Ti = Tp, Ta= 2Tp and Tw = 2Ta

Performance index at the design Parameters		3 Grades Skill Pool Model (PPAPSKPM) Design parameters for grade 1						
		Ti=1, Ta=2, Tp=1 Tw=7	Ti=2 Ta=4, Tp=2 Tw=7	Ti=1, Ta=4, Tp=4 Tw=7	Ti=4, Ta=8, Tp=6 Tw=7	Ti=4, Ta=8, Tp=8 Tw=7	Ti=4 Ta=8 Tp=4 Tw=7	Ti=3, Ta=6, Tp=3 Tw=7
Promotion completion rate measurements	Rise Time (Months)	Oscillation continuous for long time	5	3	5	6	3	3
	Peak overshoot		40	21%	30%	38%	8.6%	13.5%
	Duration of overshoot (Months)		12	10	18	19	14	13
Staff level measurements	Initial staff level droop		4.2%	1%	3%	4.8%	1%	2.4%
	Duration of staff inventory deficit		11	7	12	16	7	14
	Peak staff inventory overshoot		4.9%	2.5%	4.4%	5.5%	0.2%	0.15%
Promoted staff in process measurements	Rise Time (Months)		5	3	5	6	3	2
	Peak overshoot		12%	17%	20%	25%	14%	10%
	Duration of overshoot (Months)		31	12	17	19	14	13

Table 8.4: Performance index and associated dynamic behaviour for the three grades Promotion and Progression Automated Pipeline Skill Pool Model (PPAPSKPM), where the shaded region shown the optimum response

Performance index at the design Parameters		3 Grades Skill Pool Model (PPAPSKPM) Design parameters for grade 2						
		Ti=1, Ta=2, Tp=1 Tw=7	Ti=2 Ta=4, Tp=6 Tw=7	Ti=2, Ta=4, Tp=4 Tw=7	Ti=4, Ta=8, Tp=6 Tw=	Ti=4, Ta=8, Tp=8 Tw=7	Ti=4 Ta=8 Tp=4 Tw=7	Ti=3, Ta=6, Tp=3 Tw=7
Promotion completion rate measurements	Rise Time (Months)	Oscillations continuous for long time	4	4	5	5	3	3
	Peak overshoot		30%	9%	25%	25%	16%	8.3%
	Duration of overshoot (Months)		9	6	12	16	9	8
Staff level measurements	Initial staff level droop		1%	0.9%	1.75%	1.2%	0.4%	0.38%
	Duration of staff inventory deficit		8	18	16	9	9	6
	Peak staff inventory overshoot		1.8%	N/A	0.65%	2.2%	N/A	0.9%
Promoted staff in process measurements	Rise Time (Months)		4	3	5	4	3	3
	Peak overshoot		22%	5.5%	16.6%	16.6%	11%	5.5%
	Duration of overshoot (Months)		10	7	16	16	10	8

Table 8.5: Performance index and associated dynamic behaviour for the three grades Promotion and Progression Automated Pipeline Skill Pool Model (PPAPSKPM), where the shaded region shown the optimum response

Performance index at the design Parameters		3 Grades Skill Pool Model (PPAPSKPM) Design parameters for grade 3						
		Ti=1, Ta=2, Tp=1 Tw=7	Ti=2 Ta=4, Tp=6 Tw=7	Ti=2, Ta=4, Tp=4 Tw=7	Ti=4, Ta=6, Tp=8 Tw=	Ti=4, Ta=6, Tp=6 Tw=7	Ti=4 Ta=8 Tp=4 Tw=7	Ti=3, Ta=6, Tp=3 Tw=7
Promotion completion rate measurements	Rise Time (Months)	Oscillation continuous for long time	4	4	7	5	5	4
	Peak overshoot		40%	25%	25%	25%	25%	25%
	Duration of overshoot (Months)		11	8	18	17	14	10
Staff level measurements	Initial staff level droop		3%	1.5%	4.8%	3%	1.5%	1.5%
	Duration of staff inventory deficit		10	8	15	12	11	9
	Peak staff inventory overshoot		3%	2%	4.5%	3.5%	N/A	N/A
Promoted staff in process measurements	Rise Time (Months)		5	4	7	6	5	4
	Peak overshoot		33%	16.6%	25%	17%	16.6%	16.6%
	Duration of overshoot (Months)		11	7	15	15	13	11

Table 8.6: Performance index and associated dynamic behaviour for the three grades Promotion and Progression Automated Pipeline Skill Pool Model (PPAPSKPM), where the shaded region shown the optimum response

8.5 Discussion

One of the main benefits of using PPAPSKPM over PPSKPM that is immediately apparent is that the overall response of the controlled variables due to the usage of PPAPSKPM appears to be far less oscillatory, settling down far quicker than basic PPSKPM, as recommended by John 1992. Therefore the graphs produced offer valuable information which, when used to best advantage, can allow a company to reduce the shortages due to the far less dramatic under shoot of actual staff level for PPAPSKPM. The promotion completion rate information in Figures 8.4 and 8.9 is just as dramatic insofar as it shows that monitoring and using company recruited and promoted staff information leads to more stable staff levels in the company. The advantage of this use of PPAPSKPM is that it enables the company to reduce the staff shortages in higher staff grades more effectively, with a reduction in the stress levels in the company during periods of high staff leaving, therefore allowing far better control of workforce numbers.

Figures 8.6 and 8.11 show staff gap analysis in each grade for both models. Staff gap analysis is the process of comparing the workforce supply projection to the workforce demand forecast. and is used to identify gaps (shortages) and surpluses (excesses) in staffing and skill levels needed to meet future functional requirements

Results from the simulation run for the two models proved to be very encouraging and certainly matched the expected response improvements offered by PPAPSKPM. A summary of the visual analysis of the graphs is shown in table (8.7)

	Observed impact on promotion completion rate			Observed impact on actual staff level		
	Oscillatory nature	Peak values	Speed of Response	Oscillatory nature	Peak values	Speed of Response
SKPM	*	**	**	*	***	**
APSKPM	**	***	***	***	***	***

Note: The more *'s the better the response characteristics to the SKPM model

Table 8.7: performance index of the PPSKPM and PPAPSKPM

Tables 8.8 and 8.9 shows the performance index of the PPSKPM and PPAPSKPM. The set of parameters used are considered to be nominal values which were highlighted as good design values by Diseny and Towill, (2002).

Performance index at the optimum design parameters		Skill Pool Model & Automated Pipeline Skill Pool Model (Progression model)					
		Grade 1		Grade 2		Grade 3	
		SKPM	APSKPM	SKPM	APSKPM	SKPM	APSKPM
Promotion Completion Rate Measurements	Rise Time (Months)	**6**	**3**	**4**	**3**	**3**	**4**
	Peak overshoot (Percentage from the nominal value)	**7%**	**8.6%**	**60%**	**8.3%**	**65%**	**25%**
	Duration of overshoot (Months)	**13**	**14**	**13**	**8**	**13**	**10**
Staff Level Measurements	Initial staff level droop (Percentage from the desired value)	**1.25 %**	**1%**	**3.65%**	**0.38%**	**6%**	**1.5%**
	Duration of staff inventory deficit (Months)	**15**	**7**	**12**	**6**	**13**	**9**
	Peak staff inventory overshoot (Percentage from the nominal value)	**0.2%**	**0.2%**	**1.8%**	**0.9%**	**4%**	**N/A**

Table 8.8: Summary the effect of the optimum design parameters and corresponding performance indices

Statistical Tests at the optimum design parameters		Skill Pool Model & Automated Pipeline Skill Pool Model (Progression model					
		Grade 1		Grade 2		Grade 3	
		SKPM	APSKPM	SKPM	APSKPM	SKPM	APSKPM
Promotion completion rate measurements	Mean (X)	14.8	14.81	11.91	12	4	4.1
	Mean Square error (MSE)	0.907	1.8	2.65	0.829	0.503	0.127
	Standard deviation (δ-SD)	0.98	1.35	1.629	0.910	0.709	0.357
	Integral Time Absolute Error (ITAE)	227.6	364.15	1001.3	315.3	815.9	103.78
Staff level measurements	Mean (X)	1003.7	997	803.46	799.1	201.6	200
	Mean Square error (MSE)	16.4	44.15	48.23	24.52	13.17	1.6
	Standard deviation (δ-SD)	4.05	6.64	6.9	4.95	13.17	1.26
	Integral Time Absolute Error (ITAE)	6976	7592.1	27345	4579.3	14452.6	1593.6

Table 8.9: Summary the descriptive statistical characteristics for actual inventory level and promotion completion rate effect of the optimum design parameters

Furthermore, from initial investigation, the PPAPSKPM model definitely shows a far better system response of the overall human resource response to the organization demands as mentioned by Meason-Jones et al 1995. Figure 8.6 shows a fast response due to hierarchical control, but there is slightly more undershoot. These results will lead to implementing one control system above the other.

8.6 Summary

This chapter has investigated a three-grades staff level system by using PPSKPM and PPAPSKPM and their possible use in staff promotion. The chapter started by looking at the promotion process in such a context and the construction of the associated influence diagrams. Subsequently block diagrams were constructed for simulation analysis. The models were tested by using promotion data for each grade for a large overseas petrochemical company. For the PPSKPM the optimum parameters were found to be Ti = Tp and Ta = 2Tp. The optimum parameters for PPAPSKM were when Tw = 2Ta and Ta = 2Tp, and Ti = Tp. These ratios have been used for a single level and for the whole system. The ratio depends on the relation between total staff in each grade and the staff leaving rate in each grade. From the analysis it is observed that the PPAPSKPM model offer relatively a better opportunity to the company to produce a responsiveness HRP system. The PPAPSKPM model indicates good promotion policy for the whole system, where the oscillatory behaviour is reduced allowing the company to effectively manage over and under shoot of both the actual staff level and promotion completion rate.

8.7 References

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CHAPTER 9
Discussion and Conclusion

9.1 Introduction

Human Resource Planning (HRP) is an important subject, particularly at the time of increasing turbulent business environments exhibiting far more discontinuities in supply and demand patterns. HRP is concerned with having the right staff, with the right skills, in the right places at the right time to fill both individual and organizational needs. The research investigated ways in which system dynamics could be implemented in the human resource area to enable companies to improve their total dynamic performance by looking at the consequence for different important human resource planning factors such as staff leaving rate , recruitment and training programmes and promotion within a company. Therefore, the thesis has set out to study the effect of adopting system dynamics modeling in HRP, and has developed a number of models to investigate the overall system behaviour under a number of test conditions using fundamental principles of control system and feedback theory.

The research hypothesis as set down in Chapter 1 was to investigate that if system dynamics is an effective tool in HRP. To show this we also set down 4 research objectives which, if achieved, we claimed would demonstrate the validity of the research hypothesis. In what follows we will show that the research undertaken has, in fact, met the four objectives and therefore achieved the overall research aim and therefore demonstrated the validity of the research hypothesis.

Before doing this it is important to pass comment on the research methodology that has been adopted. To show the utility of the system dynamics models that have been developed we said we would illustrate their use with data from the Libyan petrochemical industry. It could be argued that all we might succeed in doing is demonstrating the effectiveness of system dynamics in human resource planning in the petrochemical industry. However, it should be noted that the situations considered (high staff turnover, low staff turnover, and different salary grades) are typical of many HRP situations in a range of industries. Choosing data from the petrochemical industry, we claim, in no way detracts from our conclusion which will be that system dynamics is an effective tool in HRP generally.

9.2 Conclusions for each Chapter

This thesis has attempted to enhance system dynamics modelling in HRP and to describes how System dynamics may be used as a tool to model and analyse the human resource planning problems associated with staff recruitment, staff surpluses and staff shortages. Therefore, each chapter of this thesis covered a particular stage of this research and has presented localised conclusions.

9.2.1 Review of Literature

Chapter two highlighted the role of human resource planning and the approaches involved. It looked specifically at the important definitions of human resource planning, as well as essential duties performed in carrying out the human resource planning function. Chapter three conducted a detailed literature review of different types of models used in HRP. It was concluded that some of these models were often highly mathematical, demanding considerable mathematical sophistication for successful implementation. Some models looked specifically at the linkage between business planning and HRP strategies. All of the models considered addressed various but different aspects of the HRP process. If we summarise (again) what we have said in Chapter 2 and Chapter 3 we see that models, if they are to be classified as *useful*, ought to address the following aspects of the HRP process:

- Training and recruitment (discussed in Chapter 2)
- Forecasting human resource needs (discussed in Chapter 2)
- Responding to external conditions (discussed in Chapters 2 and 3)
- Human resource flow (discussed in Chapter 3)
- Promotion (discussed in Chapter 2)
- Staff turnover (discussed in Chapter 2)
- Job analysis (discussed in Chapter 2)
- Human resource development (discussed in Chapter 2).

The additional characteristics of HRP models listed below, that are relevant to mathematical models (and in some cases to policy models), need also to be added to the above list when evaluating the effectiveness of any HRP model.

- Ease of understanding and use (discussed in Chapter 3)
- Modelling of complexity (discussed in Chapter 3)
- Forward planning (discussed in Chapters 2 and 3)

- Feedback (discussed in Chapters 3)[1].

Below in Table 9.1 we include the assessment against the above characteristics of the policy and mathematical models reviewed in Chapter 3, together with those obtained (in this thesis) using system dynamics modelling. The stars have the same meanings as those described in Chapter 3.

The above table clearly demonstrates the *usefulness* of the system dynamics models developed in this thesis. In addition, comparison of the system dynamics models (characteristic by characteristic) with any of the other models is also very favourable in each case. Note that Job Analysis has not been considered in the table because the emphasis of the research undertaken in this thesis is related more to staffing issues than to job-related issues. Demonstrating the *effectiveness* of system dynamics in HRP will be considered later after looking at the specific attributes of the various system dynamics models that have been developed.

[1] Feedback is mentioned throughout the thesis as well as in Chapter 3.

Characteristic	Tichy and Devanna model	Harvard model	Walker model	Markov model	Holonic model	System Dynamics modelling
Trainning and recruitment		*	**	**	**	**
Forecasting human resource needs	**		**	**	**	**
External conditions	*	*	**	**	**	**
Human resource Flow		**	*	*	*	*
Promotion	**	**	*	**	**	**
Staff turnover	**		*	**	**	**
Human resource development	**	*	**			*
Hiring and Firing		*	**	**	**	**
Complexity			*	**	*	*
Feedback		*				**
Forward plan	*		*	**	**	**
Ease of understanding and use	*			*	**	**
Controllability and optimisation				*	*	**

Table 9.1: Assessment of the HRP models against the characteristics listed.

Note:

- ( ): not addressed
- (*): addressed
- (**): addressed very well

9.2.2 Research Methodology

The system dynamics (SD) approach used to develop and carry out this research was then presented in Chapter 4. This was concerned with creating SD models for human resource planning, and studying their behaviour over time. The research methodology adopted four main features: literature review, development and validation of conceptual models, testing these models in the Libyan petrochemical sector, and developing policy guidelines for use of these models in HRP. To contextualise the case studies properly an introduction to the Libyan economy was given to show the importance of the oil industry to Libya and the importance and necessity to apply good HRP in the oil sector. All models under investigation were derived, by analogy, from the IOBPCS model which is the simplest and the earliest of the inventory and order based models. Much analysis of this model had been previously undertaken by Towill 1982. The major advantage of the IOBPCS model is that it allows a basic understanding of complex time variant systems.

9.2.3 The Skill Pool (SKPM) model

Chapter five presented causal relationships for human resource planning where the need to recruit new staff was prompted by staff leaving. The resulting system dynamics model was developed and run using data from the two case studies. The skill pool model (SKPM) was then optimised by tuning the design parameters associated with recruitment time, recruitment averaging time and a proportional control parameter to reduce staff pool shortages. The research show how, based on the defined performance indices, the decision maker could choose to minimize the current and future staff shortages by selecting an appropriate recruitment policy. This study illustrated that the dynamic analysis based on the SKPM simulation model greatly improved the understanding of human resource system behaviour. Furthermore, such a model can guide management to develop improved human resource policies by reducing the levels of "hiring" and "firing" needed, which is known to be costly and have negative impact on staff morale.

For each of the petrochemical case studies considered, the analysis showed that the SKPM optimum parameters were Ti = Tr and Ta = 2 Tr. These optimum settings have lead to better system behaviour in terms of staff level control without excessive fluctuations in the skills recruitment completion rate. Also the time to recover a given target staff level is not excessively long. Whilst the selection of optimum parameters has been the prime concern, non-optimal system behaviour can also be studied to give added insight. It can be seen, for example, that for Ti > 8 months the oscillations in staff levels, in response to a change in the staff leaving rate, would continue for a long period of time.

9.2.4 The Automated Pipeline Skill Pool (APSKPM) model

Chapter six improved the dynamic behaviour response of the skill pool model by adding an extra feedback term to SKPM. The addition of an extra feedback term to the skill pool model would reduce the risk of staff unavailability. The APSKPM model builds on the IOBPCS model and feeds back the recruit staff in process signal. Also it includes a further feed forward signal. Where Ti and Tw act as proportional controllers, Ti in particular has important implications ~~for~~ our system stability. As Ti   2 month we have a very fast system that shows quick staff gap recovery but leads to a very volatile response in staff recruitment completion rate, and at Tc > 12 months in case company A we avoid staff level offset (sudden changes in staff levels). Therefore, the particular advantage of recruit staff in process feedback in our recruitment rule, tuned by Tw, is that it helps to provide greater control on our system stability. The impact of changing Tw is similar to that of changing Ti and Ta to determine the degree of smoothing that is undertaken on staff leaving rate.

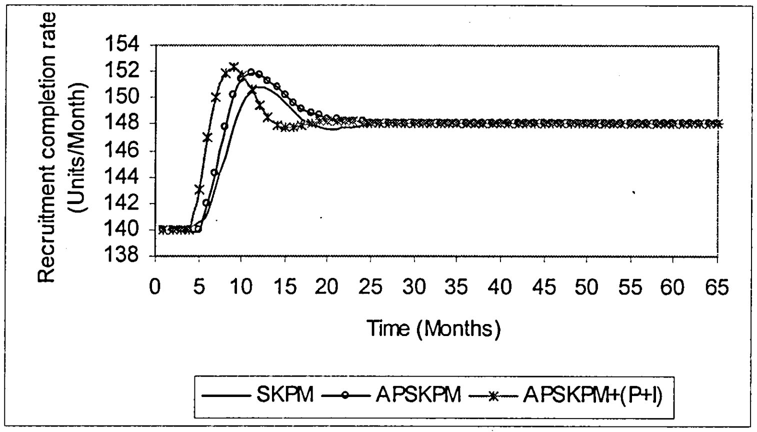
The benefit of the APSKPM model is that it improves upon the fundamental advantages of SKPM by including the interaction of recruit staff in process and lead time forecasting, thereby achieving better lead time control which leads to better overall system performance. It was concluded that the APSKPM models lead to better system performance for staff recruitment and training. The optimum design parameter values in case study A are Ti = Tr , Tc = 13 and Ta = Tw = 2 Tr for the given values of staff level and staff leaving rate, and the staff leaving rate is close to the recruitment completion rate. In case study B the values of the optimum parameters are Ti = Tr , Tc = 9 and Ta = Tw = 6 months.

9.2.5 Automated Pipeline Policy using Integral controller [APSKPM+ (P+I)]

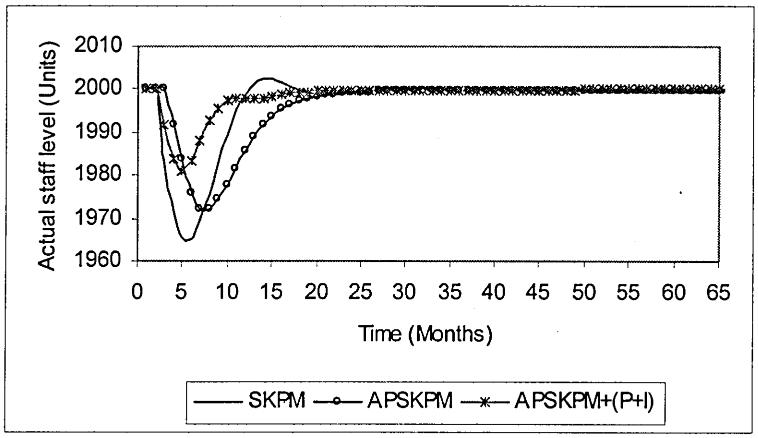
Chapter 7 improved the dynamic behaviour of the automated pipeline skill pool model by adding a proportional and integral controller. The APSKPM + (P+I) model is concerned with taking into account explicitly the error in the staff inventory to see if the system overall behaviour performance could be improved. Further enhancements to the estimation of the lead-time would improve the system performance for both case companies which would lead to improvements in the actual value of staff level, making it close to the target staff value. The simulation results show the actual staff level being in a very close approximation to its target staff level. Therefore, the aim of using such a model is to improve the performance of the APSKPM model by removing more quickly any steady state error. This was achieved by adding a new control term Ki, which is the integral controller. The simulation also showed that the ratio of the proportional controller to the integral term specifies how quickly the system attempts to achieve zero error. It was concluded that use of an integral controller would lead to better system performance for staff recruitment and training, and would reduce the staff gap to zero more quickly. Finally, there were clear advantages in the APSKPM+(P+I) over SKPM and APSKPM as shown in the figure 9.1 and explain in section 9.2.6.

9.2.6 Comparison of SKPM, APSKPM and APSKPM+ (P+I)

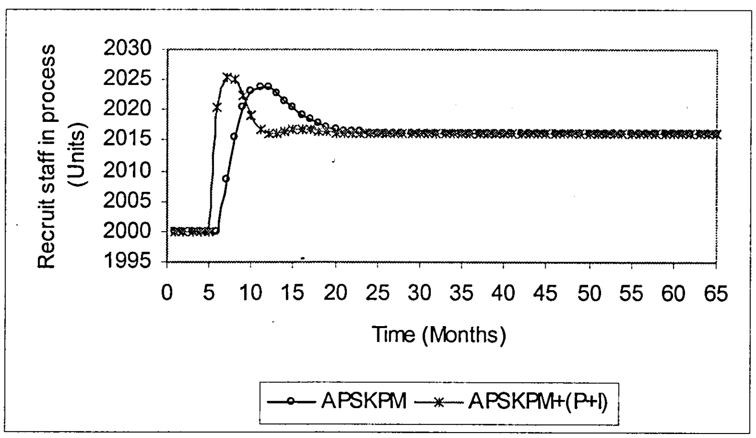
Figure 9.1 shows "Comparison between SKPM, APSKPM and APSKPM+ (P+I)" for case company A and Figure 9.2 shows "Comparison between SKPM, APSKPM and APSKPM+ (P+I)" for case company B at optimum design parameter values. The intention is to propose an optimum value of the time to recover the recruit staff in process adjustment Tw. The smoothing element Ta and the time to recover staff gap Ti are varied "between 0.5 month to 18 months" to find the optimum policy parameters. John et al. (1994), in the context of production control (and not HRP), have shown that Ta = 2 Tr and Ti = Tr appear to be good designs as fluctuations are removed and the system recovers well. The optimum set of parameters for the Skill pool model is the same as for the automated skill pool model and the APSKPM+(P+I) model. Table 9.2 and 9.3 summarise the effect of the optimum design parameters and responding performance indices for both case companies.



(a) Recruitment completion rate behaviour

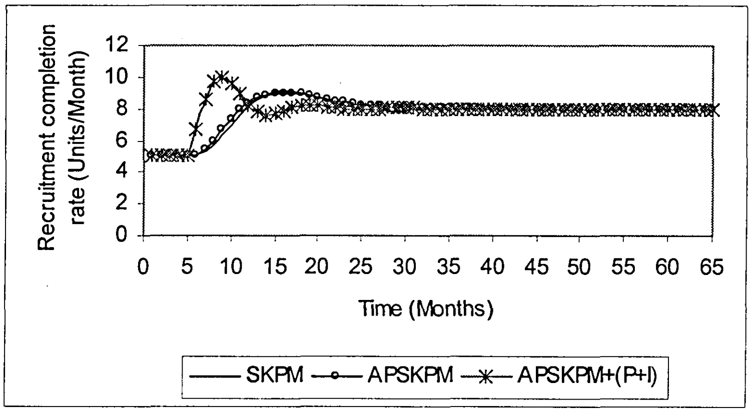


(b) Staff level behaviour

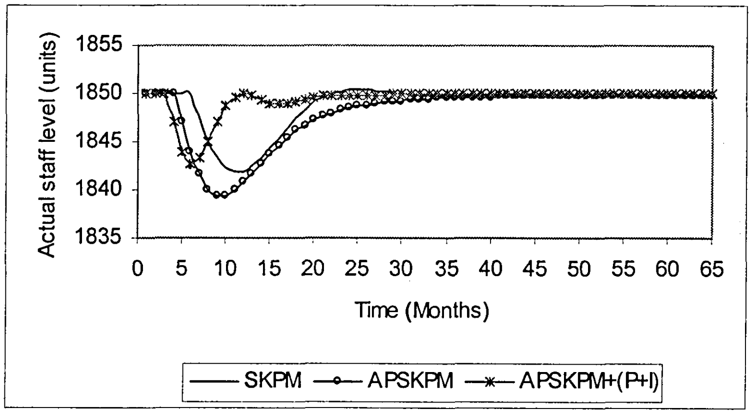


(c) Recruit staff in process behaviour

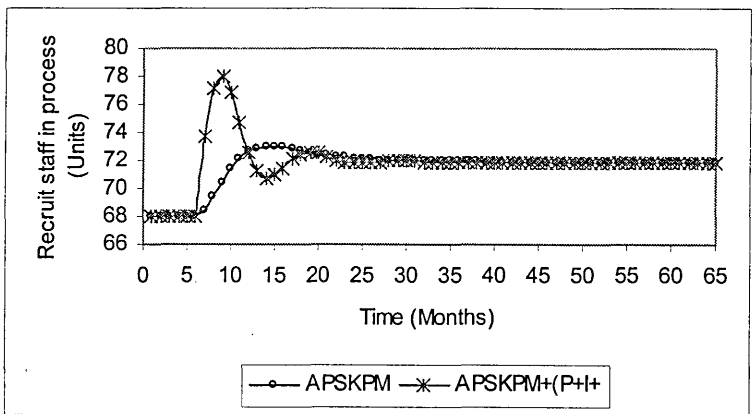
Figure 9.1: Response of SKPM, APSKPM and APSKPM+(P+I) at the optimum design values for case study A



(a) Recruitment completion rate behaviour



(b) Staff level behaviour



(c) Recruit staff in process behaviour

Figure 9.2: Response of SKPM, APSKPM and APSKPM+(P+I) at the optimum design values for case study B

Performance index at the optimum design parameters (Ti=Tr= 2 months, Ta=2Tr, Tw ≥ 2Tr and Tc=14 months)		**Skill Pool Models**		
		SKPM	**APSKPM**	**APSKPM+(P+I)**
Recruitment completion rate measurements	Rise Time (Months)	**4**	**3**	**3**
	Peak overshoot	**24.7%**	**6.08%**	**3.4%**
	Duration of overshoot	**5**	**5**	**5**
	Integral Time Absolute Error	**539.8**	**1124**	**380**
Staff level measurements	Initial staff level droop	**1%**	**1.8%**	**2.4%**
	Duration of staff inventory deficit	**8**	**5**	**5**
	Peak staff inventory overshoot	**0.15%**	**025%**	**0.02%**
	Integral Time Absolute Error	**1153**	**5924**	**5905**
Recruit Staff in process measurements	Rise Time (Months)	**N/A**	**4**	**3**
	Peak overshoot	**N/A**	**0.35%**	**0.34%**
	Duration of overshoot (Months)	**N/A**	**6**	**6**
	Integral Time Absolute Error (ITAE)	**N/A**	**5924**	**4346**

Table 9.2: Summary the effect of the optimum design parameters and corresponding performance indices for case study A

Performance index at the optimum design parameters (Ti=Tr= 3months, Ta=2Tr, Tw $\geq$ 2Tr and Tc= 9 months)		Skill Pool Models		
		SKPM	APSKPM	APSKPM+(P+I)
Recruitment completion rate measurements	Rise Time (Months)	**7**	**4**	**3**
	Peak overshoot (Percentage from the nominal value)	**12.5%**	**12.5%**	**12.5%**
	Duration of overshoot (Months)	**13**	**9**	**9**
	Integral Time Absolute Error (ITAE)	**330**	**158**	**156**
Staff level measurements	Initial staff level droop (Percentage from the desired value)	**0.38%**	**0.27%**	**0.25%**
	Duration of staff inventory deficit (Months)	**16**	**8**	**16**
	Peak staff inventory overshoot (Percentage from the nominal value)	**0.05%**	**0%**	**0%**
	Integral Time Absolute Error (ITAE)	**1041**	**2484**	**2791**
Staff in process measurements	Rise Time (Months)	**N/A**	**5**	**5**
	Peak overshoot (Percentage from the nominal value)	**N/A**	**3.1%**	**1.7%**
	Duration of overshoot (Months)	**N/A**	**10**	**12**
	Integral Time Absolute Error (ITAE)	**N/A**	**788**	**583**

Table 9.3: Summary the effect of the optimum design parameters and corresponding performance indices for case study B

A qualitative comparison of the three models is presented in Table 9.4, where features of the behaviour of the models regarding recruitment completion rate and actual staff level are recorded using star values. In this case the more stars the better the response characteristic is.

	Observed impact on recruitment completion rate			Observed impact on actual staff level		
	Oscillatory nature	Peak values	Speed of Response	Oscillatory nature	Peak values	Speed of Response
SKPM	*	**	**	*	***	**
APSKPM	**	***	**	***	***	***
APSKPM+(P+I)	***	**	***	**	***	***

Note: The more *'s the better the response characteristics to the SKPM model

Table 9.4: A qualitative summary of the different models in respect of the performance characteristics indicated (Oscillatory nature, Peak values, Speed of Response)

9.2.7 Promotion and Progression Model

Chapter nine has investigated a three grades staff level situation by using PPSKPM and PPAPSKPM and its possible use in staff progression and promotion. The chapter started by looking at the promotion process and the construction of the associated influence diagram. From final analysis of the PPAPSKPM model it was observed that the approach of using an automated pipeline model over the skill pool model offered some dramatic opportunities to the company to fine tune responsiveness to the need for progression and promotion. The philosophy behind using the PPAPSKPM model indicates good promotion policy across all staff grades. However, the oscillatory behaviour in the actual staff level and promotion completion rates was reduced and the company can gain a reduction in over and under shoot of both actual staff level and promotion completion rate. Therefore the benefits of PPAPSKPM can be realized in both management control and reduced staff-level gaps in each grade. On the other hand, the PPAPSKPM model definitely shows a far better control availability of the overall promotion and actual staff level response for each grade. Therefore, the results from the simulation run for the two models proved to be very encouraging and certainly matched the expected response improvements offered by PPAPSKPM. A summary of the visual analysis of the graphs is shown in table (9.5)

	Observed impact on promotion completion rate			**Observed impact on actual staff level**		
	Oscillatory nature	Peak values	Speed of Response	Oscillatory nature	Peak values	Speed of Response
SKPM	*	**	**	*	***	**
APSKPM	**	***	***	***	***	***

Note: The more *'s the better the response characteristics to the SKPM model

Table 9.5: performance index of the PPSKPM and PPAPSKPM

9.3 Contribution to knowledge

This research is an attempt to use system dynamics for the purposes of solving human resource planning problems. Specifically the work builds on that carried out previously by Hafeez and Abdelmeguid (2003) on developing the Skill Pool Model which used limited data to validate the theoretical concepts. The work in this thesis extends the Skill Pool Model to enable more realistic modelling of an organization's staff recruitment and training, promotion and progression needs. As we have seen the models are applied to two overseas petrochemical companies' staff recruitment, staff promotion and attrition situation and shown to be useful in that context.

Therefore, the major contribution to knowledge of the research undertaken in this thesis is demonstration of the fact that system dynamics can be used in human resource planning as an effective tool for decision making. The specific contributions can be summarized as:-

1. The research introduced the system thinking tools to develop influence diagrams to display all major influences and feedback loops that exist between HRP variables.
2. A large group of researchers (Coyle, 1977; Towill, 1982; Hafeez, 1996; Cheema et al., 1989; Mason et al., 1995) has very successfully applied system dynamics in industrial system, customer service level production control system, supply chain management, and efficient consumer response. This research work goes in similar lines and finds its use in studying the aspects of human resource planning such as (recruitment, training, promotion and progression) in a range of situations.
3. The research illustrates how system dynamics enables the HRP manager to explore several what-if type scenarios. This is achieved by varying the (HRP policy) parameters on which a dynamic simulation depends. By evaluating the scenarios against criteria agreed beforehand it is possible to determine an optimum scenario and hence determine the optimum policy parameters. This concept of policy optimisation is not a feature of most other HRP models.
4. System dynamics modelling provides an ideal tool for learning about complexity in HRP systems which are necessary because the accelerating

pace of change is transforming all aspects of our world from the "prosaic to the profound.

5. System dynamics has enabled a whole suite of models to be developed and validated for use in HRP to address recruitment, training, progression and promotion in a range of situations.
6. All IOBPCS models were tested with theoretical data, but in my thesis I have tested all models with real data.
7. The SKPM presented in this thesis allows the organisation to maximise the value of their intellectual assets and workforce. By adjusting human resource policy parameters Ti, Ta, and Tr, management should be able to optimise target recruitment patterns while looking at current workforce shortages. Also by using system dynamics models it is possible to minimise the current and future staff shortages and staff surpluses by devising appropriate recruitment programmes.
8. The APSKPM model has shown how the addition of extra feedback has improved the system behaviour by reducing the risk of staff unavailability.
9. The APSKPM+(P+I) model has shown that, by the inclusion of two new features - a proportional and an integral controller, the staff gap created by changes to the staff leaving rate can be reduced to zero more quickly that with using the prevous two models.
10. Hafeez's work has been extended to consider different salary grades and the research has addressed the promotion and progression of staff between three salary grades.

11. A three grades promotion and progression model has demonstrated that the use of such a model can improve the performance of actual staff level and promotion completion rates within a system.
12. From analysis of the PPAPSKPM model it was observed that the approach of using an automated pipeline model over the skill pool model offered some dramatic opportunities to the company to fine tune responsiveness to the need for progression and promotion. The philosophy behind using the PPAPSKPM model indicates good promotion policy across all staff grades. However, the oscillatory behaviour in the actual staff level and promotion completion rates was reduced and the company can gain a reduction in over and under shoot of both actual staff level and promotion completion rates.
13. The benefit of the PPAPSKPM is that it improves on the fundamental advantages of the PPSKPM model by including the interaction between promoted staff in process and lead time forecasting, thereby achieving better lead-time control.
14. The models presented offer guidelines for setting human resource planning system "control" values to minimise staff shortages as well as staff overshoots.

The above contributions are now reviewed in detail in the following sections.

9.3.1 Contribution in HRP

Regardless of organization size or nature, the underlying motive behind human resource planning is to have the right staff, with the right skills, in the right places at the right time to fill both individual and organization needs (Walker, 1980). For that reason, HRP is viewed by many as being a very important business function. However, it requires considerable staff expertise to carry out, and it is time consuming as well. Nevertheless, a number of organization have realized the benefit of implementing effective human resource planning models to forecast their future human resource needs as well as optimising their recruitment and training policies. Others have realized the importance of managing staff promotion and progression. All these important factors in HRP require effective models which help the manager to plan their human resource needs to meet their targets as well as remaining responsive to changes in the environment and the global economy. The research described in this thesis has led to the development of such effective models.

9.3.2 Contribution of system dynamics and system thinking fields

System thinking and system dynamics deals with how things change over time. This research has considered the application of system thinking and system dynamics in the field of human resource planning to show how applying systems thinking and system dynamics might make human resource planning models extremely effective for the most difficult types of problems to solve.

The research work has shown how system dynamics may be used as a tool to model and analyse the human resource planning problems associated with staff recruitment, staff surpluses and staff shortages. An integrated system dynamics framework has been discussed and the models are mapped onto petrochemical companies' staff recruitment and attrition situations and subsequently tested using real data. Optimum design guidelines have been provided to reduce the unwanted scenario of staff surpluses and staff shortages.

Therefore the main contributions of system dynamics modelling are:

- System dynamics models are relatively easy to formulate and solve and they provide equal or greater analytical power than many other models. The System Dynamics approach provides a means of describing rich, complex problem situations in a way that ensures all assumptions are consistent, explicit and easily communicable, as well as providing the analytical power to process this rich model without complex mathematics.
- The greatest advantages in adopting system dynamics as an effective analytical tool is that it takes into account various interrelationships that influence the behaviour of a complex system. It looks at policies as well as processes.
- System dynamics concentrates on the policies and dynamic behaviour of the system and how it influences its own evolution into the future.
- System dynamics can be uses as an effective tool, which can be applied to a very wide range of HRP problems. The table below summarises specific mathematical and modelling features of systems dynamics in the context of an HRP Manager's concerns.

System Dynamics Characteristics	*HRP Manager's Concerns*
Holistic system viewpoint	Whole company
Feedback analysis	Consequences of actions
Dynamic modelling	Concern with future testing of ideas
Optimisation and robustness	Robustness against uncertainty
Transparency of influence diagram	Understanding input and control
Medium to long term	Long term view

9.4 Research Limitations and Further work

If we look at the limitations of the research work carried out, then we see that there are several limitations:

- The models have been developed within the context of the petrochemical industry, and it may be argued that the models are therefore of limited use.
- The data used to validate the models are based on monthly values.
- The models have been optimised with respect to changes in the staff leaving rate. Companies often need to recruit new staff to cope with changes in production. Linking recruitment to production has not been considered.
- The models, whilst addressing the impact of promotion and progression, do not address the management of staff development in situations where staff may need to effectively "leave" the company to be trained up or developed.

With regard to the petrochemical industry limitation, This author argued earlier that the petrochemical industry is typical of many industries, and in many senses is representative of many HRP situations. In claiming that system dynamics is an effective tool in HRP, because it produces effective models for use in this sector, I feel that there is strong justification for this claim for the reasons given earlier in Chapter 4. I feel, however, that application of system dynamics to study HRP problems in other sectors, such as in the Health Service or in Higher Education, would be relatively straight forward.

With regard to having to work with monthly data, I feel that this has put no significant limitation on the research findings. The issue of whether optimum policies would be the same, had weekly data been available, is a debatable point, however. The policy would clearly have been phrased in terms of weekly measures, and because of the different granularity of data available, may well have been different. If a policy in terms of weekly data is required for a company, then the company would have to furnish weekly data to arrive at such a policy.

With regard to linking staff recruitment to production, then this author would agree that this is a significant opportunity for further work. Finally, with regard to the management of staff development, we agree that in companies where training and development of staff is an important consideration, then it may become necessary to develop a model to manage this process - especially if staff "leave" for development in significant numbers.

Regarding the linkage of production and recruitment it may be appropriate to build two SKPM models, one for the production department and the other for the human resource planning department. The two models would be coupled together to show how production scheduling and hiring policies can interact with each other to generate instability and oscillation. It would then be possible to study the overall system behaviour and explore policies to enhance stability and responsive to find the optimum parameters for example to reduce both the staff gap and inventory gap.

9.5 References

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APPENDIX 1

Origins and fundamental notions of system dynamics

1.1 Introduction

System dynamics is a policy modelling methodology based on the foundations of decision-making, feedback mechanism analysis and simulation. Decision-making focuses on how actions are to be taken by decision makers, feedback deals with the way information generated provides insights into decision making and affects decision making in similar cases in the future. Simulation provides decision makers with a tool to work in a virtual environment where they can view and analyse the effects of their decisions in the future, unlike in a real social system.

Forrester first used the concept of a system to aid the Decision Maker. His initial work focused on analysing and simulating micro level industrial systems such as production, distribution, order handling, inventory control, and advertising. Forrester expanded his system dynamics techniques in principles of system in 1968, where he detailed the basic concepts of system dynamics in a more technical form, outlining the mathematical theory of feedback system dynamics (Forrester, 1968).

The problems we face today are often complex and dynamic in nature, i.e. there are many factors and forces at play that we do not comprehend easily. Also these factors and forces are dynamic in nature. Many thinkers, who advocated holistic thinking and the conceptualisation of system wherein everything is connected to everything else, advocate system thinking. System dynamic is an approach whose main purpose is to understand and model complex and dynamic systems. It employs concepts of non-linear dynamics and feedback control, concepts that will be discussed in detail shortly.

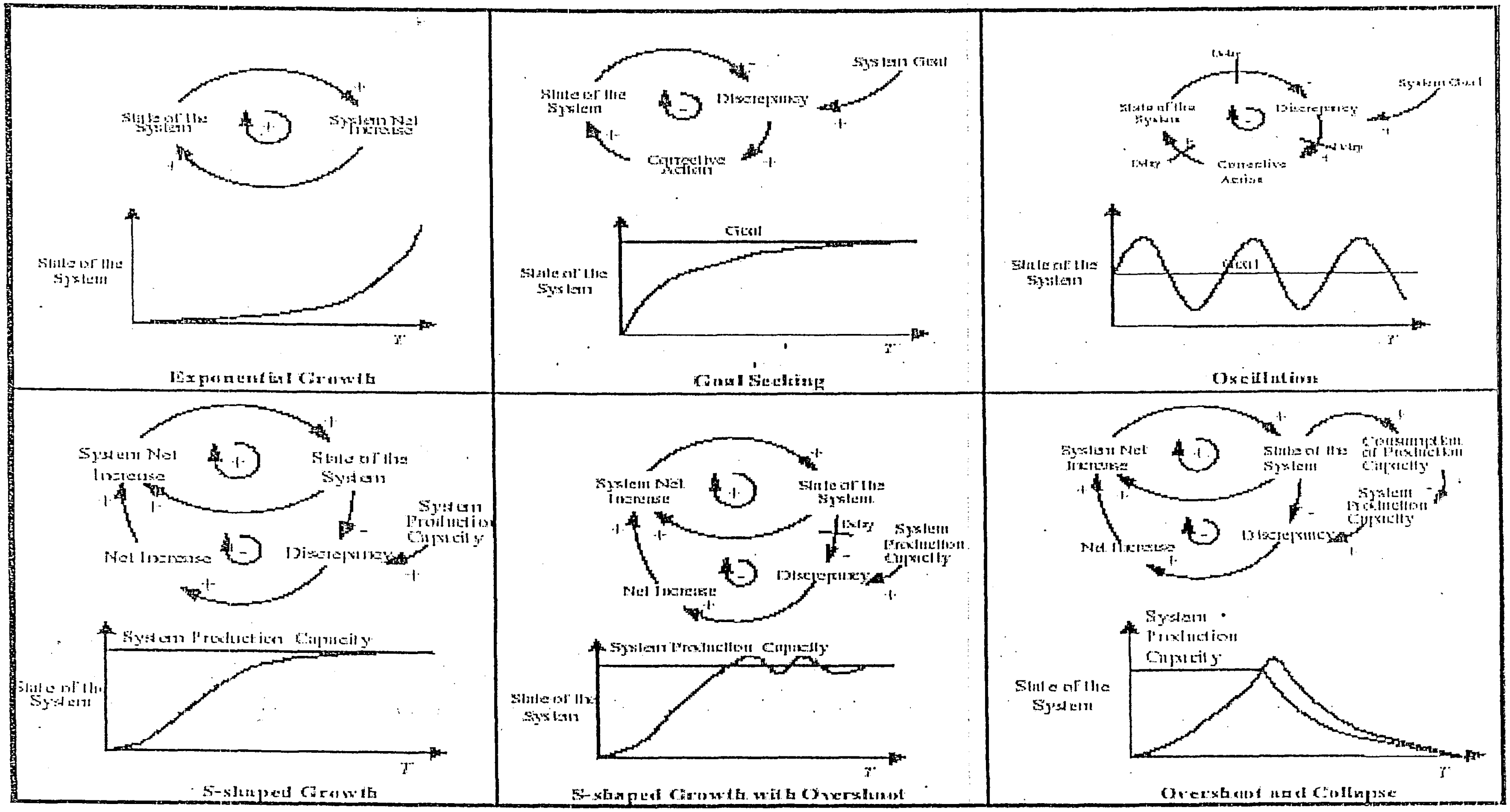
1.2Feedback

Action taken on an element in a system results in changes in state of the element. These in turn bring about changes in other linked elements, and the effects may trail back to the first element. This is called feedback. Feedback can be of two types - positive and negative feedback:

1. Positive feedback. or reinforcing. which amplifies the current change in the system.
2. Negative, or self-correcting, which seeks to balance and provide equilibrium by opposing the change taking place in the system.

1.3 System dynamic behaviour

System behaviour is a result of the structure of the system. Most dynamics observed in systems fall under three fundamental modes of behaviour: exponential behaviour, goal seeking and oscillation (sterman,2000). These modes of behaviour are shown in Figure 1.1. Exponential behaviour arises from positive or self-reinforcing feedback. The greater a quantity is, the greater is its net change (increase/decrease), and this is the feedback to the process that further augments the net change. Thus this is a self-reinforcing feedback and there is an exponential growth/decline. Goal seeking behaviours arises from negative or self-controlling feedback. Negative feedback loops tend to oppose any changes or deviations in the state of the system; they tend to restore equilibrium and hence are goal seeking. The rate of change diminishes as the goal is approached, such that there is a smooth attainment of the goal/equilibrium state of the system. Oscillation arises due to negative feedback with significant time delays. The principle that behaviour is a result of the structure of the system enables a discovery of the system structure (its feedback loops, non-linear interactions etc) by observing the behaviour of the system. Therefore, when the pattern of behaviour is observed, conclusions can be drawn about the dominant feedback mechanisms acting in the system. Non-linear interactions among the three major feedback structures give rise to other complex patterns of behaviour of the system (Sterman, 2000). *S-shaped* growth arises when there is a positive feedback initially, and later negative feedback dominates, leading to attainment of equilibrium by the system. *S-shaped* growth with overshoot occurs when, after an initial exponential growth phase, negative feedback with time delays kicks in. In this case the system oscillates around the equilibrium state itself declining after the exponential growth phase has commenced, and negative feedback gets activated, wherein the system approaches the new equilibrium state.



Figur 1.1: System dynamics structres and their behaviour (Sterman, 2000)

1.4 Causal loop diagram

The feedback structure of a complex system is qualitivity mapped using causal diagrams. A causal loop diagram consists of variables connected by causal links, shown as arrows. A causal loop diagram is a method of sketching out what causes what in the system. The emphasis is on understanding the overall behaviour of complex systems in terms of stability, response time, etc. A cause and effect diagram is a pictorial display of a list of system components. Each diagram has a large arrow pointing to the name of a problem. The line off the large arrow represents main categories of potential causes (or solutions). Typical categories are equipment, personnel, method, materials, and environment. Causal loop diagrams are used to develop cause and effect relationships between the main variables of systems. (Coyle, 1977). The sign for the link tells whether the variables at two ends move in the same (+) or opposite direction (-). And the sign of a loop is an algebraic product of the signs of its links.

For example Figure 1.2 illustrates the causal loop format for human resource planning as a basic tool for examining the structure of a system, including the interactions among components, and to anticipate the recruitment policy in the future.

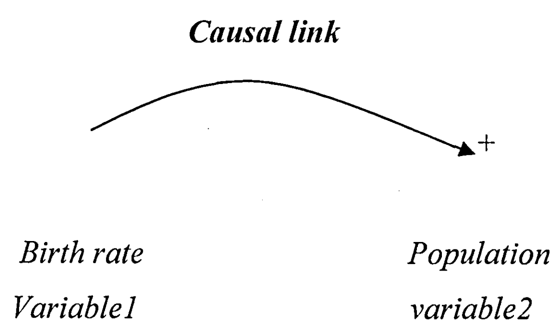


Figure (1.2) Example of a causal link

1.5 Stock and flows

- Causal loops are used effectively at the start of modelling to capture mental models. However, one of the most important limitations of causal diagrams is their inability to capture the stock and flow structure of systems. Stock and flow, along with feedback, are the two central concepts of dynamic system theory. To improve our ability to learn about and manage complex systems, we need tools capable of capturing the feedback process, the tools must enable us to understand how these structures create a system dynamics and generate policy resistance. Also they must help us to evaluate the consequences of new policies and new structures we might design. Stocks are accumulations as a result of a difference in input flow rates to a process in a system. Stocks give the systems inertia and memory, based on which decision and action are taken and also create delays in a system and generate disequilibria (Sterman, 2000). Figure 1.3 shows Stock & Flow Diagrams, which are composed of four different components: Stocks, Flows, Converters and Connectors.

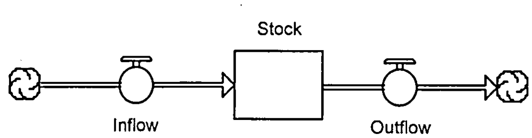


Figure (1.3) General structure of a stock and flow

Mathematical Representation of Stock and Flow

Stock(t) = stock(to) + ∫ [inflow(t) – outflow(t)] dt

Stocks are the state variables or integrals in the system. They accumulate (integrate) their inflows less their outflows. Flows are all those which are rates or derivatives. If a snapshot of a system was taken at any instant time, what would be seen is the state of different processes or components of the system. These are the stocks in the systems, the inflows and outflows are what have been frozen and so cannot be identified. Stock and flow networks undoubtedly follow the laws of conservation of material, the contents of stock and flow network are conserved in the sense that items entering a stock remain there until they flow out

1.8 References

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APPENDIX 2

Simulation based on the exponential smoothing function

2.1 Introduction

Exponential smoothing is one technique which we can use to predict events in the future by studying events in the past. By employing weighted averages to smooth past values, it let you forecast the values in the next period.

The basic model for exponential smoothing is

$Y\ t{+}1 = Yt * (Y1\ t - Y\ t)$

where

$Y\ t{+}1$ = predicted value at period $t + 1$

$Y\ t$ = predicted value at period t

$Y1\ t$ = actual value at period t

2.1 Exponential Smoothing of Step Change

The exponential smoothing equation (Towill, 1977) can be described below;

$$Y\,(t{+}1) = Y\,(t) + \alpha\,[X\,(t{+}1)] \qquad (1)$$

By expending he exponential smoothing equation

$$Y\,(t{+}2) = Y\,(t + 1) + \alpha\,[X\,(t{+}2) - Y\,(t + 1)]$$

$$Y\,(t{+}3) = Y\,(t + 2) + \alpha\,[X\,(t{+}3) - Y\,(t + 2)]$$

$$Y\,(t{+}4) = Y\,(t + 3) + \alpha\,[X\,(t{+}4) - Y\,(t + 3)]$$

.

.

$$Y\,(t{+}n) = Y\,(t + (n\text{-}1)) + \alpha\,[X\,(t{+}n) - Y\,(t + (n\text{-}1)] \qquad (2)$$

For a unit step change, $X\,(t{+}i) = 1$ for all values of I, and $Y(t)=0$

Substituting for X (t+i) and Y(t) in equation 2

$Y(t+1) = \alpha$

$Y(t+2) = 2\alpha - \alpha^2$

$Y(t+3) = 3\alpha - 3\alpha^2 + \alpha^3$

Or

$Y(t+1) = \alpha = 1 - (1 - \alpha)$

$Y(t+2) = 2\alpha - \alpha^2 = 1 - (1 - \alpha)^2$

$Y(t+3) = 3\alpha - 3\alpha^2 + \alpha^3 = 1 - (1 - \alpha)^3$

Therefore, for the general case "n"

$$\boxed{Y(t+1) = 1 - (1 - \alpha)^n}$$

Figure ( ) shows the exponential smoother response to a step change in the input

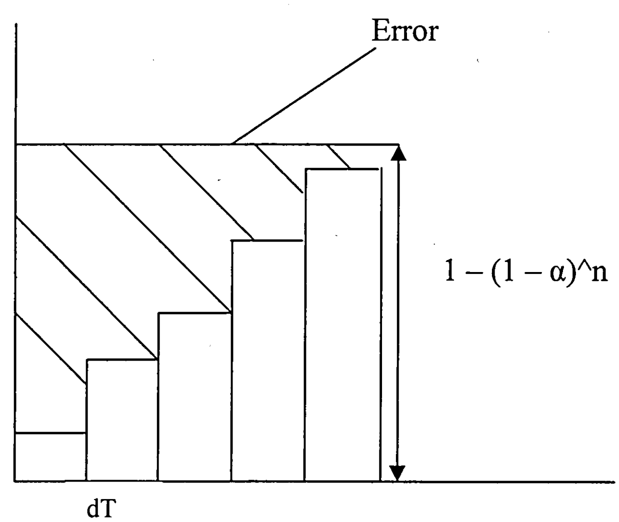

Figure ( ) exponential smoother response to a step change in the input

Error in the exponential smoother is

$Error = 1 - (1 - (1 - \alpha)^n$

or

Error = $(1 - \alpha)^n$

The sum of the error is the sum under the error curve

$\sum$ error = dT $\sum(1 - \alpha)^n$

Considering the series expansion for the error

Series = (first term – last term)/(last term – ratio of terms)

.. Series = $[(1 - \alpha) - 0]/[1-(1 - \alpha)]$

Error = dT$[1 - \alpha/ \alpha]$

Matsuburu, 1965, has defined the smoothing constant α as

T=dT$[(1 - \alpha)/ \alpha]$

Therefore,

$\alpha = 1/(1 +T/dT)$

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APPENDIX 3
Calculation of damping ratio

3.1 Introduction

Physically in control system, there is no system that's vibrates forever, that means there is always some kind of damping in the system, and the disturbance disappear after period of time. Therefore the system disturbance depends on the magnitude of damping (Daniel 1994). A damped system can be under damped, critically damped or over damped. In our case the critical damping coefficient is determined by the system response according the time to reduce staff gap, time to recruit new staff and the time reduce recruit staff gap deficit to zero, the damping ratio is unity. Critical damping separates non oscillatory motion from oscillatory motion.

The quadratic term in the transfer functions equations can be written in standard second order form in control theory (Marshall 1986). The characteristic equation is

$$\left[1+\frac{2\zeta}{\omega_n}S+\frac{1}{\omega_n^{\,2}}S^2\right]$$

Where

ω_n Is the undamped natural frequency

ζ Is the damping ratio

$$\zeta = 0.5 * \sqrt{\lambda i} * [\,1 + 1/\lambda w\,]$$

$$\lambda i = Ti / Tp$$

$$\lambda w = Tw / Tp$$

$$\zeta = \sqrt{Ti} * (0.25 + 1 / Tw)$$

Figure 3.1 shows the relationships between damping ratio, Tw and Ti. Therefore this figure will used to determine the boundary limit of parameters Ti and Tw for optimum value of damping ratio. The damping ratio is regarded by systems engineers as a direct measure of system performance. When the damping ratio is grater than 1, which is called over damping (which can imply long recovery times), the system does not oscillate for damping ratio less than 1 which is called under damping, and the value of damping ratio equal 1 indicates that a system is critically damped. Towill 1982 has suggested that the ideal values of damping ratio is $(0.5 < \zeta < 0.707)$.

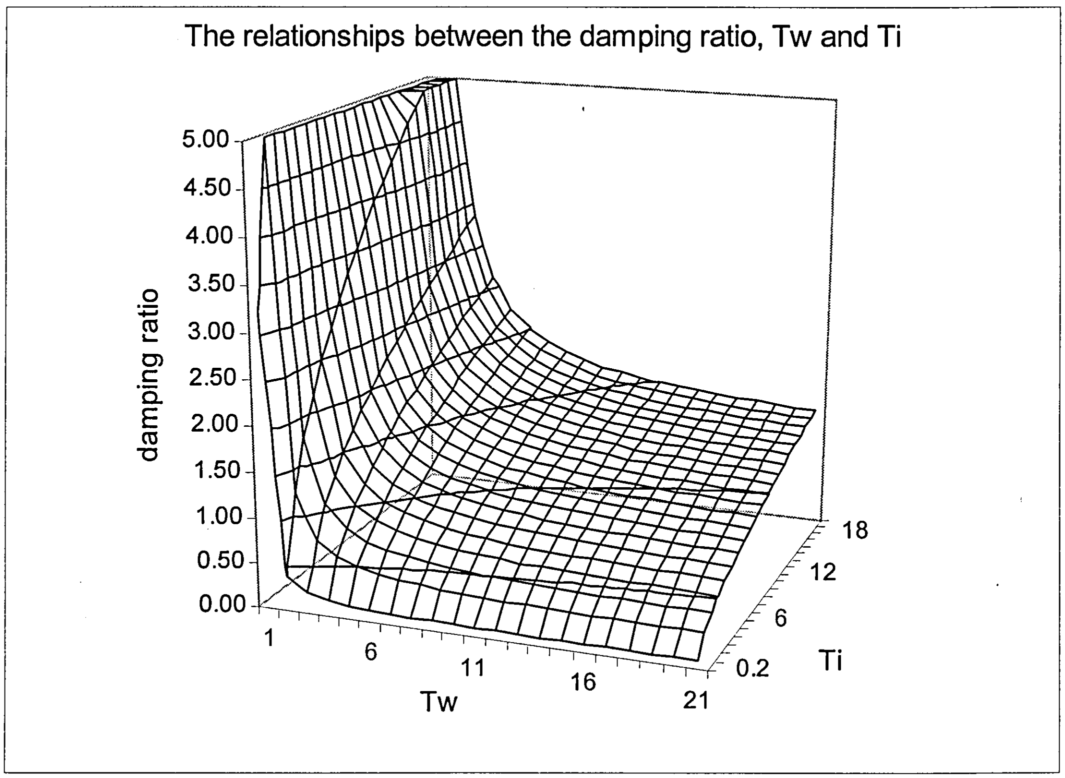


Figure 3.1: The relationships between damping ratio, Tw and Ti

The damping ratio determine the overshoot and under shoot in the system, and from figure above we can observe that for Ti > 9 the value of damping ratio is grater than one. Therefore, the design parameter Ti should be setting as ($0 < Ti \leq 9$). On the other hand, the parameter of Tw should setting in the rage ($1 \leq Tw \leq 16$), which have ideal values of damping ratio.

3.2 References

- Marshall, S. A., (1986). "Introduction to control theory", Published by Macmillan Education Limited, ISBN 0-333-18311-8.
- Towill, D. R., (1982). Dynamic analysis of an inventory and order based production control system International Journal of Production Research 1982; 20: 671-687.
- Towill. D. R., 1970, 'Transfer function techniques for control engineers'. Published by ILIFFE Books Ltd. pp 49-54.
- Daniel J. Inman, Engineering Vibration, Prentice Hall, Englewood Cliffs, New Jersey, 1994.

APPENDIX 4

Transfer Function Derivation

4.1- Transfer function derivation of APSKPM

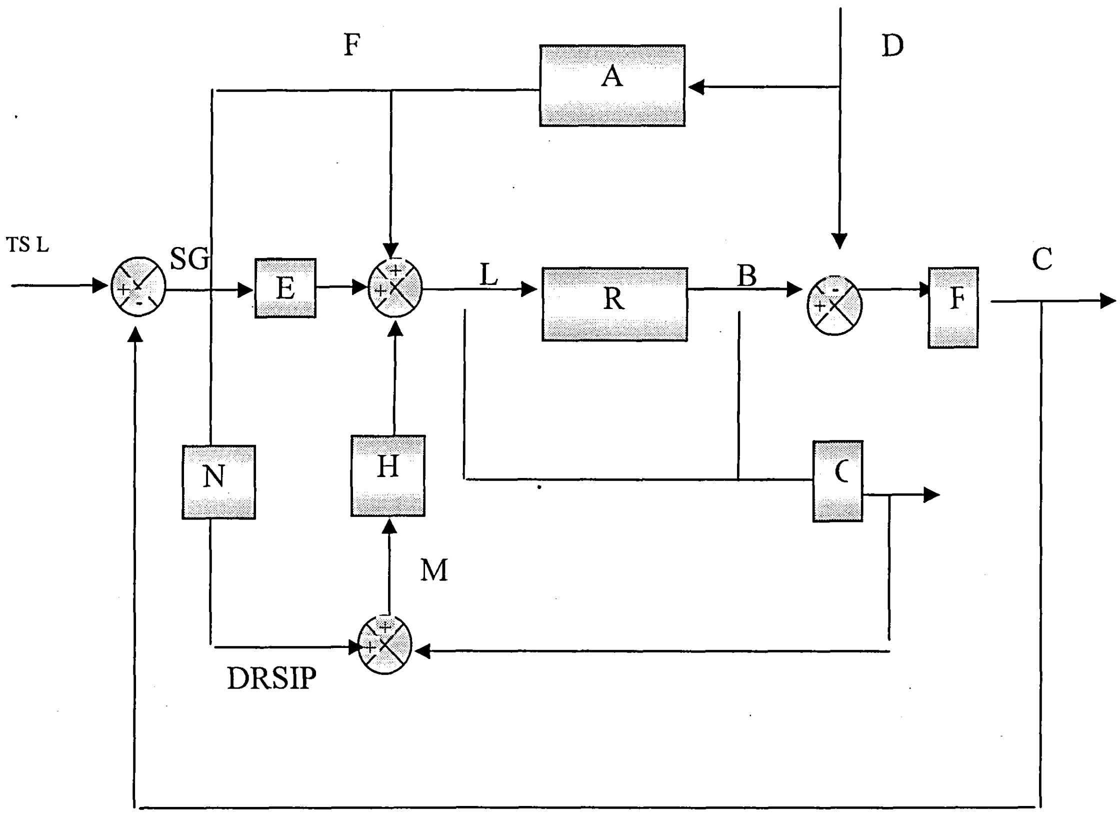


Figure 2.1: A block diagram representation of APSKPM

The Automated Pipeline Skill pool is represented in this appendix with different symbols to help us ease the derivation of the transfer function

For recruitment completion rate

B = [(DAN - K) * H + DA – CE] * R   1

For actual staff level

$$C = (B - D) * 1/S \qquad 2$$

For recruit staff in process

$$K = (1 - R) * B/(R*S) \qquad 3$$

Now substituting equations 2 & 3 in equation 1

$$B = [(DAN - (1 - R)* B/(R*S))H + DA - (B - D)*E/S] R$$

$$B = [(DAN - B/(R*S) + BR/(R*S))H + DA - B*E/S + D*E/S] R$$

$$B = [(DANH - BH/(R*S) + BRH/(R*S) + DA - BE/S + DE/S] R$$

$$B = DANH - BH/S + BRH/S + DAR - BRE/S + DER/S$$

Now we have to re arranging equations in terms of B and D

$$B + BH/S - BHR/S + BER/S = DANHR + DAR + DER/S$$

$$B[1 + H/S - HR/S + ER/S] = DR[ANH + A + E/S]$$

Recruitment completion rate/Present staff leaving rate = B/D

$$B/D = [RANH + AR + ER/S] / [1 + H/S - HR/S + ER/S] \qquad \text{multiplied by } (S/S)$$

$$B/D = [RANHS + ARS + ER] / [S + H - HR + ER]$$

$$B/D = R[ANHS + AS + E] / [S + H - HR + ER]$$

Substituting symbols for their block representations

$$\frac{recruitment.completion.rate}{present.staff.leaving.rate} = \left[\frac{1 + \left(Ta + Ti + \frac{TcTi}{Tw} \right) * S}{(1 + TaS)\left(1 + \left(1 + \frac{Tr}{Tw} \right) * TiS + TrTiS^2 \right)} \right]$$

Divided equation 3 by D

$$K/D = [(1-R)/D] * B/(RS)$$

Substituting for R, B/D and K/D

RSIP/PSLR = Tc *(RCR/PSLR)

$$\frac{recruitment.staff.in.process}{present.staff.leaving.rate} = Tr\left[\frac{1+\left(Ta+Ti+\frac{TcTi}{Tw}\right)*S}{(1+TaS)\left(1+\left(1+\frac{Tr}{Tw}\right)*TiS+TrTiS^2\right)}\right]$$

Dividing equation 2 by D

C/D = (1/S)* (B/D – 1)

Substituting for R, D and C

ASL/PSLR = (1/S)* [RCR/PSLR)

$$\frac{actual.staff.level}{present.staff.leaving.rate} = -Ti\left[\frac{\frac{(Tr-Tc)}{Tw}+\left(Ta+Tr+\frac{TaTr}{Tw}\right)*S+TaTrS^2}{(1+TaS)\left(1+\left(1+\frac{Tr}{Tw}\right)*TiS+TrTiS^2\right)}\right]$$

4.2 Transfer function derivation of APSKPM + (P + I)

The Automated Pipeline Skill pool plus integral controller is represented in this appendix with different symbols to help us ease the derivation of the transfer function

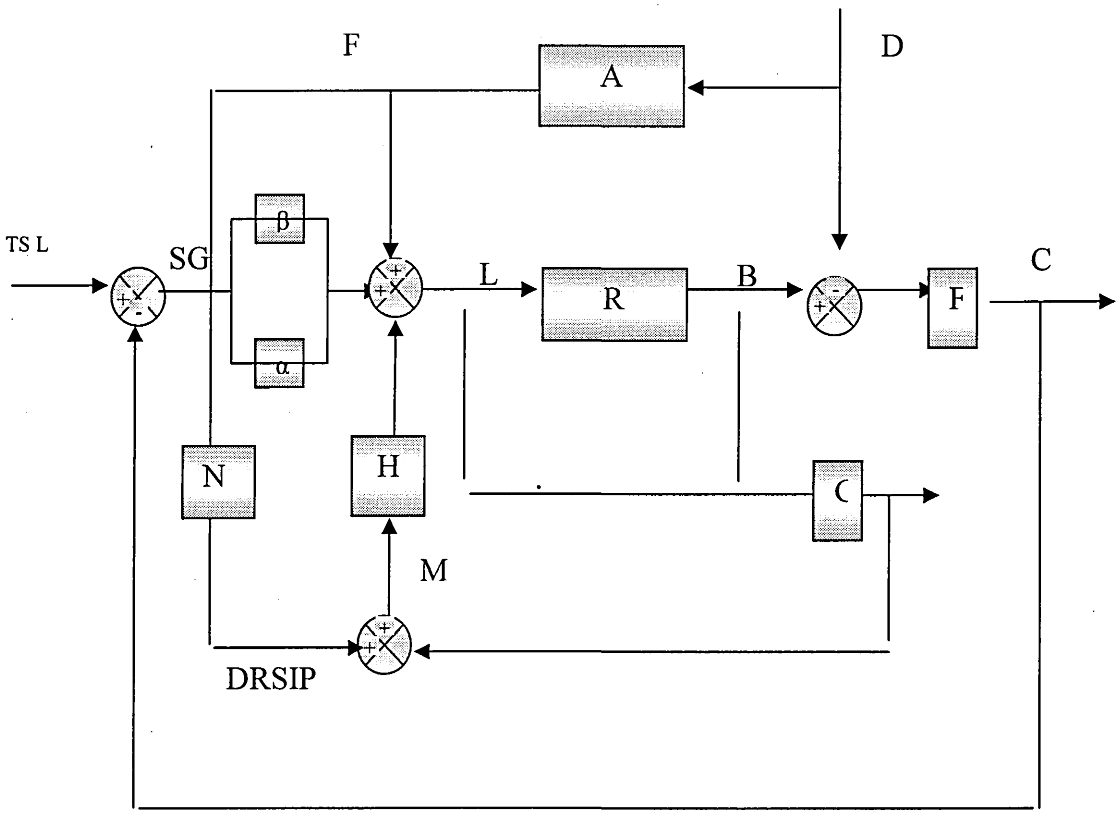


Figure 2.2: A block diagram representation of APSKPM +(P+I)

For recruitment completion rate

$$B = [(DAN - K) * H + DA - C(\beta - \alpha)] * R \qquad (1)$$

For actual staff level

$$C = (B - D) * 1/S \qquad (2)$$

For recruit staff in process

$$K = (1 - R) * B/(R*S) \qquad (3)$$

Now substituting equations 2 & 3 in equation 1

$$B = [(DAN - (1 - R)* B/(R*S))H + DA - (B - D)*()/S] R$$

$$B = [(DAN - B/(R*S) + BR/(R*S))H + DA - B*(\beta - \alpha) /S +D*(\beta - \alpha) /S] R$$

$$B = [(DANH - BH/(R*S) +BRH/(R*S) +DA - B(\beta - \alpha) /S +D(\beta - \alpha) /S] R$$

$$B = DANH - BH/S + BRH/S + DAR - BR(\beta - \alpha)/S + D(\beta - \alpha) R/S$$

Now we have to re arranging equations in terms of B and D

$$B + BH/S - BHR/S + B(\beta - \alpha) R/S = DANHR + DAR + D(\beta - \alpha) R/S$$

$$B[1 + H/S - HR/S + (\beta - \alpha) R/S] = DR[ANH + A + (\beta - \alpha)/S]$$

Recruitment completion rate/Present staff leaving rate = B/D

$$B/D = [RANH + AR + (\beta - \alpha) R/S] / [1 + H/S - HR/S + (\beta - \alpha) R/S]$$ multiplied by (S/S)

$$B/D = [RANHS + ARS + (\beta - \alpha) R] / [S + H - HR + (\beta - \alpha) R]$$

$$B/D = R[ANHS + AS + (\beta - \alpha)] / [S + H - HR + (\beta - \alpha) R]$$

$$B/D = R[ANHS + AS + \beta - \alpha] / [S + H - HR + \beta R - \alpha R]$$

Substituting symbols for their block representations

$$\frac{recruitment.completion.rate}{present.staff.leaving.rate} = \frac{TS^2(Tc + Tw) + Tw(1 + TaS)(TiKi + S)}{(1 + TaS)(TwTiS^2(1 + TrS) + S(Tw + TiTrS) + TwTiKi)}$$

Divided equation 3 by D

$$K/D = [(1-R)/D] * B/(RS)$$

Substituting for R, B/D and K/D

RSIP/PSLR = Tc *(RCR/PSLR)

$$\frac{recrui.staff.in.process}{present.staff.leaving.rate} = \frac{TiS[\ TS^2(Tc + Tw) + Tw(1 + TaS)(TiKi + S)\ ]}{(1 + TaS)(TwTiS^2(1 + TrS) + S(Tw + TiTrS) + TwTiKi)}$$

Dividing equation 2 by D

C/D = (1/S)* (B/D – 1)

Substituting for R, D and C

ASL/PSLR = (1/S)* [RCR/PSLR)

$$\frac{acual.staff.level}{present.staff.leaving.rate} = \frac{TiS[(Tc+Tw)+(1+TaS)[Tw(1+TrS)+Tr]]}{(1+TaS)(TwTiS^2(1+TrS)+S(Tw+TiTrS)+TwTiKi)}$$

4.3 Transfer function derivation of SKPM

The extra feedback algorithm can be reduced to one block as shown the following

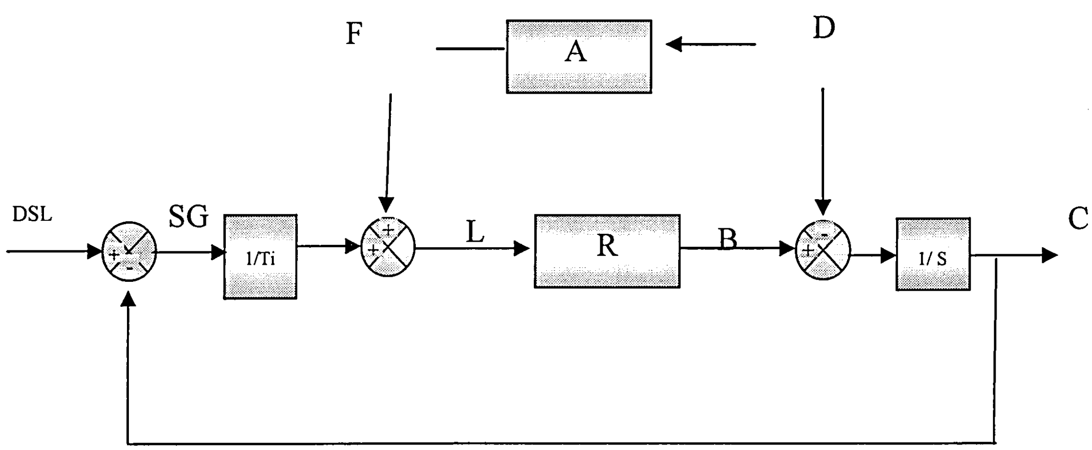


Figure 2.3: A block diagram representation of the SKPM

The equations in APSKPM can be written down directly from Figure 2.3 using the block diagram analysis.

Staff gap = target staff level – actual staff level

$$DSL - ASL = SG$$

Forecast staff leaving rate = Multiplier used in simulation to take account of Ta to average the staff leaving rate over the demand average time * present staff leaving rate

$$F = A * D$$

Recruitment demand rate = forecast staff leaving rate + staff gap / time to reduce staff gap to zero

$$RDR = FSLR + SG/Ti$$

Recruitment completion rate = Multiplier used in simulation to take account of Tr, and it is the recruitment process to acquire staff during recruitment session * recruitment demand rate

$$B = L * R$$

Finally the actual staff level = actual staff level accumulated over time through the recruitment and training development and is affected by the present staff leaving rate * (recruitment completion rate – present staff leaving rate)

$$C = (1/S)*(B - D)$$

Equations 1 to 5 are used to develop associated transfer functions. Using the block diagram Figure 5.2. Furthermore, the transfer function can be derived as (actual staff leaving rate / present staff leaving rate) and (staff recruitment completion rate / present staff leaving rate), these transfer functions are shown in equations A and B respectively.

$$\frac{Actual.staff.level}{\Pr esent.staff.leaving.rate} = \frac{-Ti[(Tr+Ta).S + TrTa.S^2]}{(1+Ta.S)(1+Ti.S+TiTr.S^2)}$$

$$\frac{Recruitment.completion.rate}{Present.staff.leaving.rate} = \frac{1+(Ti+Ta).S}{(1+Ta.S)(1+Ti.S+TiTrS^2)}$$

Reference:

- Towill, D. R., 1970, "Transfer function techniques for control engineers", Published by ILIFFE Books Ltd, pp 49-54.
- Towill, D. R., 1981, "Coefficient plane models for control system analysis and design", Published by Research Studies Press, pp 193-198.

APPENDIX 5

Results in Ithink software

5.1 Skill Pool Model (SKPM) in ITHINK software

The following equations shows SKPM simulation model using Ithink software in both case studies.

5.1.1 Case study A

ASL(t) = ASL(t - dt) + (RCR - PSLR) * dt

INIT ASL = 2000

INFLOWS:

RCR = Recrutes/Tr

OUTFLOWS:

PSLR = GRAPH(140+STEP(8,5))

(1.0, 140), (4.0, 137), (7.0, 149), (11.0, 152), (14.0, 151), (17.0, 139), (21.0, 137), (24.0, 151), (27.0, 142), (31.0, 148), (34.0, 148), (38.0, 146), (41.0, 146), (44.0, 130), (48.0, 148), (51.0, 129), (54.0, 142), (58.0, 152), (61.0, 141), (65.0, 148)

Recrutes(t) = Recrutes(t - dt) + (RDR - RCR) * dt

INIT Recrutes = 280

INFLOWS:

RDR = FSLR+ASL_adjustment

OUTFLOWS:

RCR = Recrutes/Tr

ASL_adjustment = SG/Ti

FSLR = SMTH1(PSLR,Ta)

SG = TSL-ASL

Ta = 4

Ti = 2

Tr = 2

TSL = 2000

5.1.2 Case study B

ASL(t) = ASL(t - dt) + (RCR - PSLR) * dt

INIT ASL = 1850

INFLOWS:

RCR = Recrutes/Tr

OUTFLOWS:

PSLR = GRAPH(6+STEP(2,3))

(1.0, 140), (4.0, 137), (7.0, 149), (11.0, 152), (14.0, 151), (17.0, 139), (21.0, 137), (24.0, 151), (27.0, 142), (31.0, 148), (34.0, 148), (38.0, 146), (41.0, 146), (44.0, 130), (48.0, 148), (51.0, 129), (54.0, 142), (58.0, 152), (61.0, 141), (65.0, 148)

Recrutes(t) = Recrutes(t - dt) + (RDR - RCR) * dt

INIT Recrutes = 30

INFLOWS:

RDR = FSLR+ASL_adjustment

OUTFLOWS:

RCR = Recrutes/Tr

ASL_adjustment = SG/Ti

FSLR = SMTH1(PSLR,Ta)

SG = TSL-ASL

Ta = 6

Ti = 3

Tr = 3

TSL = 1850

5.2 Automated Pipeline Skill Pool Model APSKPM in ITHINK software

The following equations shows APSKPM simulation model using Ithink software in both case studies.

5.2.1 Case study A

ASL(t) = ASL(t - dt) + (RCR - PSLR) * dt
INIT ASL = 2000

INFLOWS:
RCR = Recru_tes/Tr
OUTFLOWS:
PSLR = GRAPH(140+STEP(8,3))
(1.0, 140), (4.0, 137), (7.0, 149), (11.0, 152), (14.0, 151), (17.0, 139), (21.0, 137), (24.0, 151), (27.0, 142), (31.0, 148), (34.0, 148), (38.0, 146), (41.0, 146), (44.0, 130), (48.0, 148), (51.0, 129), (54.0, 142), (58.0, 152), (61.0, 141), (65.0, 148)
Recru_tes(t) = Recru_tes(t - dt) + (RDR - RCR) * dt
INIT Recru_tes = 280

INFLOWS:
RDR = FSLR+ASL_adjustment+Recrutes__adjustment
OUTFLOWS:
RCR = Recru_tes/Tr
ASL_adjustment = SG/Ti
descrepancy = TRIP-RSIP
FSLR = SMTH1(PSLR,Ta)
Recrutes__adjustment = descrepancy/Tw
RSIP = 1850+RCR
SG = TSL-ASL
Ta = 4
Tc = 13.75

Ti = 2

Tr = 2

TRIP = FSLR*Tc

TSL = 2000

Tw = 7

5.2.2 Case Study B

ASL(t) = ASL(t - dt) + (RCR - PSLR) * dt

INIT ASL = 1850

INFLOWS:

RCR = Recru_tes/Tr

OUTFLOWS:

PSLR = GRAPH(6+STEP(2,3))

(1.0, 140), (4.0, 137), (7.0, 149), (11.0, 152), (14.0, 151), (17.0, 139), (21.0, 137), (24.0, 151), (27.0, 142), (31.0, 148), (34.0, 148), (38.0, 146), (41.0, 146), (44.0, 130), (48.0, 148), (51.0, 129), (54.0, 142), (58.0, 152), (61.0, 141), (65.0, 148)

Recru_tes(t) = Recru_tes(t - dt) + (RDR - RCR) * dt

INIT Recru_tes = 12

INFLOWS:

RDR = FSLR+ASL_adjustment+Recrutes__adjustment

OUTFLOWS:

RCR = Recru_tes/Tr

ASL_adjustment = SG/Ti

descrepancy = TRIP-RSIP

FSLR = SMTH1(PSLR,Ta)

Recrutes__adjustment = descrepancy/Tw

RSIP = 12+RCR

SG = TSL-ASL

Ta = 6

Tc = 10

Ti = 3

Tr = 3

TRIP = FSLR*Tc

TSL = 1850

Tw = 7

5.3 Automated Pipeline Skill Pool Model APSKPM +(P+I) in ITHINK software

The following equations shows APSKPM +(P+I) simulation model using Ithink software in both case studies.

5.3.1 Case study A

ASL(t) = ASL(t - dt) + (RCR - PSLR) * dt

INIT ASL = 2000

INFLOWS:

RCR = Recru_tes/Tr

OUTFLOWS:

PSLR = GRAPH(140+STEP(8,3))

(1.0, 140), (4.0, 137), (7.0, 149), (11.0, 152), (14.0, 151), (17.0, 139), (21.0, 137), (24.0, 151), (27.0, 142), (31.0, 148), (34.0, 148), (38.0, 146), (41.0, 146), (44.0, 130), (48.0, 148), (51.0, 129), (54.0, 142), (58.0, 152), (61.0, 141), (65.0, 148)

Recru_tes(t) = Recru_tes(t - dt) + (RDR - RCR) * dt

INIT Recrutes = 280

INFLOWS:

RDR = (FSLR+ASL_adjustment+Recrutes__adjustment)*Ki

OUTFLOWS:

RCR = Recru_tes/Tr

ASL_adjustment = SG/Ti

descrepancy = TRIP-RSIP

FSLR = SMTH1(PSLR,Ta)

Ki = 0.8

Recrutes__adjustment = descrepancy/Tw

RSIP = 1850+RCR

SG = TSL-ASL

Ta = 4

Tc = 13.75

Ti = 2

Tr = 2

TRIP = FSLR*Tc

TSL = 2000

Tw = 7

5.3.2 Case Study B

ASL(t) = ASL(t - dt) + (RCR - PSLR) * dt

INIT ASL = 1850

INFLOWS:

RCR = Recru_tes/Tr

OUTFLOWS:

PSLR = GRAPH(6+STEP(2,3))

(1.0, 140), (4.0, 137), (7.0, 149), (11.0, 152), (14.0, 151), (17.0, 139), (21.0, 137), (24.0, 151), (27.0, 142), (31.0, 148), (34.0, 148), (38.0, 146), (41.0, 146), (44.0, 130), (48.0, 148), (51.0, 129), (54.0, 142), (58.0, 152), (61.0, 141), (65.0, 148)

Recru_tes(t) = Recru_tes(t - dt) + (RDR - RCR) * dt

INIT Recru_tes = 12

INFLOWS:

RDR = (FSLR+ASL_adjustment+Recrutes__adjustment)*Ki

OUTFLOWS:

RCR = Recru_tes/Tr

ASL_adjustment = SG/Ti

descrepancy = TRIP-RSIP

FSLR = SMTH1(PSLR,Ta)

Ki = 0.8

Recrutes__adjustment = descrepancy/Tw

RSIP = 12+RCR

SG = TSL-ASL

Ta = 6

Tc = 8

Ti = 3

Tr = 3

TRIP = FSLR*Tc

TSL = 1850

Tw = 7

5.4: Three Grades promotion SKPM model in ITHINK software

The following equations shows 3 Grades promotion model in SKPM simulation model using Ithink software.

ASLG1(t) = ASLG1(t - dt) + (PCRG1 - PSMFG1) * dt

INIT ASLG1 = 1000

INFLOWS:

PCRG1 = PSIG1/Tp1

OUTFLOWS:

PSMFG1 = GRAPH(20+STEP(3,2))

(1.0, 140), (4.0, 137), (7.0, 149), (11.0, 152), (14.0, 151), (17.0, 139), (21.0, 137), (24.0, 151), (27.0, 142), (31.0, 148), (34.0, 148), (38.0, 146), (41.0, 146), (44.0, 130), (48.0, 148), (51.0, 129), (54.0, 142), (58.0, 152), (61.0, 141), (65.0, 148)

ASLG2(t) = ASLG2(t - dt) + (PCRG2 - PSMFG2) * dt

INIT ASLG2 = 800

INFLOWS:

PCRG2 = PSIG2/Tp2

OUTFLOWS:

PSMFG2 = PDRG1*k12

ASLG3(t) = ASLG3(t - dt) + (PCRG3 - PSMFG3) * dt

INIT ASLG3 = 200

INFLOWS:

PCRG3 = PSIG3/Tp3

OUTFLOWS:

PSMFG3 = PDRG2* k23

PSIG1(t) = PSIG1(t - dt) + (PDRG1 - PCRG1) * dt

INIT PSIG1 = 40

INFLOWS:

PDRG1 = FPSMG1+ASLG1_adj

OUTFLOWS:

PCRG1 = PSIG1/Tp1

PSIG2(t) = PSIG2(t - dt) + (PDRG2 - PCRG2) * dt

INIT PSIG2 = 10

INFLOWS:

PDRG2 = FPSMG2+ASLG2_adj

OUTFLOWS:

PCRG2 = PSIG2/Tp2

PSIG3(t) = PSIG3(t - dt) + (PDRG3 - PCRG3) * dt

INIT PSIG3 = 4

INFLOWS:

PDRG3 = FPSMFG3+ASLG3_adj

OUTFLOWS:

PCRG3 = PSIG3/Tp3

ASLG1_adj = SGG1/Ti1

ASLG2_adj = SGG2/Ti2

ASLG3_adj = SGG3/TI3

FPSMFG3 = SMTH1(PSMFG3,Ta3)

FPSMG1 = SMTH1(PSMFG1,Ta1)

FPSMG2 = SMTH1(PSMFG2,Ta2)

k12 = 0.6

k23 = 0.2

SGG1 = TSLG1-ASLG1

SGG2 = TSLG2-ASLG2

SGG3 = TSLG3-ASLG3

Ta1 = 8

Ta2 = 8

Ta3 = 8

Ti1 = 4

Ti2 = 4

TI3 = 4

total_staff_gap = SGG1+SGG2+SGG3

Tp1 = 4

Tp2 = 4

Tp3 = 4

TPCR = PCRG1+PCRG2+PCRG3

TSL = ASLG1+ASLG2+ASLG3

TSLG1 = 1000

TSLG2 = 800

TSLG3 = 200

5.5: Three Grades promotion model in APSKPM in ITHINK software

The following equations shows 3 Grades promotion model in APSKPM simulation model using Ithink software.

ASL1(t) = ASL1(t - dt) + (PCR1 - PSLR) * dt
INIT ASL1 = 1000

INFLOWS:
PCR1 = Promoted1/Tr1
OUTFLOWS:
PSLR = GRAPH(20+STEP(3,2))
(0.00, 6.00), (3.42, 18.0), (6.84, 14.0), (10.3, 17.0), (13.7, 15.0), (17.1, 23.0), (20.5, 21.0), (23.9, 16.0), (27.4, 25.0), (30.8, 25.0), (34.2, 20.0), (37.6, 20.0), (41.1, 20.0), (44.5, 20.0), (47.9, 20.0), (51.3, 20.0), (54.7, 20.0), (58.2, 20.0), (61.6, 20.0), (65.0, 20.0)
ASLG2(t) = ASLG2(t - dt) + (RCRG2 - PSLR_2) * dt
INIT ASLG2 = 800

INFLOWS:
RCRG2 = Recru_tes_2/Tr_2+PCR1*k12
OUTFLOWS:
PSLR_2 = 10+STEP(2,2)
ASLG3(t) = ASLG3(t - dt) + (RCRG3 - PSLR_3) * dt
INIT ASLG3 = 200

INFLOWS:
RCRG3 = Recru_tes_3/Tr_3+RCRG2*k23
OUTFLOWS:
PSLR_3 = 3+STEP(1,2)
Promoted1(t) = Promoted1(t - dt) + (PDR1 - PCR1) * dt
INIT Promoted1 = 60

INFLOWS:

PDR1 = (FSLR+ASL_adjustment+Recrutes__adjustment/Tw1)

OUTFLOWS:

PCR1 = Promoted1/Tr1

Recru_tes_2(t) = Recru_tes_2(t - dt) + (RDR_2 - RCRG2) * dt

INIT Recru_tes_2 = 20

INFLOWS:

RDR_2 = (FSLR_2+ASL_adjustment_2+Recrutes__adjustment_2/Tw_2)

OUTFLOWS:

RCRG2 = Recru_tes_2/Tr_2+PCR1*k12

Recru_tes_3(t) = Recru_tes_3(t - dt) + (RDR_3 - RCRG3) * dt

INIT Recru_tes_3 = 6

INFLOWS:

RDR_3 = (FSLR_3+ASL_adjustment_3+Recrutes__adjustment_3/Tw_3)

OUTFLOWS:

RCRG3 = Recru_tes_3/Tr_3+RCRG2*k23

ASL_adjustment = SG/Ti1

ASL_adjustment_2 = SG_2/Ti_2

ASL_adjustment_3 = SG_3/Ti_3

FSLR = SMTH1(PSLR,Ta1)

FSLR_2 = SMTH1(PSLR_2,Ta_2)

FSLR_3 = SMTH1(PSLR_3,Ta_3)

k12 = 0.2

k23 = 0.05

Recrutes__adjustment = target_staff__in_process-Promoted1

Recrutes__adjustment_2 = target_staff__in_process_2-Recru_tes_2

Recrutes__adjustment_3 = target_staff__in_process_3-Recru_tes_3

SG = TSL-ASL1

SG_2 = TSL_2-ASLG2

SG_3 = TSL_3-ASLG3

Ta1 = 8

target_staff__in_process = FSLR*Tc1

target_staff__in_process_2 = FSLR_2*Tc_2

target_staff__in_process_3 = FSLR_3*Tc_3

Ta_2 = 6

Ta_3 = 4

Tc1 = 4

Tc_2 = 4

Tc_3 = 4

Ti1 = 4

Ti2 = 4

Ti3 = 4

Total_promotion__rate = PCR1+RCRG2+RCRG3

Total_staff__level = ASL1+ASLG2+ASLG3

Tr1 = 4

Tr_2 = 6

Tr_3 = 4

TSG = SG+SG_2+SG_3

TSL = 1000

TSL_2 = 800

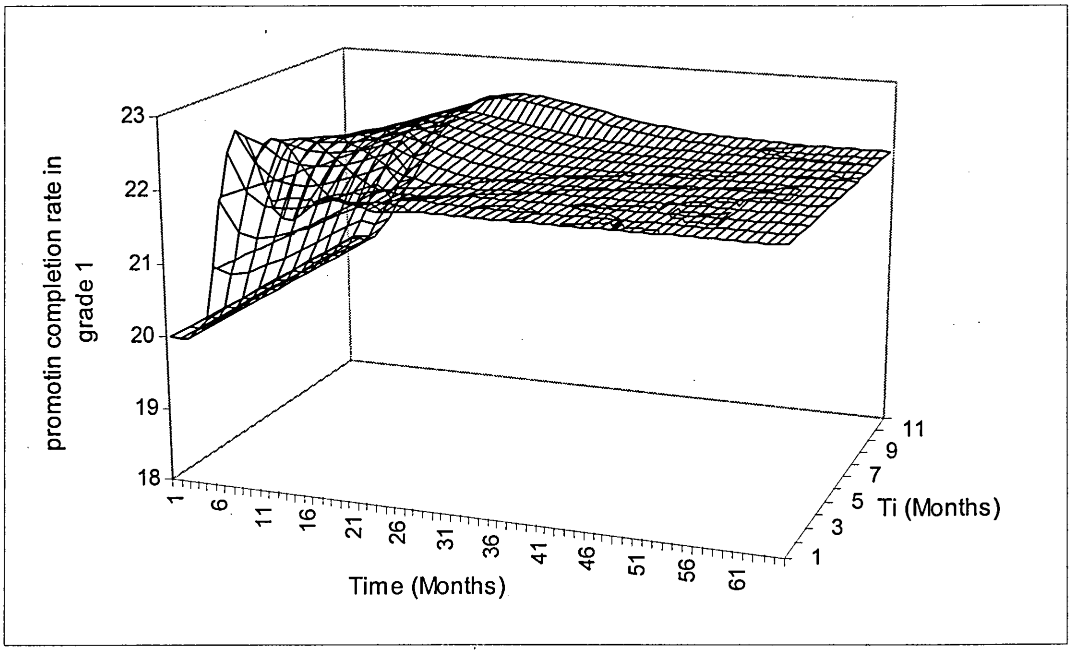
TSL_3 = 200

Tw1 = 12

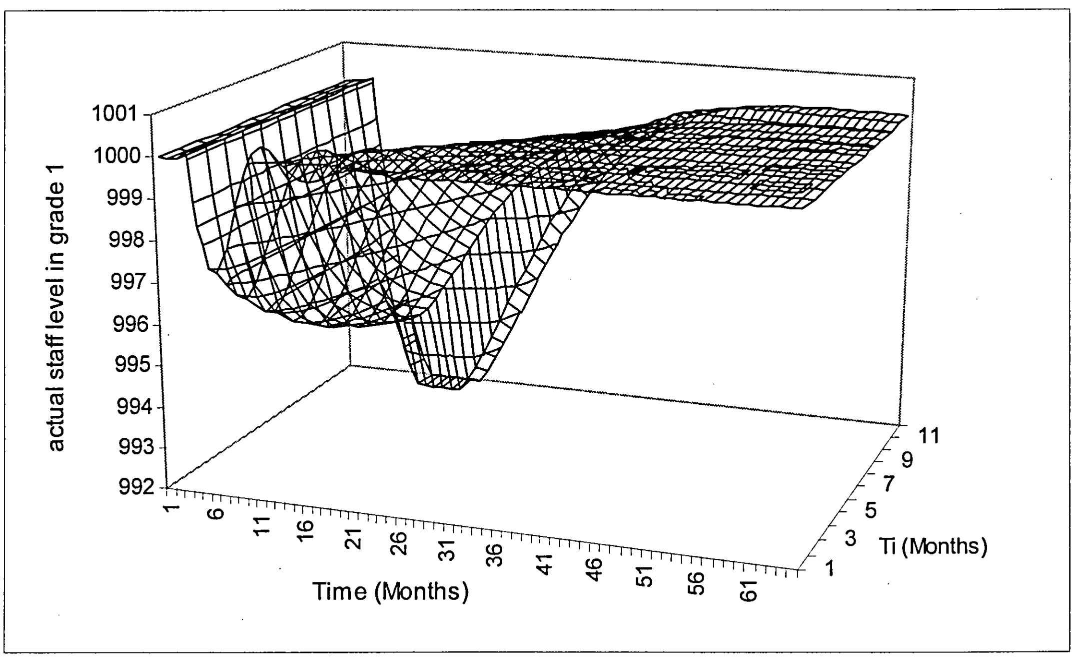
Tw_2 = 8

Tw_3 = 7

Appendix 6
Simulation results for promotion and progression Skill pool model (PPSKPM)

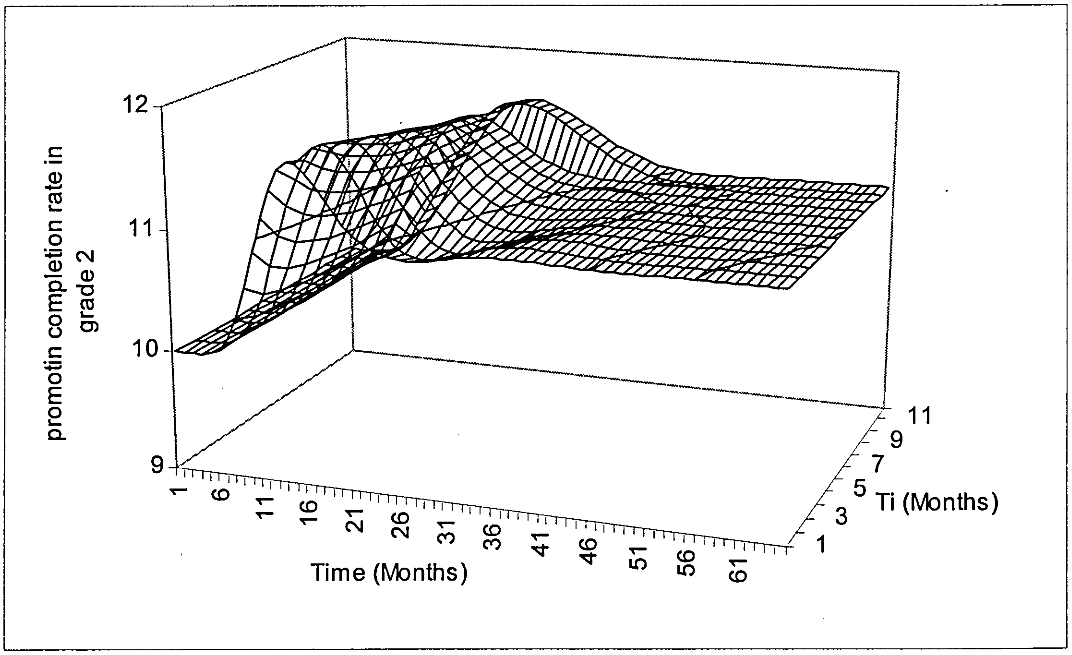


(a) Promotion completion rate behaviour for grade 1

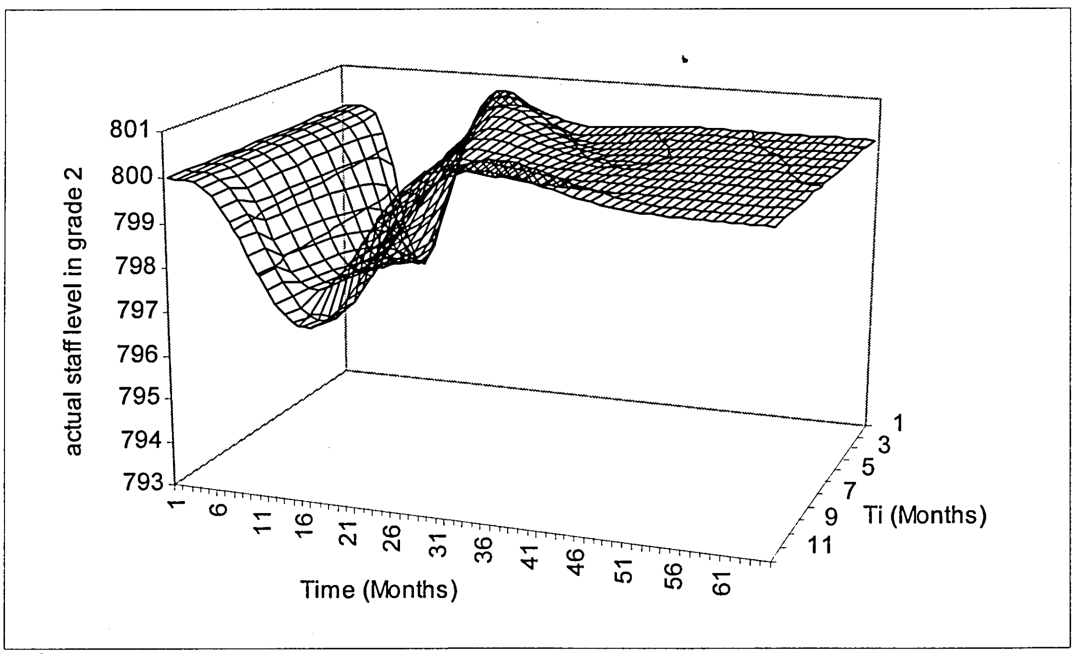


(b) Staff level behaviour for grade 1

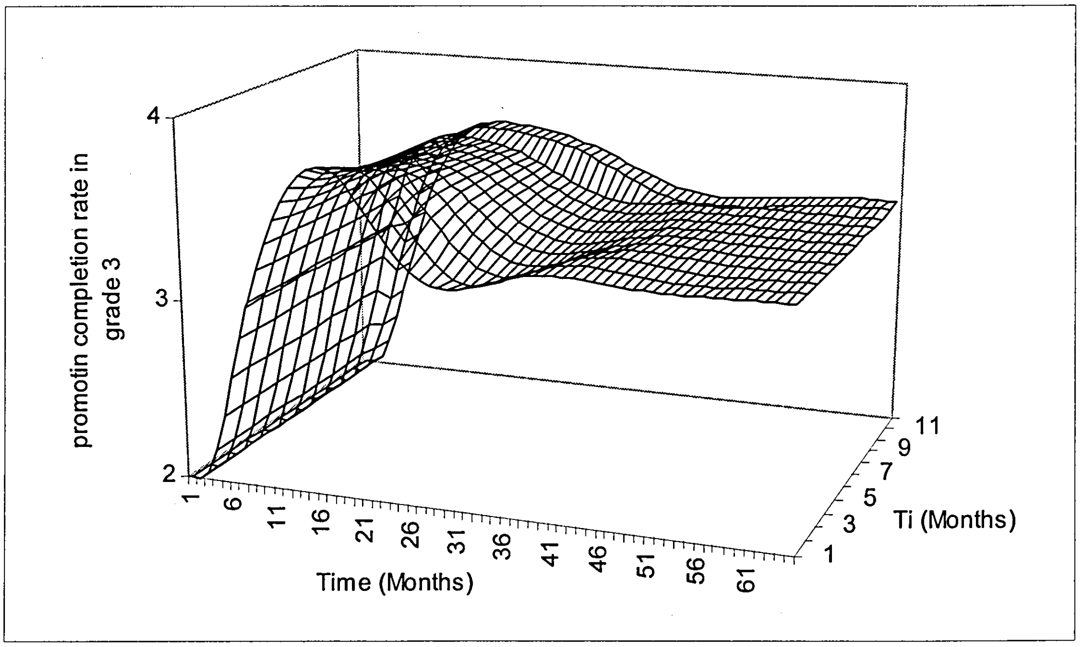
Figure 6.1: Response of PPSKPM for varying values of Ti



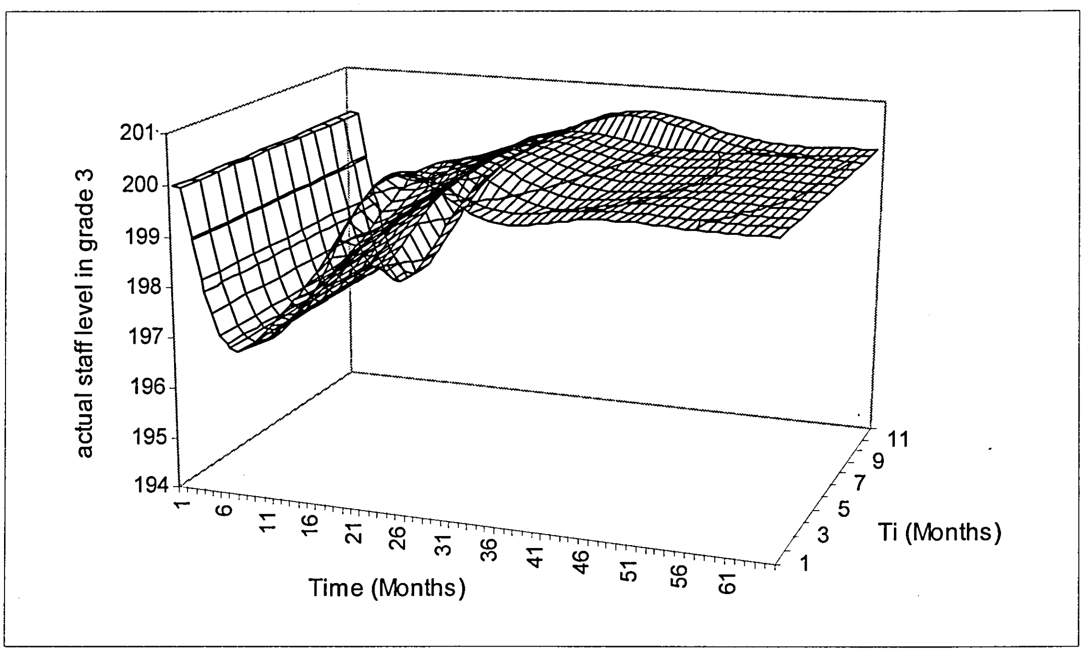
(a) Promotion completion rate behaviour for grade 2



(b) Staff level behaviour for grade 2
Figure 6.2: Response of PPSKPM for varying values of Ti

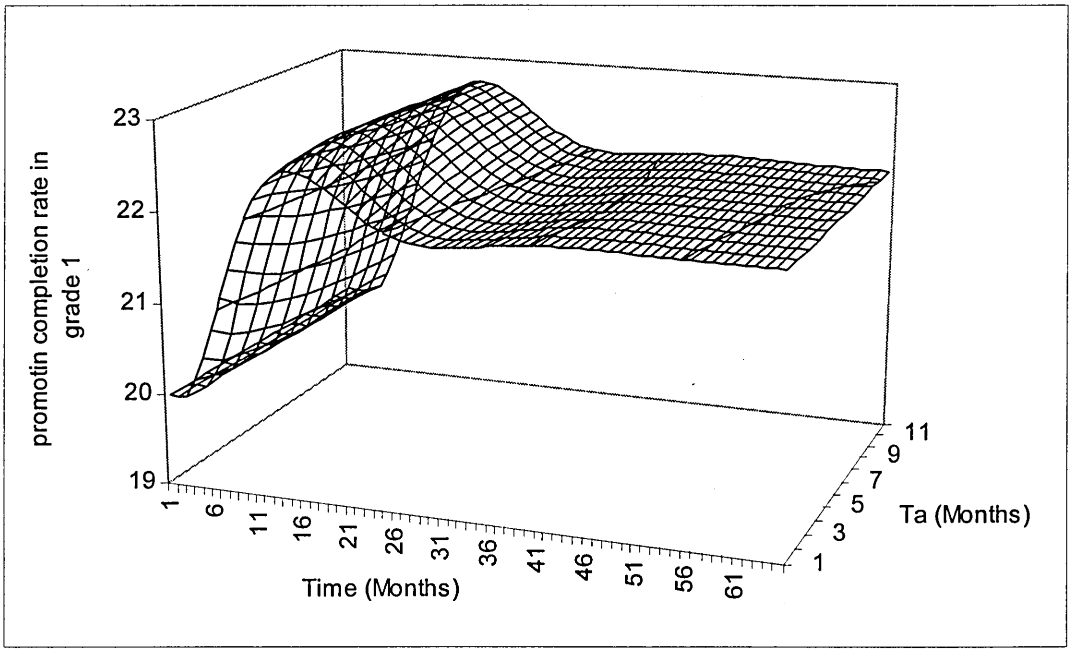


(a) Promotion completion rate behaviour for grade 3

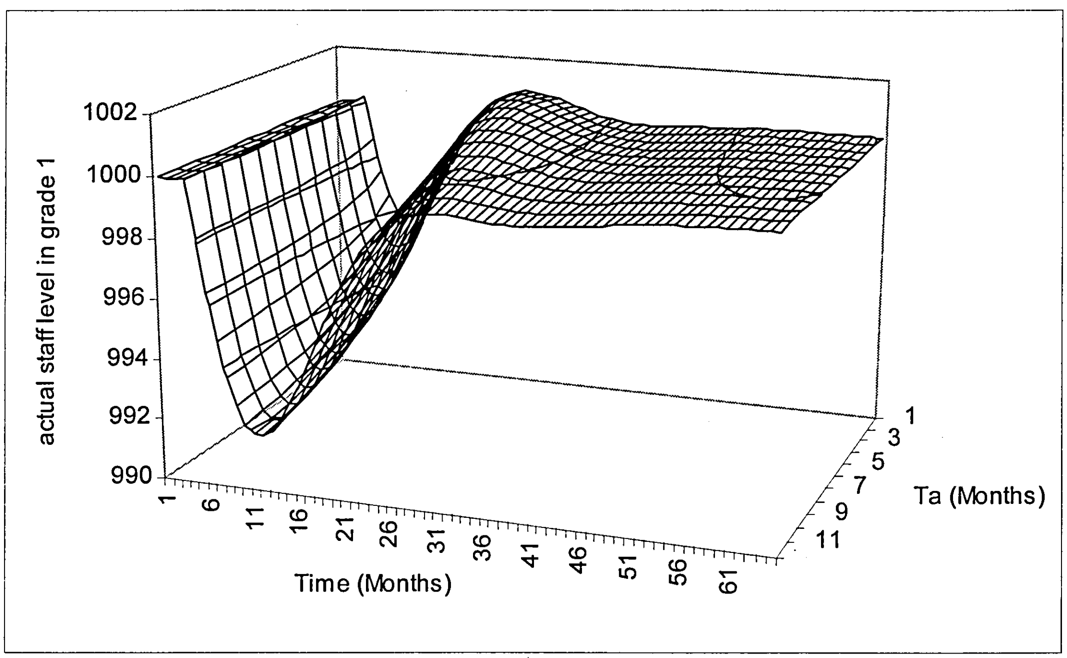


(b) Staff level behaviour for grade 3

Figure 6.3: Response of PPSKPM for varying values of Ti

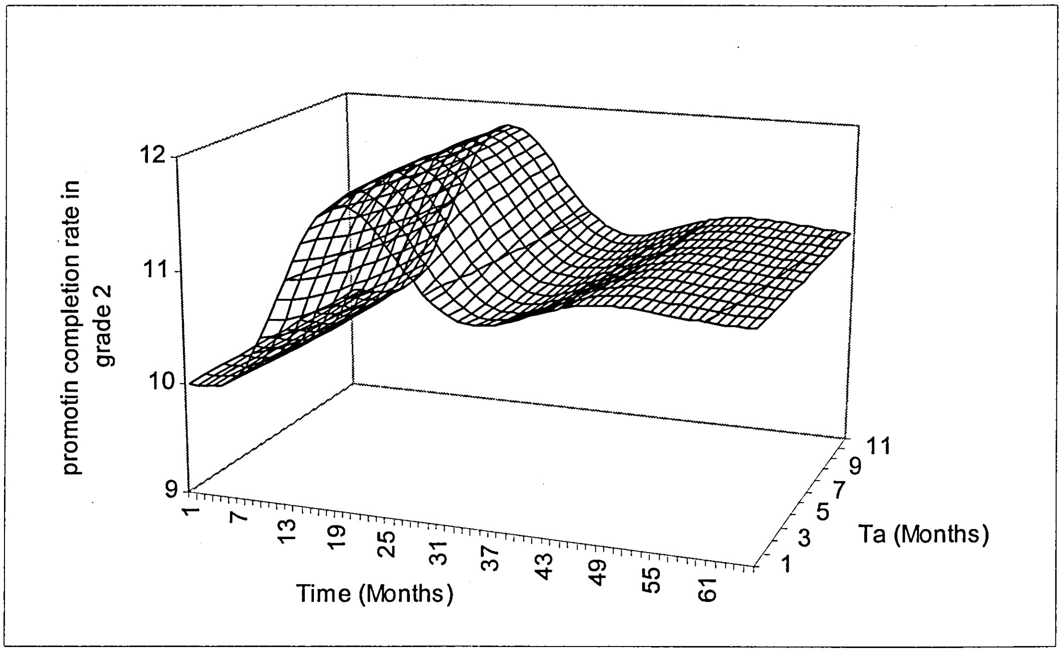


(a) Promotion completion rate behaviour for grade 1

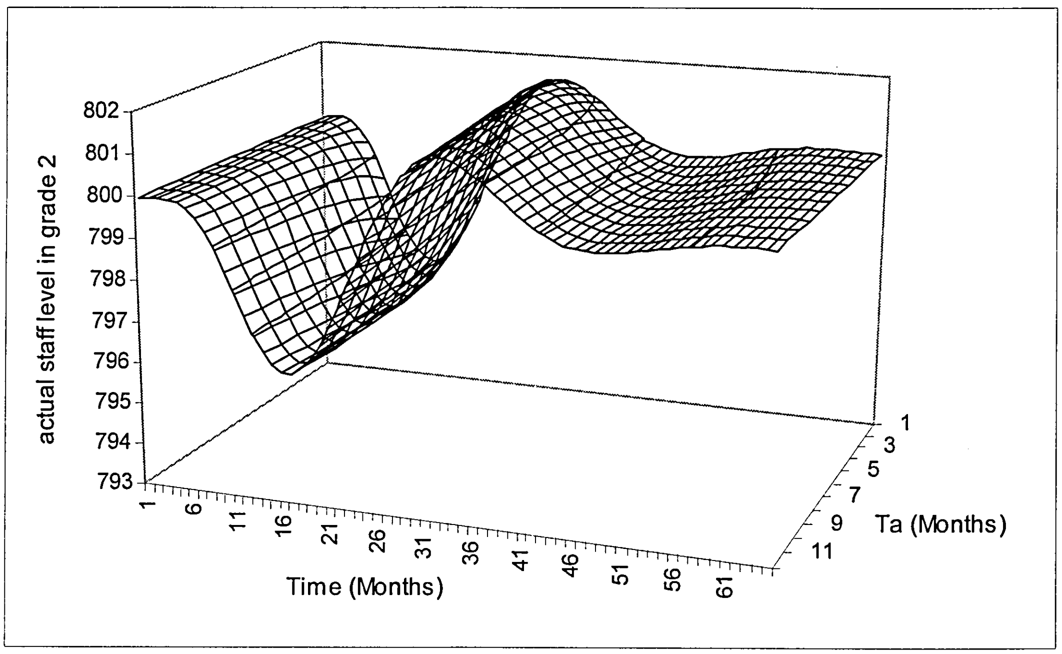


(b) Staff level behaviour for grade 1

Figure 6.4: Response of PPSKPM for varying values of Ta

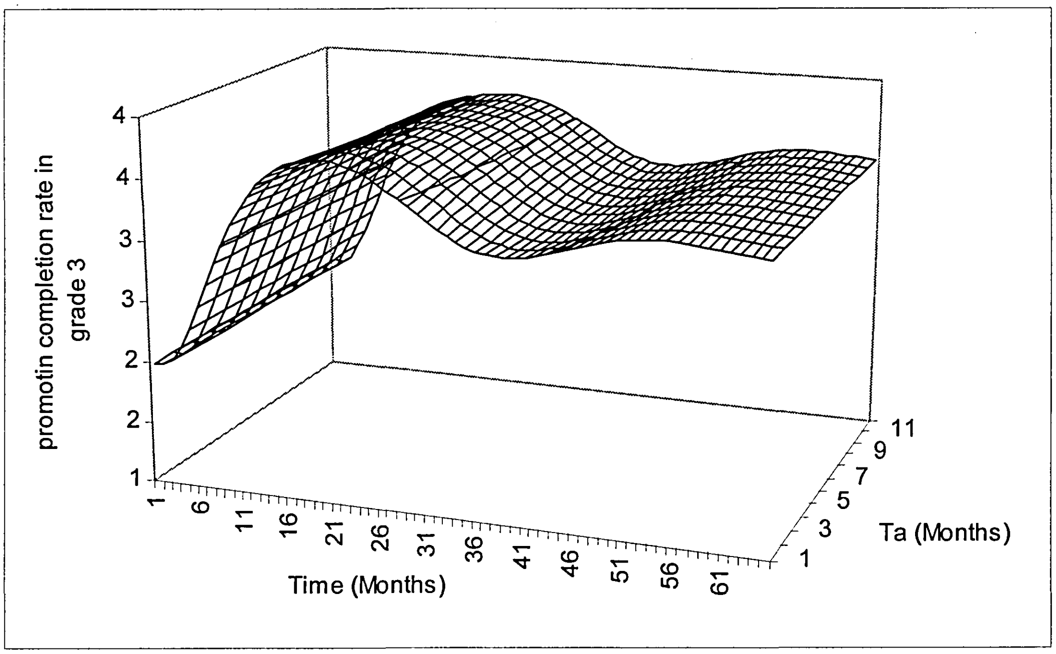


(a) Promotion completion rate behaviour for grade 2

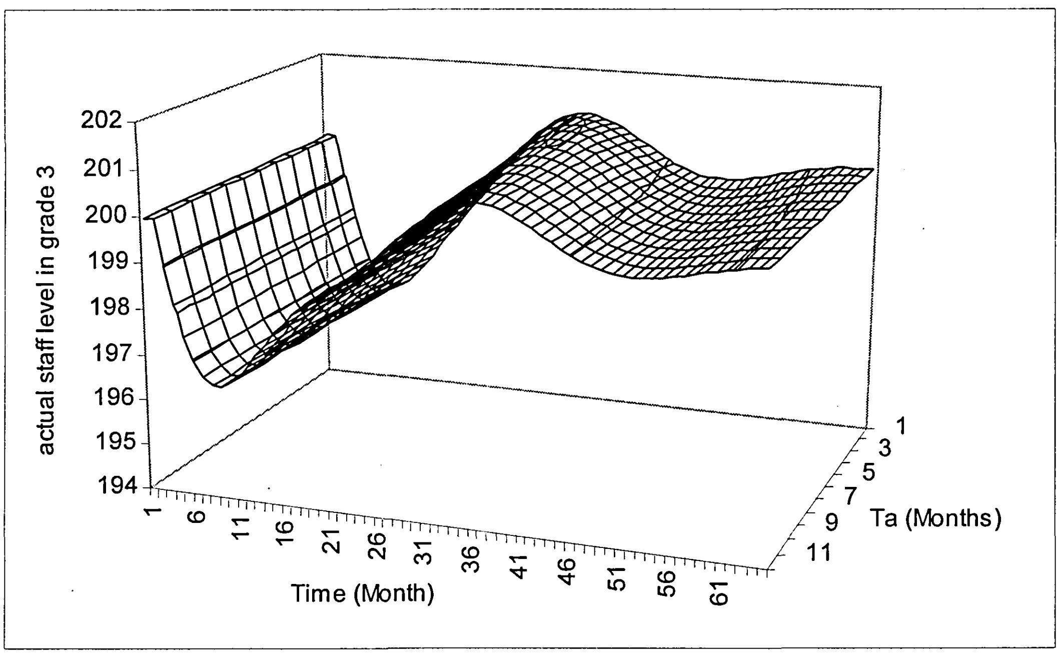


(b) Staff level behaviour for grade 2

Figure 6.5: Response of PPSKPM for varying values of Ta

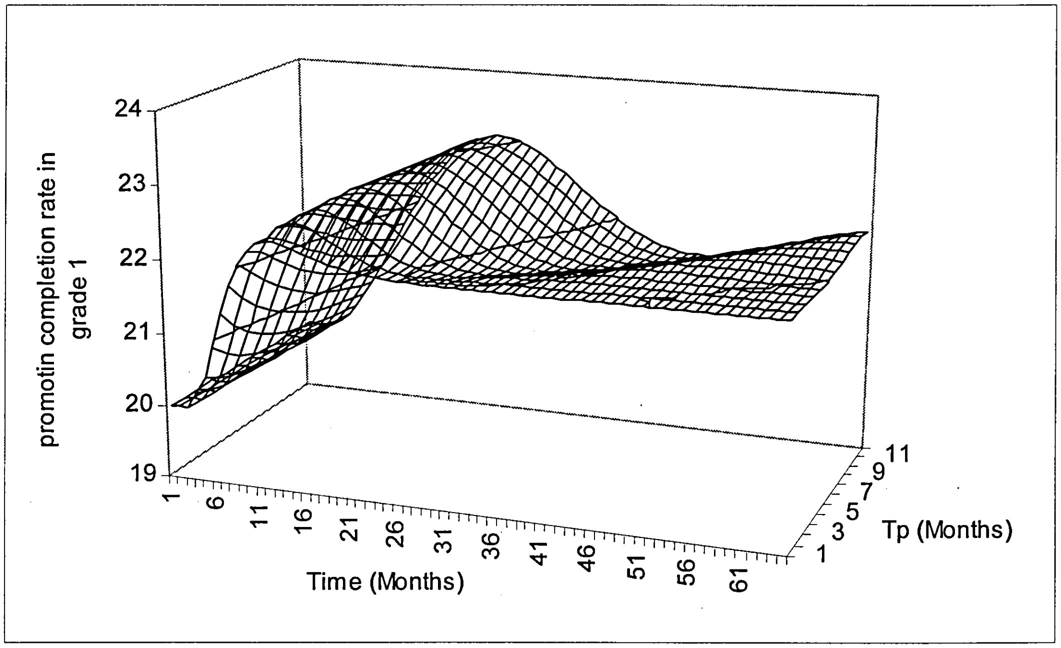


(a) Promotion completion rate behaviour for grade 3

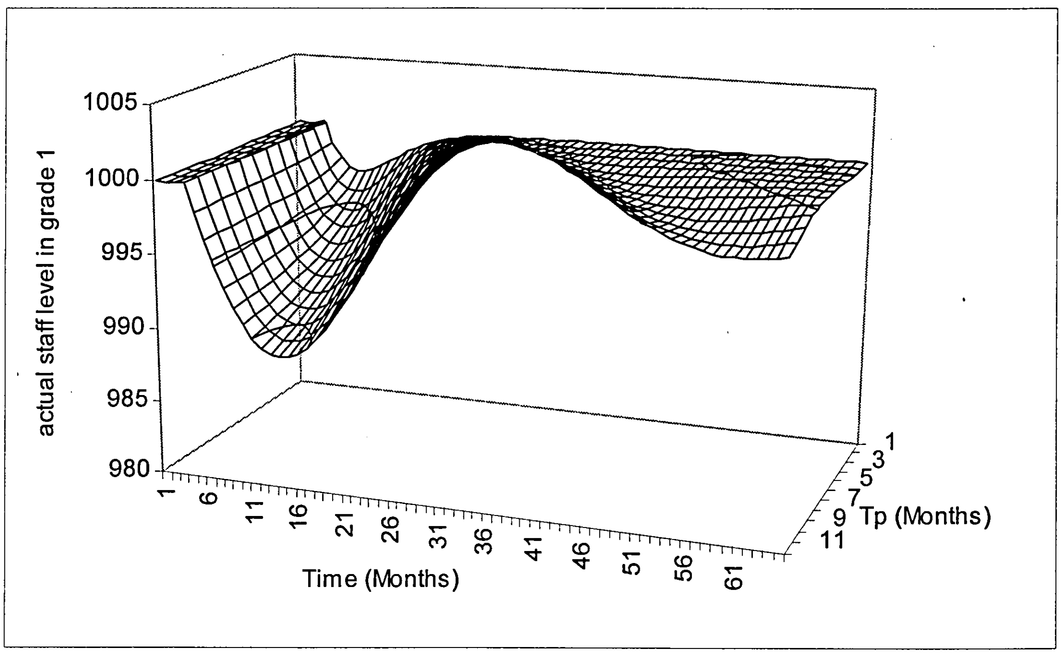


(b) Staff level behaviour for grade 3

Figure 6.6: Response of PPSKPM for varying values of Ta

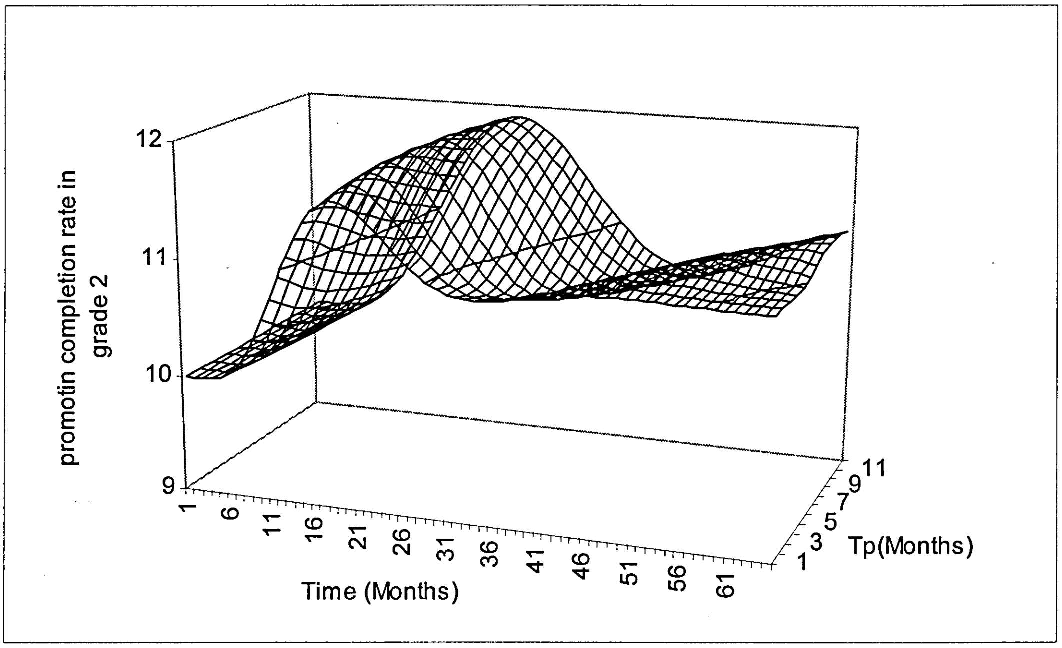


(a) Promotion completion rate behaviour for grade 1

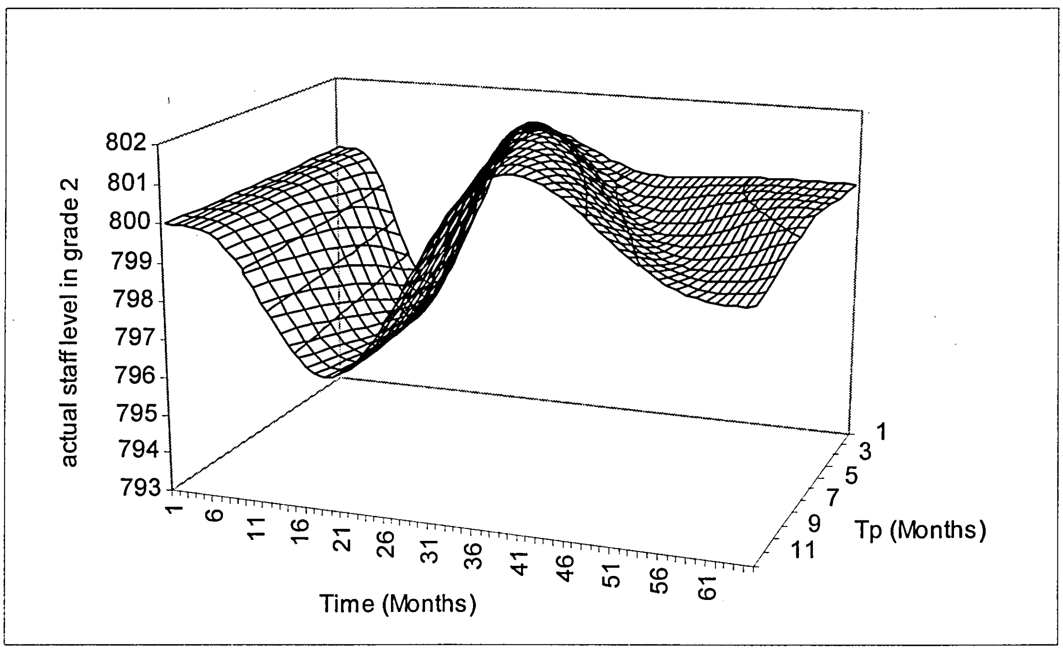


(b) Staff level behaviour for grade 1

Figure 6.7: Response of PPSKPM for varying values of Tp

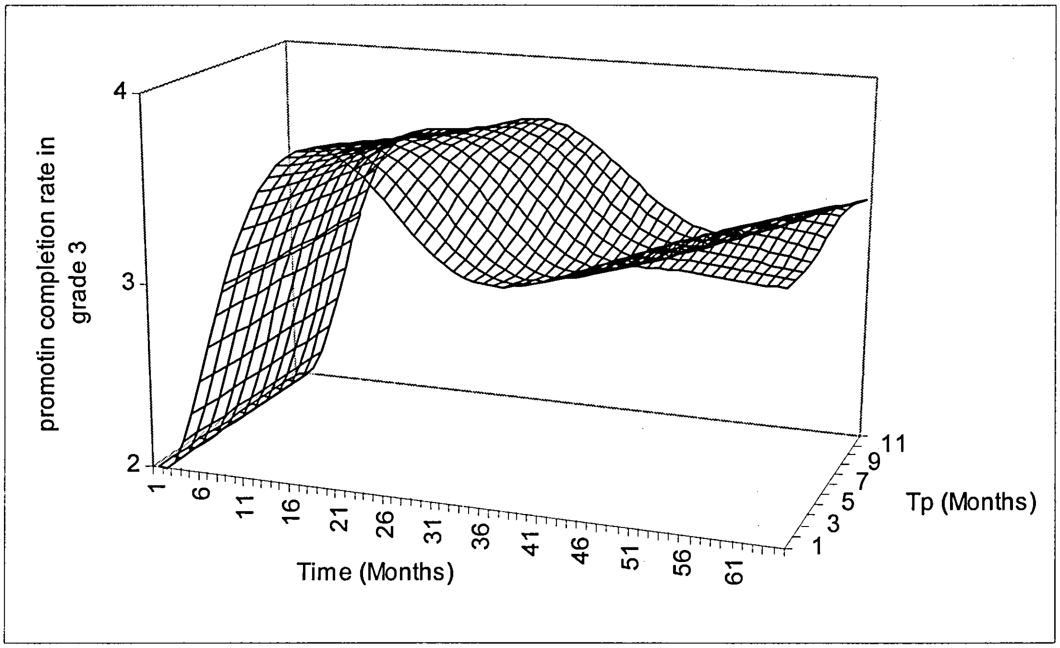


(a) Promotion completion rate behaviour for grade2

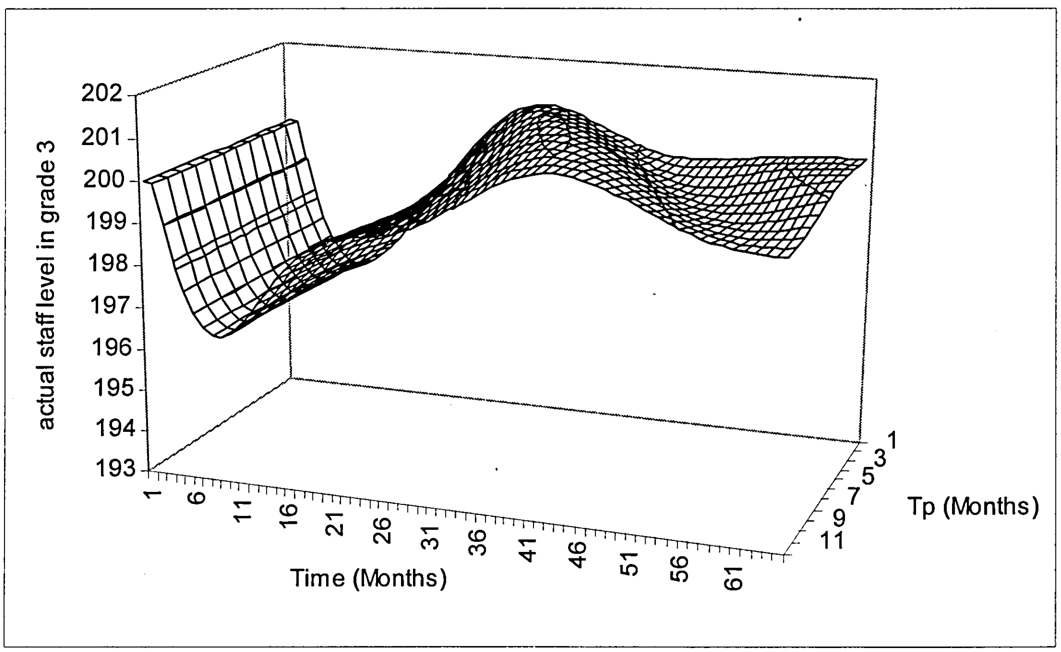


(b) Staff level behaviour for grade 2

Figure 6.8: Response of PPSKPM for varying values of Tp



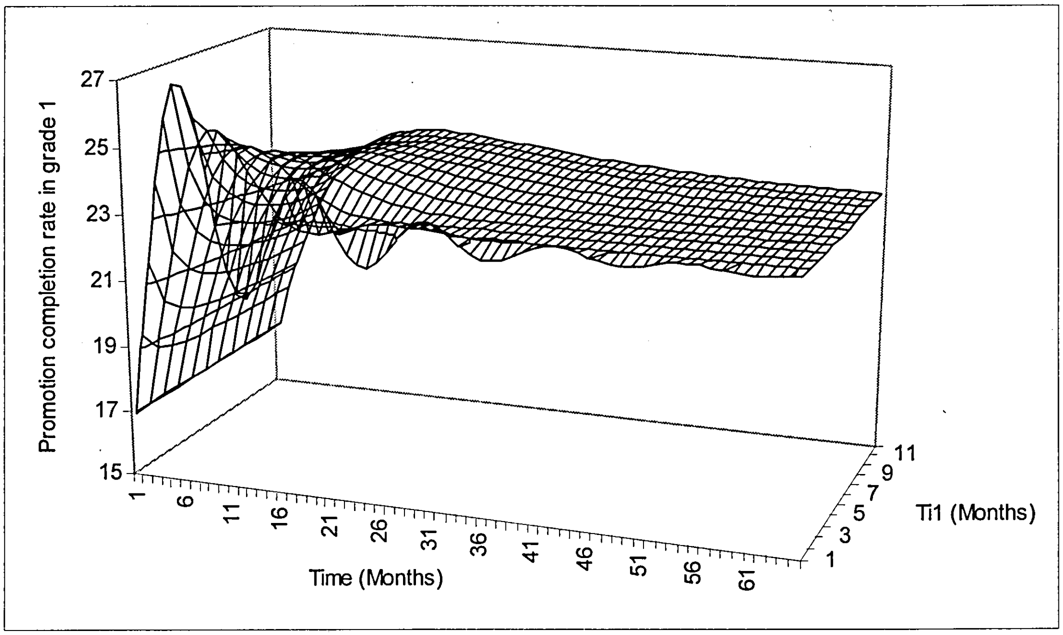
(a) Promotion completion rate behaviour for grade 3



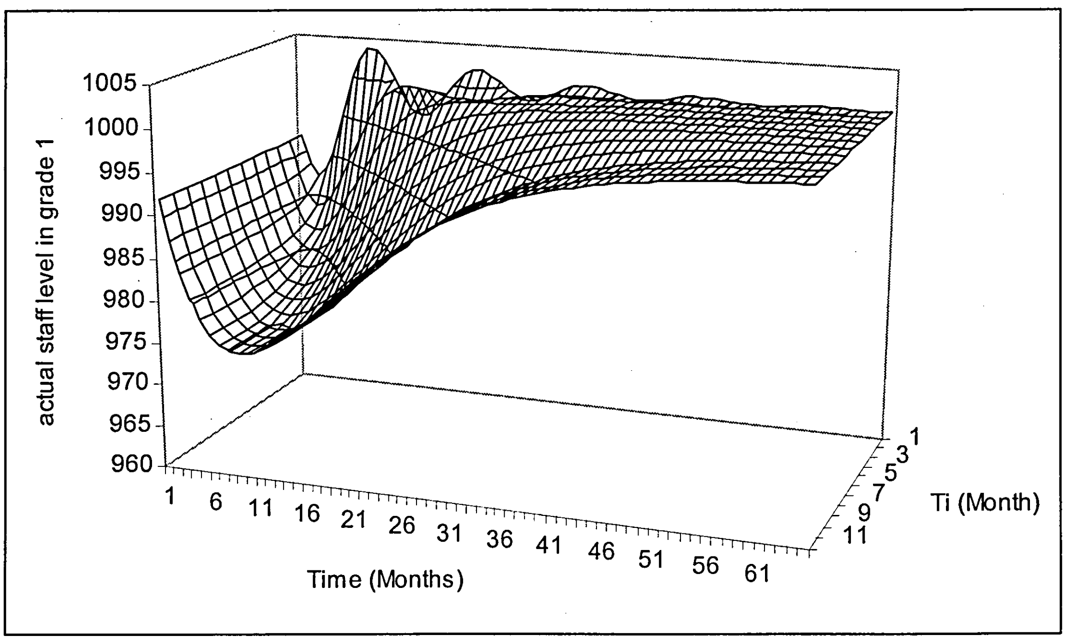
(b) Staff level behaviour for grade 3

Figure 6.9: Response of PPSKPM for varying values of Tp

APPENDIX 7
Simulation results for promotion and progression Skill pool model (PPAPSKPM)

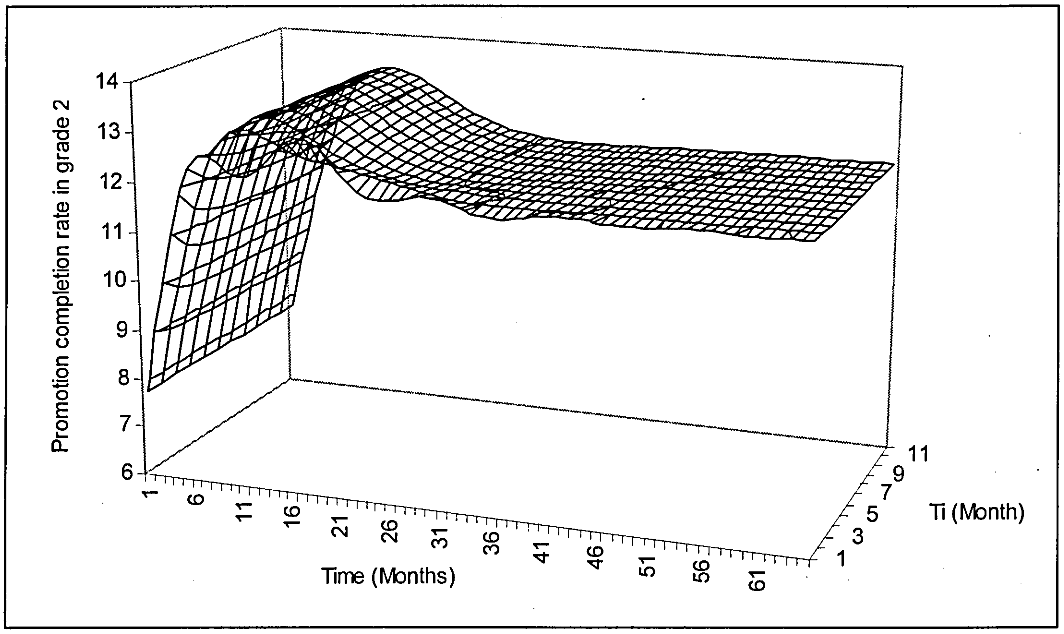


(a) Promotion completion rate behaviour for grade 1

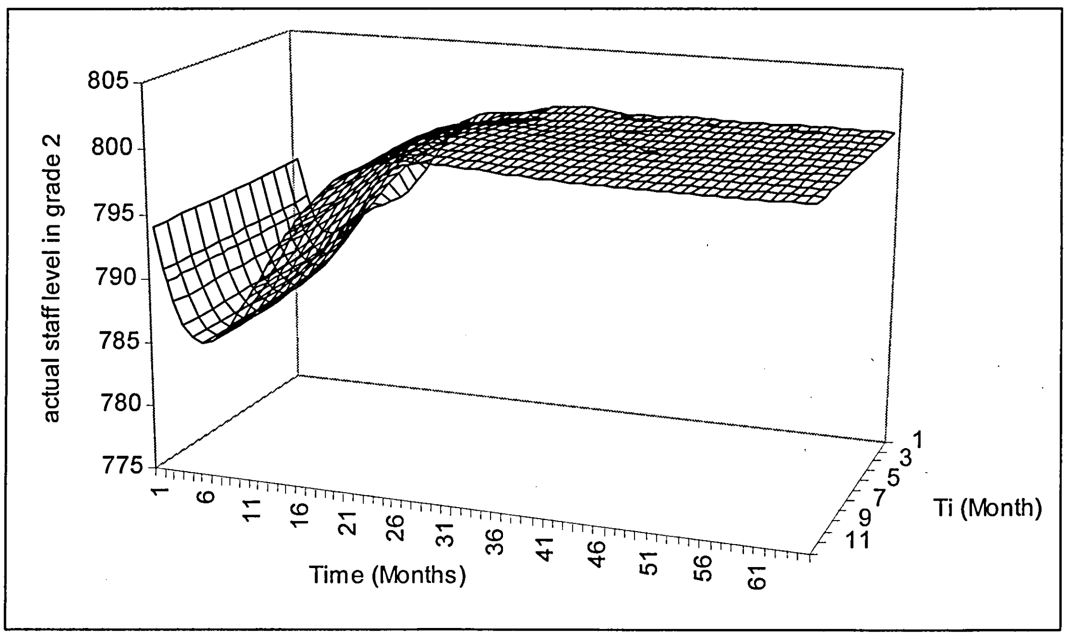


(b) Staff level behaviour for grade 1

Figure 6.10: Response of PPAPSKPM for varying values of Ti

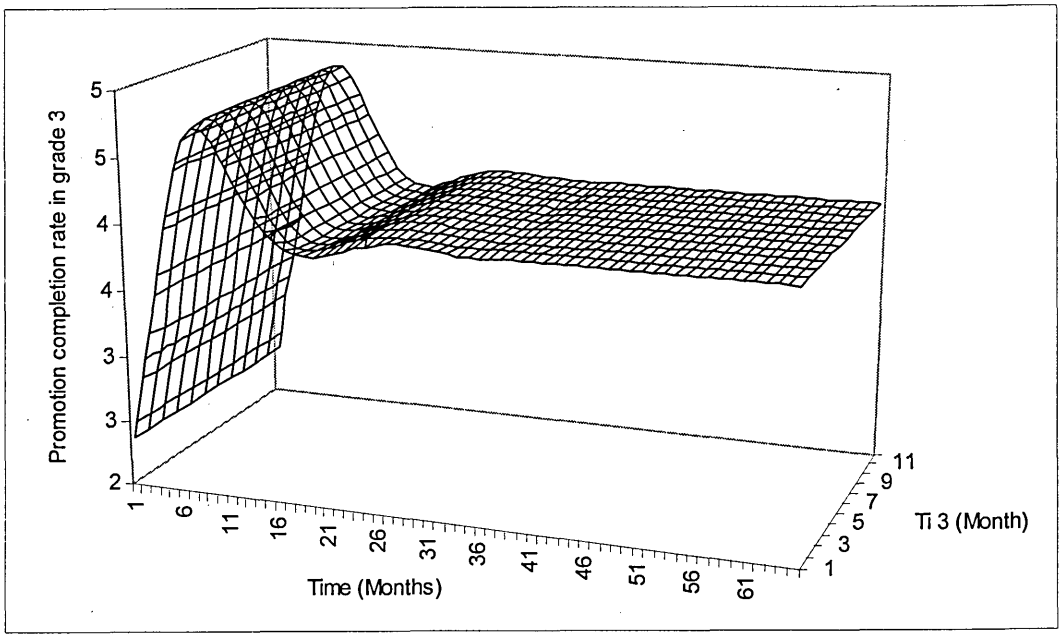


(a) Promotion completion rate behaviour for grade 2

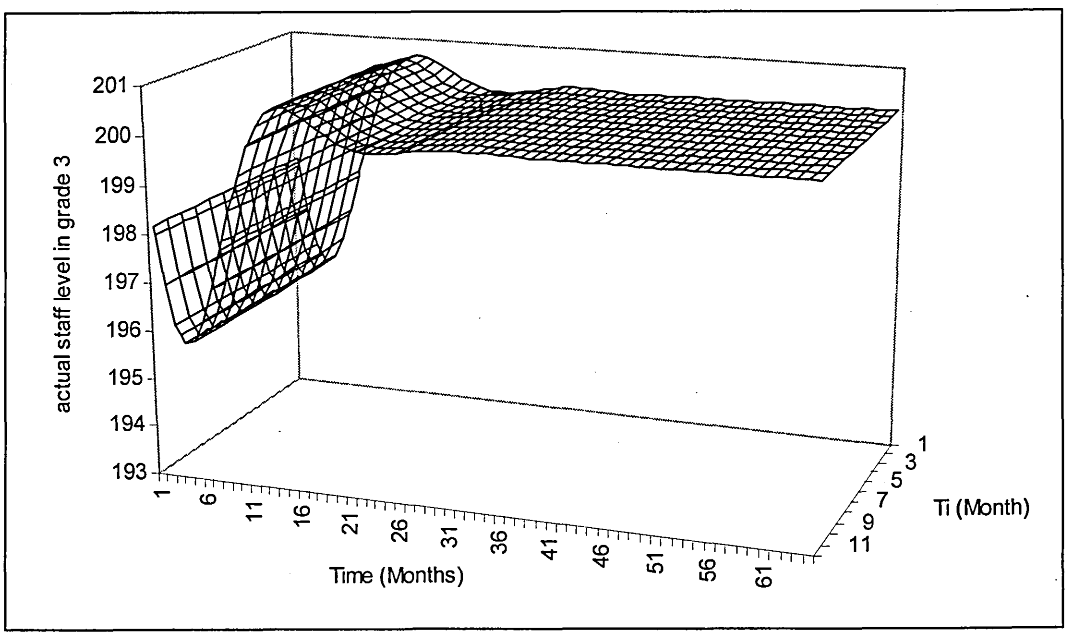


(b) Staff level behaviour for grade 2

Figure 6.11: Response of PPAPSKPM for varying values of Ti

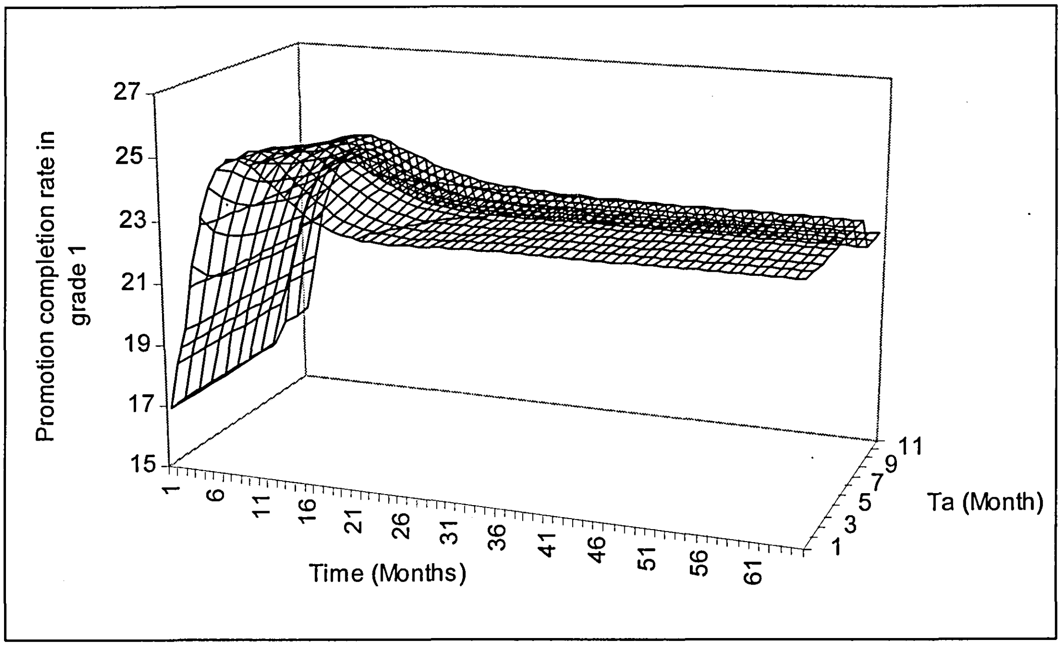


(a) Promotion completion rate behaviour for grade 3

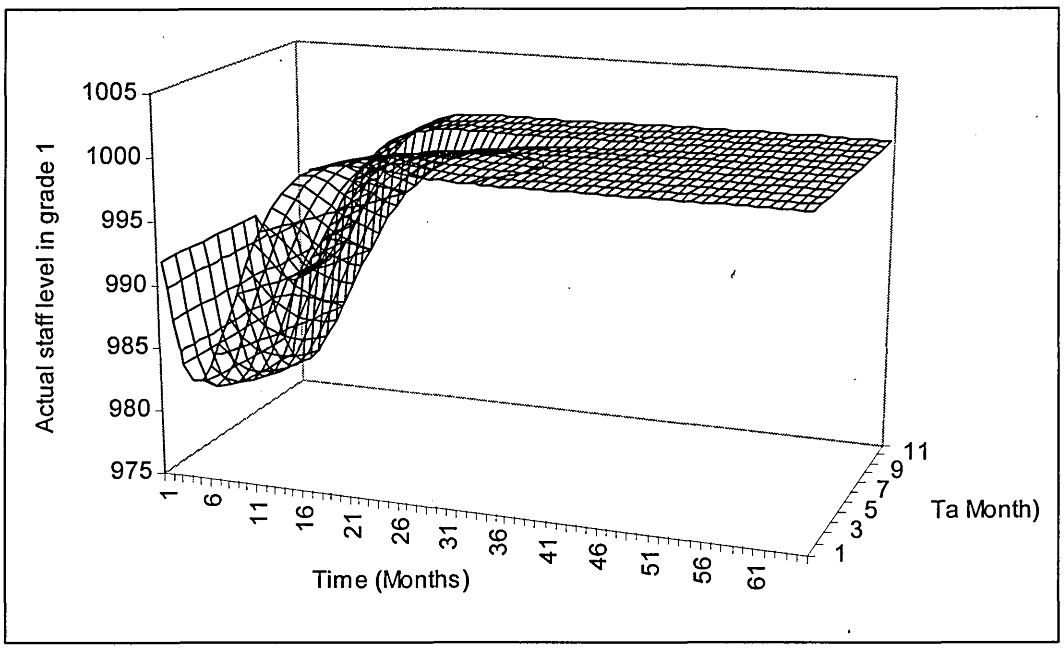


(b) Staff level behaviour for grade 3

Figure 6.12: Response of PPAPSKPM for varying values of Ti

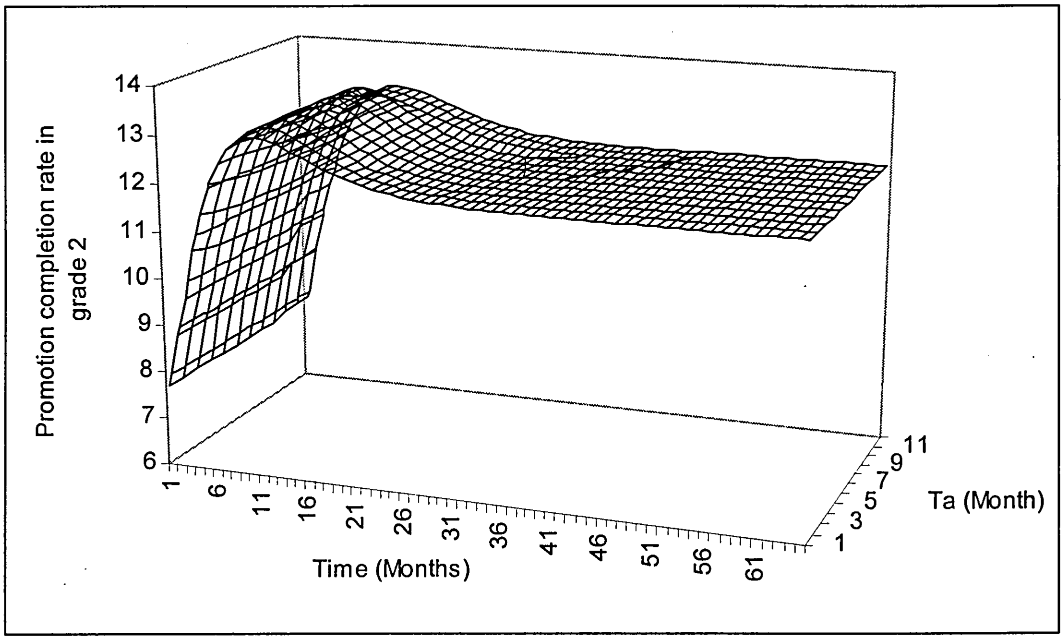


(a) Promotion completion rate behaviour for grade 1

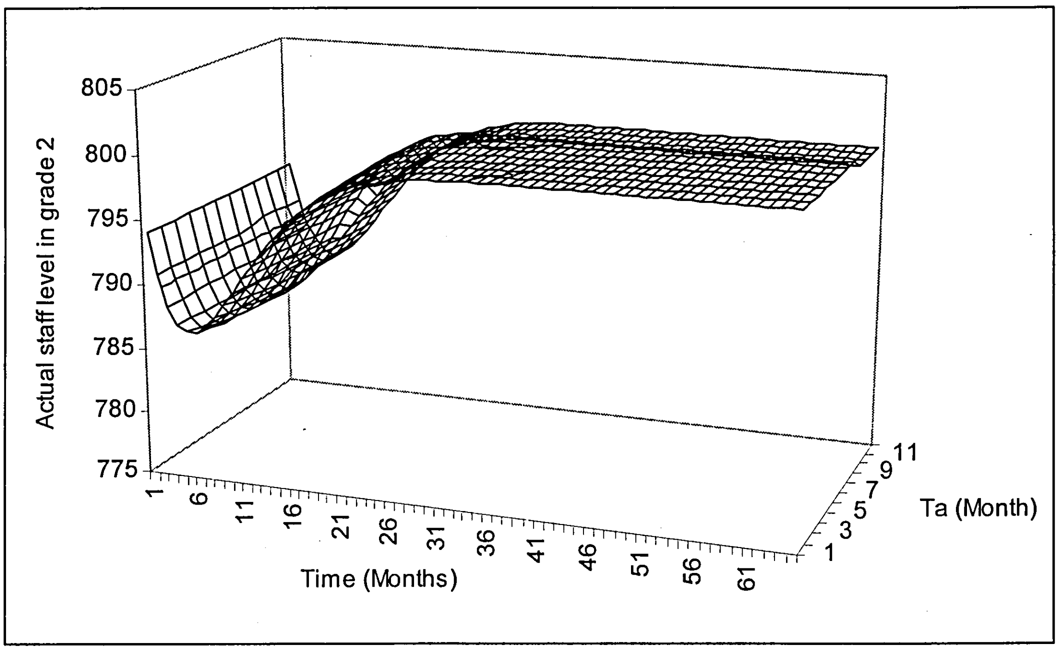


(b) Staff level behaviour for grade 1

Figure 6.13: Response of PPAPSKPM for varying values of Ta

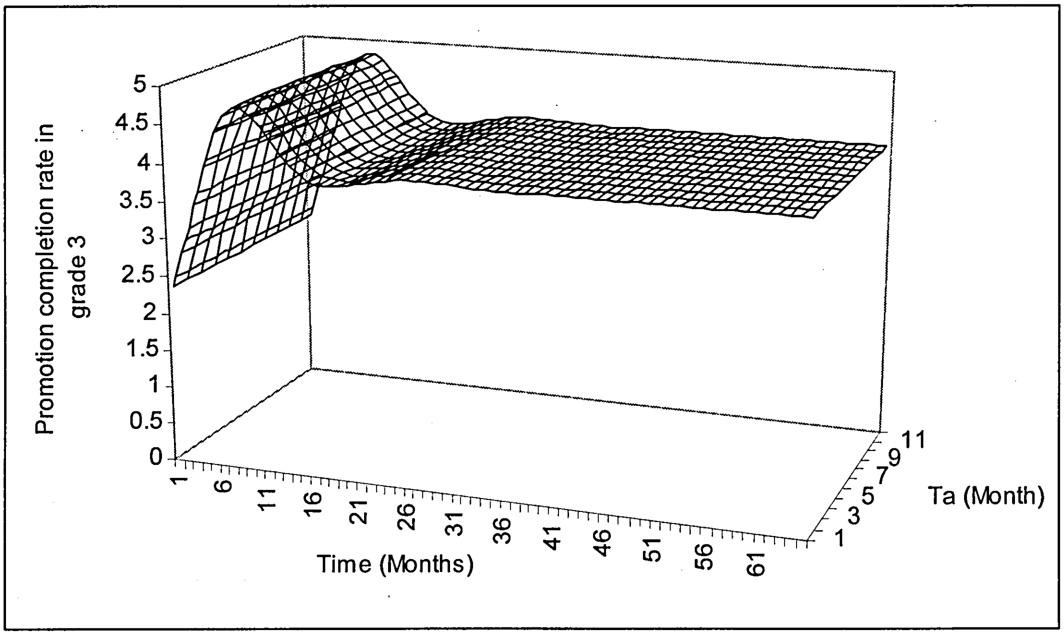


(a) Promotion completion rate behaviour for grade 2

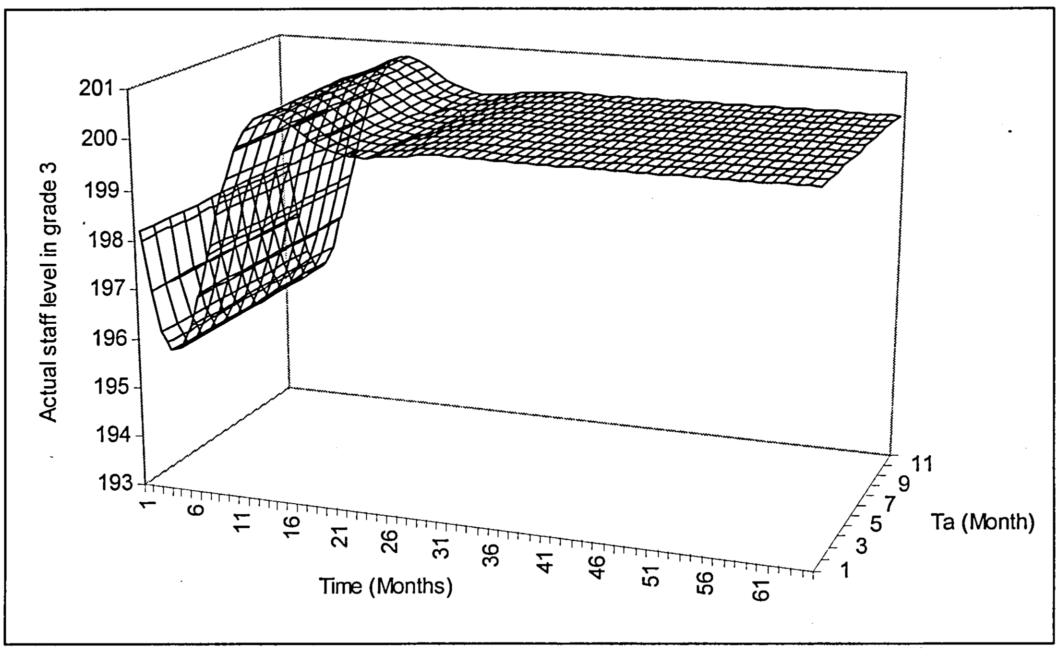


(b) Staff level behaviour for grade 2

Figure 6.14: Response of PPAPSKPM for varying values of Ta

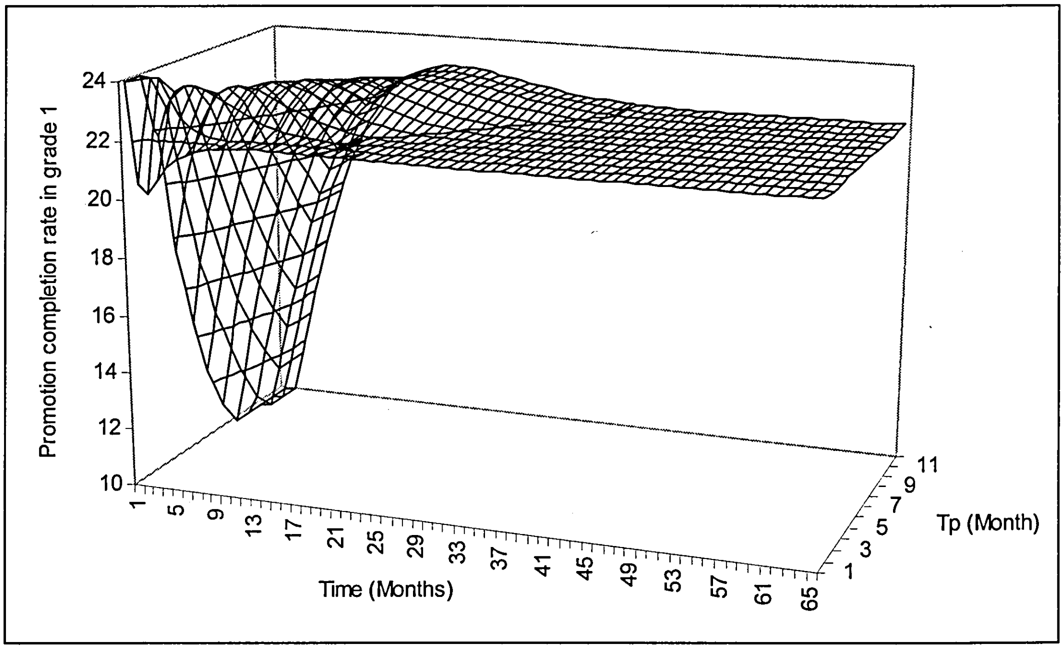


(a) Promotion completion rate behaviour for grade 3

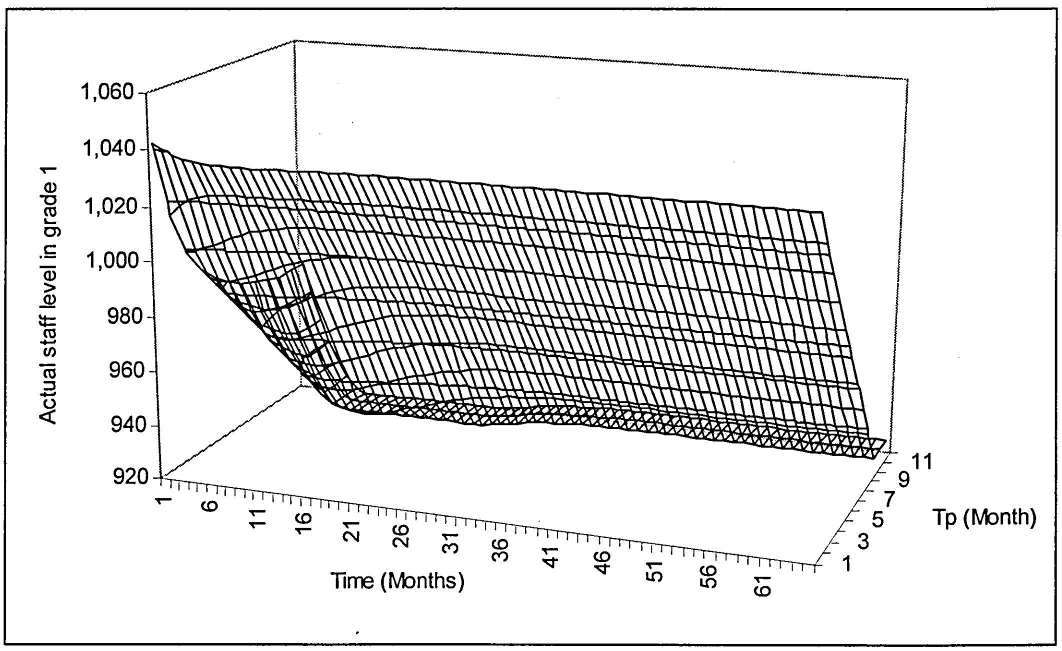


(b) Staff level behaviour for grade 3

Figure 6.15: Response of PPAPSKPM for varying values of Ta

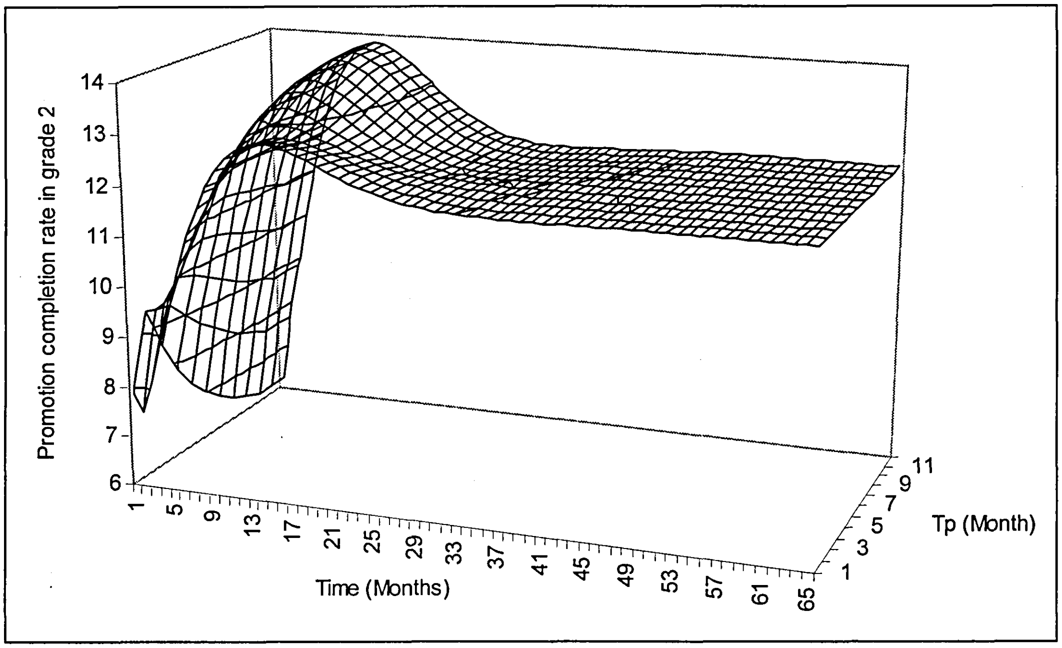


(a) Promotion completion rate behaviour for grade 1

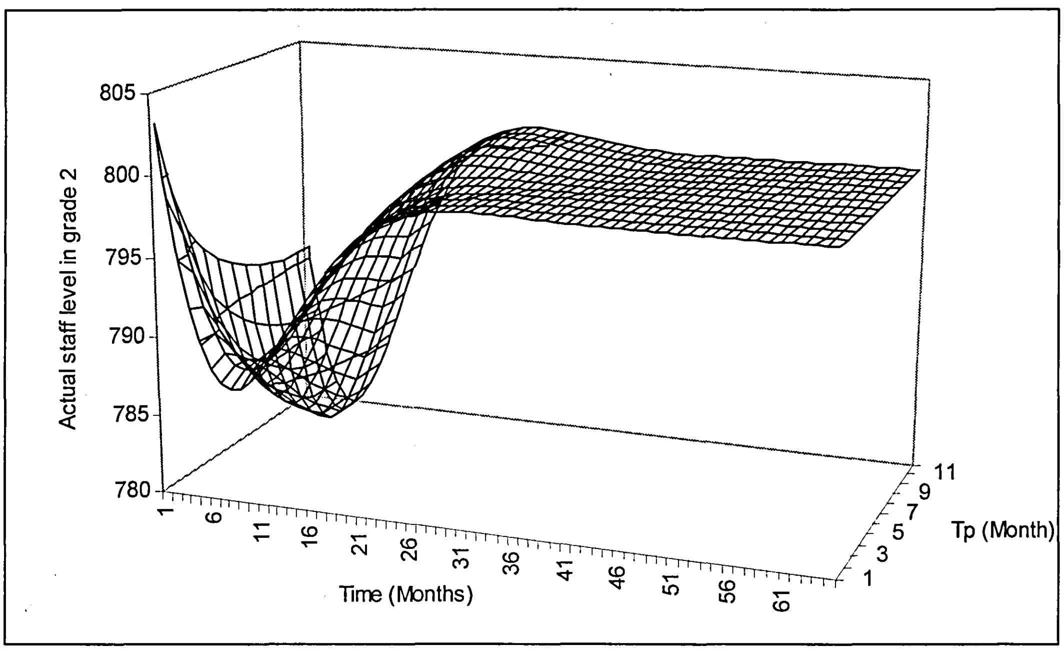


(b) Staff level behaviour for grade 1

Figure 6.16: Response of PPAPSKPM for varying values of Tp

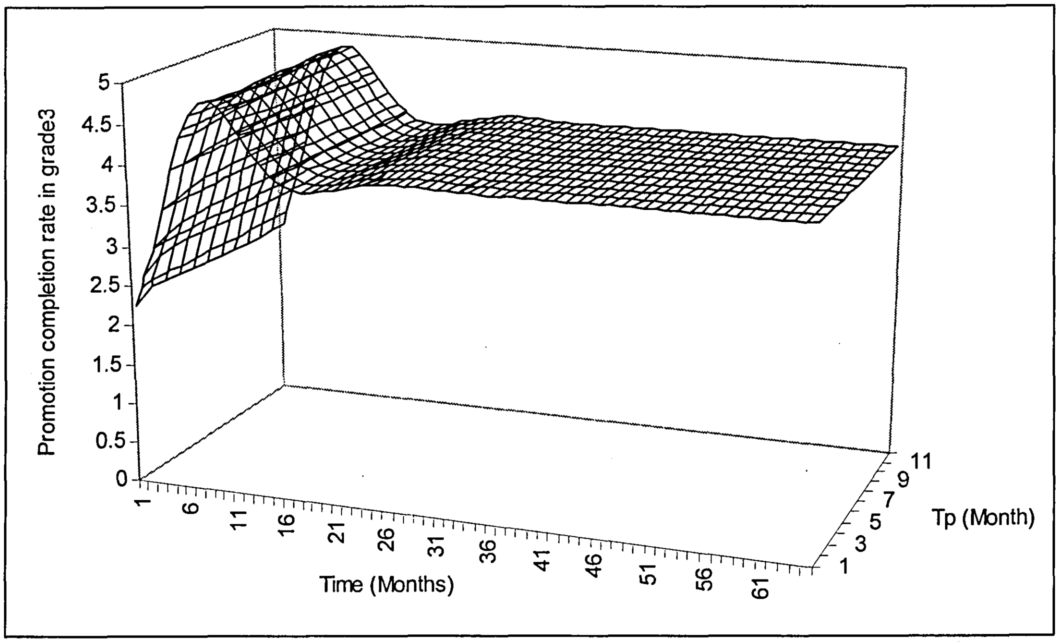


(a) Promotion completion rate behaviour for grade 2

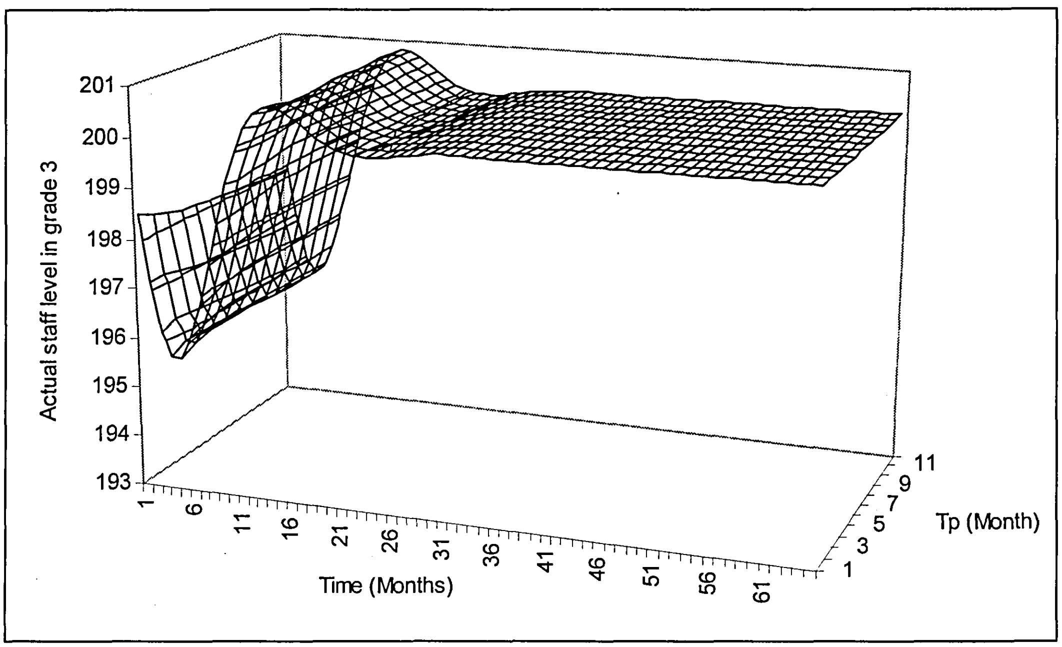


(b) Staff level behaviour for grade 2

Figure 6.17: Response of PPAPSKPM for varying values of Tp

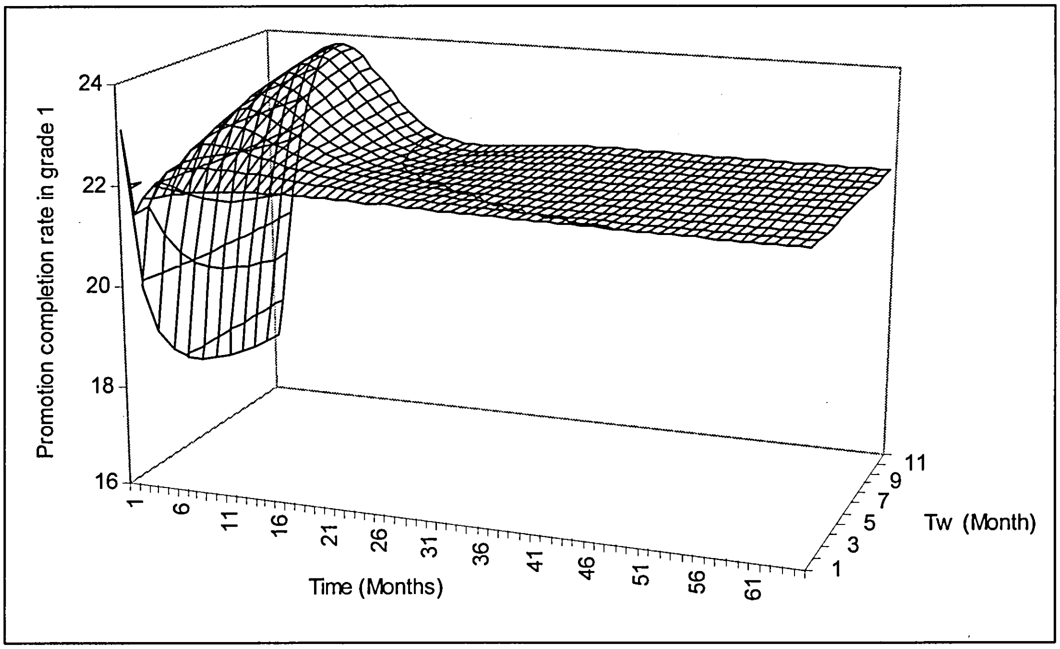


(a) Promotion completion rate behaviour for grade 3

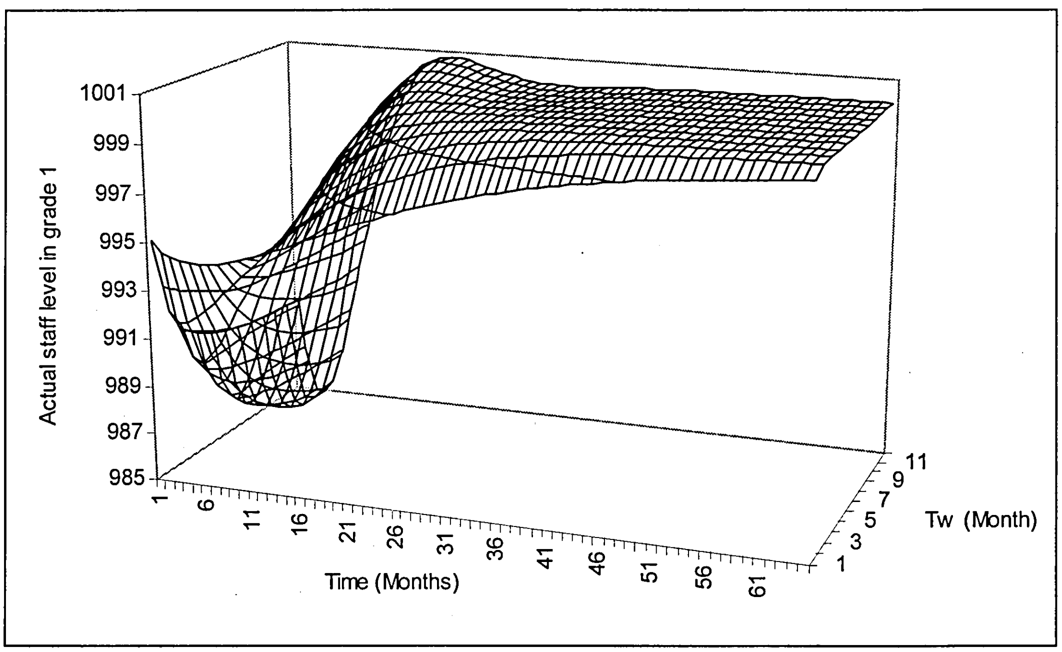


(b) Staff level behaviour for grade 3

Figure 6.18: Response of PPAPSKPM for varying values of Tp

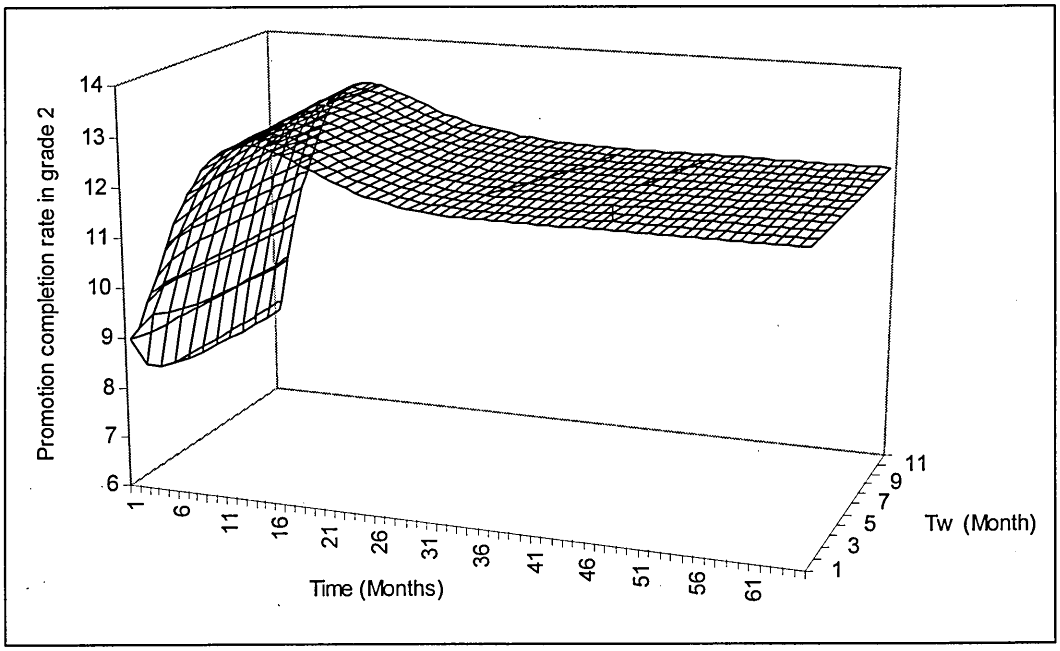


(a) Promotion completion rate behaviour for grade 1

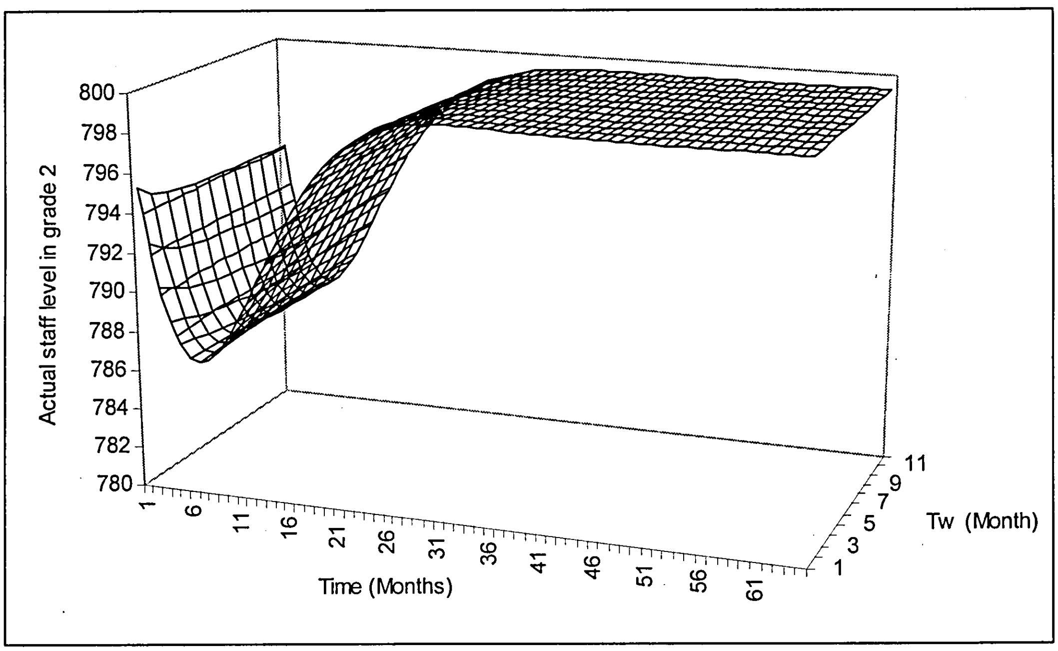


(b) Staff level behaviour for grade 1

Figure 6.19: Response of PPAPSKPM for varying values of Tw

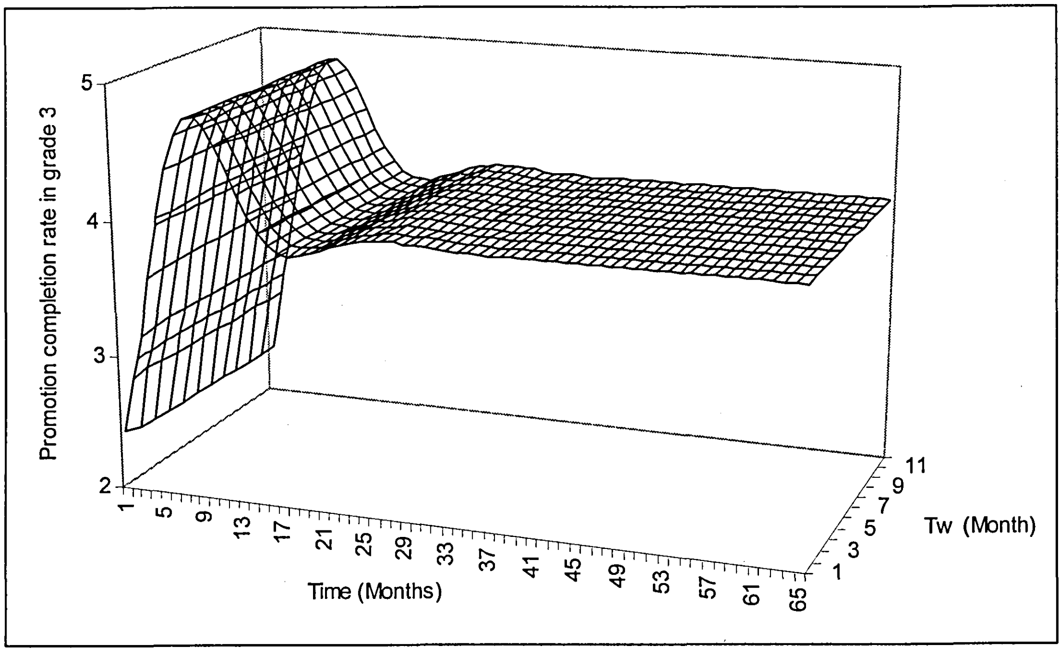


(a) Promotion completion rate behaviour for grade 2

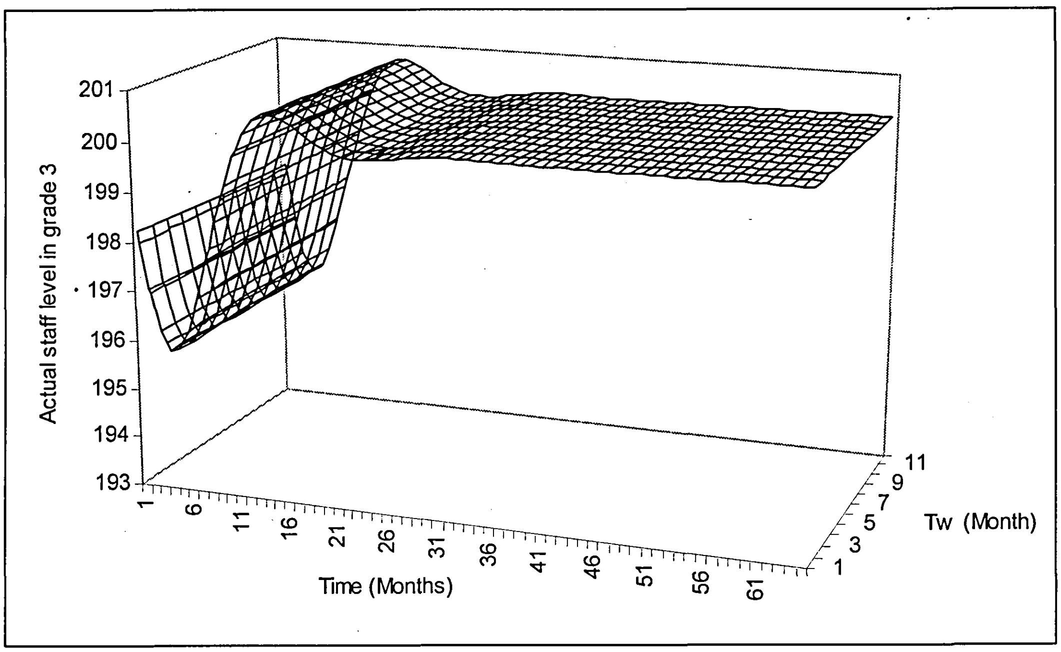


(b) Staff level behaviour for grade 2

Figure 6.20: Response of PPAPSKPM for varying values of Tw



(a) Promotion completion rate behaviour for grade 3



(b) Staff level behaviour for grade 3

Figure 6.21: Response of PPAPSKPM for varying values of Tw