

A CONFINED WORKFORCE PLANNING MODEL WITH PLUGGING
FOR SERVICE ORGANIZATIONS USING NETWORK
FLOW UNDER FINITE HORIZON, VARYING
DEMAND SCENARIO

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ABSTRACT

Managing the workforce of a service industry is a key factor for its success. An ideal quantitative model for workforce management should be efficient in terms of time, cost, volume and the simplicity of use. The aim of this study is to develop a user-friendly quantitative model to determine the magnitude of changes in workforce strength of a service industry to meet the varying demands, while maintaining a desired level of quality and cost effectiveness. The scope of the study is limited to finite planning horizon. Also, employee-learning through experience is not considered in this study. The study uses the Shortest Path method of the network flow models and identifies the optimum capacity required in each period of the planning horizon using Dijkstra's Algorithm. Two non-linear, zero-one integer programming models have been developed – first one is the Confined Workforce Planning (CWP) model in which cost for changing the workforce strength is assumed as uniform and the second, a Confined Workforce Planning with Plugging (CWPP) model where workforce changing cost is non-uniform. These models are then converted into network flow models and optimization is done using shortest path method. Three extensions, pertaining to the impacts of controlled violation of the constraints and more system constraints, and the applicability of the models in other problem domains are discussed. The study finds that both models will have the same size, if no additional force is acquired at any period of the horizon, and maximum size of CWPP model occurs when acquiring is done in the first period. The study also reveals that the optimal solution can be obtained in polynomial time and the network size depends on workforce strength changing levels, planning horizon length and the ratio of the initial essential capacity to the available capacity - which are computationally verified.

APPROVAL PAGE

I certify that I have supervised /read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in quality and scope, as a thesis for the fulfilment of the requirements for the degree of Doctor of Philosophy.



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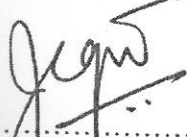


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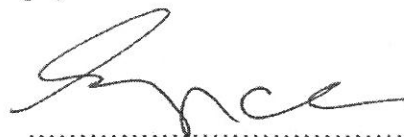


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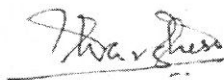
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Declaration

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CHAPTER 1

INTRODUCTION

The success of every business organization depends on how far it can realize its objectives. Effective utilization of available resources will help the business firms to realize its objectives. Human resource is a costly asset for every organization and its management has an important role in the realization of the business objectives. The efficient planning and management of a large workforce is a challenge faced by many organizations, especially those in the service sector. There should have an urge on the part of the business leaders to dedicate more time to enhance effectiveness of their costly human resource assets.

When we think of human resource management, the picture of a smart vibrant manager busily engaging in his work may flash in our mind. This imagery has some validity; but the field of human resource management is deeper and it is indeed a complex task. Some intellects like to define human resource management as a modern version of the earlier used personnel management function because in the entire life-cycle of an employ's involvement in an organization, from the stage of filing application for a job till he leaves the company by retirement or by any other reason, the human resource people stand by him and support him. Human resource management is, therefore, the systematic process of managing workforce in a business firm so that the process covers all the related fields such as staffing, pay and perks settings, training and development etc.

There is another line of thinking about human resource management: managing human resources of an organization in the form of a collective relationship between the management and the employees. This approach focuses on employ-enabling and

employ-development together with the fulfilment of the objectives of the organization. Thus one can say that personnel management is employ centred while human resource management is resource centred. An ideal HR manager has to cater employee expectations as well as business firm's objectives.

1.1 Background of the Study:

The pressing issue of the human resource department of a business organization is supplying the right quantum of right people at the right time and at the right place. A typical service engagement consists of different tasks which may be executed simultaneously by a group of workforce with varying attributes or skills. Any shortage of the required resource may result into the failure of the entire engagement causing heavy loss to the firm. Practicing human resource systems like HR Planning, Recruitment and Selection etc. will help an organization to get the right quantity of workforce with right attributes that matches the business requirements. Business firms that practice human resource planning are more likely to know what specific characteristics they are looking for in employees and thereby the firms can improve the quality of hiring decision.

A major challenge that business organizations have to face today is the imbalances between the quantum of work and the availability of skilled labour force. According to the IPMA Workforce Planning Resource Guide (2002), business firms of the 21st century have to face the 'Talent and Successor Crisis'. The present workforce as a whole is aging; the growth in the number of business firms demands more workforce and the personnel to replace the present aging workforce suffer a dearth in their number. As a result, employers should ask 'who will do our work'. The situation is graver because the employers have to compete for the right labour force

from the same labour pools due to globalization. It highlights the necessity of strategic thinking, planning and foresight for the future, failing which will result into a downsizing of the workforce in the business firms. Adopting human resource planning procedure is a remedial measure for this problem. It will ensure the availability of the right people, in quality and quantity, in a cost effective fashion. It affects the full life-cycle and range of human resource activities. The concept of making available the right people in the right place at the right time and at the right cost is often referred to as 'workforce readiness'. An organization is only as good as its talented workforce and success depends on achieving a high level of readiness, which requires the ability to anticipate, to rapidly respond to the changing labour needs and to allocate resources to meet the needs.

Workforce Management, a synonym for Human Resource Planning is a subject of debate. Bramham (1994) has distinguished human resource planning from manpower planning. According to him, human resource planning is a process in which costs, numbers, controls and systems interact and play its role and manpower planning is more concerned with numerical elements of forecasting of manpower. However, authors like Bennis & Casson (1984) do not agree with such perceptual differences. They argue that both concepts are the same. Moschetto (2014) has given a simple definition for workforce management. According to him, workforce management refers to all the process and activities required to maintain a productive workforce. Workforce management practices, when properly implemented create the kind of lead time necessary to ward off potential problems that might otherwise threaten the company's competitive positions.

The workforce utilization in IT and Call Centre sectors of service industries requires more attention because there is no notion of physical products, production facilities,

inventory or supply chain in their business processes. Human capital is the precious resource for them. Managing knowledge workers is highly complex because of two reasons mainly. One reason is that, it is very expensive for the service providers to hire and train new IT professionals and hold them idle when situation demands. The other reason is the necessity to meet the market demand as quickly as possible. The service providers have to balance these two factors. Therefore it has become a very pertinent question at the time of planning strategies in such firms whether workers are to be hired as apprentice and train and hold them or hire skilled workers just- in-time to meet the uncertain demand. A study on this problem by Kim, Kim, Lim, & Park (2013) revealed the facts that in high seasonal effects on demand, a hiring policy based on decision thresholds proportional to the seasonal demands outperforms the hiring policy based on a constant decision threshold. The study also revealed that high holding and training cost, high mobility of skilled workers and high elasticity in the supply of skilled workers decrease recruitment of apprentices.

Contingent employment has become an integral feature of HR management and it has been on the rise in most of the industrialized countries. They are now providing the employers a buffer against uncertainty in demand. There is a substantial short-run of labour cost due to contingent employment policy compared to the use of core workforce who performs similar jobs. Economic conditions have increased the variability and uncertainty of product demand. It expanded and internationalized the scope of markets and decreased firm market shares. The realities of competition pressurize firms to cut labour costs. It makes an urge to achieve greater flexibility in the quantity and skills of their workforce. According to Tilly (1991) employers try to shift the costs and risks of production onto different forms of contingent employment such as temporary employees hired directly by the firm, contract

employees who can work on-site or off-site, subcontractors with freedom for planning and managing their own work, leased employees where a leasing firm leases employees to a client company etc.

Decision making in today's social and business environment has become a complex task. High cost of technology, materials, labour, competitive pressures and many other external factors such as those in the social and political arena increase the complexity of managerial decision making. Rapid technological changes give rise to new problems. To effectively address the arising problems and to provide leadership in the advancing global age, decision makers cannot afford to make decisions by simply relying on their experiences or applying guess-work or intuition, because the consequence of wrong decisions may become costly. Here comes the importance of quantitative approach to decision making. Wrong decisions such as keeping a huge quantum of workforce in a less demand period, entering the wrong markets, providing inappropriate services etc. may cause disastrous consequences for the organizations. There are more than one alternative (course of action) for a problem and quantitative models help us to compare all possible alternatives. It enables us to know the potential outcome and permits examination of the sensitivity of the solution to changes or errors in numerical values. It also encourages rational decision making based on the best available approaches and techniques.

While solving a problem, the decision-maker should examine the problem both quantitatively and qualitatively. The data are to be analyzed in both perspectives. For example, suppose a decision-maker has to make decision on the problem related to an investment. There are three alternatives, namely, investment in Stock Market, investment in Real Estate and investment in any public sector Bank. In order to make an acceptable decision, he has to consider certain quantitative factors and that

should be examined in the light of the problem. The financial stability of the companies whose stocks are under consideration to buy is to be analyzed using the balance sheets in the case of stock market investment. For investment in real estate, the cash flows of the real estate companies, rates of return for investment in properties etc. are to be analyzed. For bank deposits, the rate of interest, depreciation of money value etc. are to be examined. This quantitative analysis is not enough to reach a conclusion; qualitative factors such as political situations, weather conditions, government policies etc. are also to be examined. A decision-maker should examine quantitative and qualitative factors while solving a problem. Our focus in the present work is to provide a quantitative model to help the decision maker to plan and take appropriate decisions on the quantum of workforce to be assigned to meet the fluctuating demand in different periods of the planning period in a cost effective fashion and maintaining a desired level of quality.

1.2 Statement of Problem:

A survey conducted in various industrial organizations in US and Canada to explore the use of management science models in human resource planning revealed the fact that there is only a very little use of the models by the industrial firms in their manpower planning processes due to the complexity of the models and lack of its cost effectiveness (Ashton & Ashton, 1988). These findings reflect the necessity and relevancy for quantitative models in workforce management to be simple and cost effective. Most of the quantitative models developed in this domain are highly cumbersome and very complex in nature. A well-crafted workforce management model empowers the HR leaders and thereby enables the organizations to respond to the constantly changing markets and industry conditions across the nations.

Potentially effective management science model to overcome the cost and complexity barriers is the need of the day.

The dynamics governing a service industry and the flow of demands through it involve uncertainty and variability. These features point to a requirement of improved workforce management models which incorporate time dependent demand profiles. Moreover service cannot be stocked for inventory for using it in peak demand period. Understaffing produces loss in opportunity to attend some customers and overstaffing invites losses due to insufficient demand to put to good use the available capacity. Utilizing workforce at an optimal level is essential, though some service industries such as IT services cannot avoid occasional retaining of excess staff due to the nature of their service and uncertainty of demands. Such firms are compelled to keep idle workforce but the number can be made less using workforce management models capable of tackling demand fluctuations. The ideal situation for a service enterprise would be the possibility of reducing its capacity in low demand period and increasing it in peak demand season. The problem is how much to reduce or how much to increase. To answer this, a suitably developed quantitative model is required. Many of the existing models are not addressing the demand uncertainty.

Quality aspect is another area to be addressed in a service industry. An unhappy customer is usually more costly than a happy customer is profitable. Delivering quality service is a key factor for the success of an industry. A customer can be made happy by delivering quality service even if the customer has to bear a bit higher price for it. There is a strong relationship between capacity level and quality level. There should have a minimum staff level required to carry out all functions within an ideal service while guaranteeing a previously fixed level of quality.

Relating staffing decisions with quality is not so frequent in literature. Assigning workers based on productivity and ignoring quality may drop black dots in the work culture of an ideal service industry. In high-contact services like nursing care given by a hospital, looking for better productivity will usually create a reduction of contact time and hence to have a lower quality index.

These are some of the problems the researcher intends to address through this study.

1.3 Objectives of the Study:

The study is designed to achieve the following objectives:

1. To develop a Non-Linear Integer Programming Problem model (NLIPP) for workforce management under finite horizon to meet the fluctuating demand while maintaining a desired level of cost-effectiveness and quality, assuming that the incurring cost for changing workforce level is uniform and to convert it into a non-linear 0-1 integer programming formulation, called the Confined Workforce Planning (CWP) model adopting a practical approach of changing workforce level in batches.
2. To develop a network flow representation for the CWP model and to get the optimal solution and its computational time by identifying the shortest path satisfying the quality constraint and budgetary constraint for workforce level change, using Dijkstra's algorithm.
3. To develop a workforce management model, called the Confined Workforce Planning with Plugging (CWPP) model, by taking into consideration of the real life situation that cost for changing workforce level is non-uniform.

4. To develop a Network flow representation for the CWPP model and to get the optimal solution satisfying system constraints by identifying the shortest path using Dijkstra's algorithm.

1.4 Significance of the Study:

As stated earlier, the non-availability of a workforce management model that is easy to use, precise in solution and cost effective is a barrier for the extensive use of quantitative models in human resource planning in service organizations. Because of the complexity in the solution process of management science models developed using OR techniques like linear programming, non-linear programming, integer programming, simulation techniques, Markov decision process etc. a lot of researchers rely on heuristic approach. But the solution process based on these tools are either complex or solution lacks preciseness. In some cases researchers have to satisfy with approximate values. Network flow approach to solve an optimization problem in workforce management is very simple and handy to use and is highly effective in getting a precise solution. But to the best of our knowledge, the study based on this is very rare in the field of workforce management. In the current study, we used network flow approach to provide a quantitative model for workforce management in service industries and hence our study is significant.

Planning is essential for the successful functioning of an organization, especially in the case of demand fluctuation. We considered this aspect in our study and the model we developed is capable of planning in a finite horizon.

One of the extensions to our core model is based on considering the problem in a global perspective. It provides a wider applicability of our model to a number of problem domains such as air craft assignment and crew scheduling, public transport

assignment including train services and other surface transport systems, tanker and truck scheduling, warehouse management etc. Our study gives an effective substitute to the quantitative models that the service firms in these domains are using. This study is significant because the model developed through this study is adaptable to more problem domains instead of limiting its usage to manpower management alone.

We also considered system performance, budgetary control, demand fluctuation, cost effectiveness etc., all of which add the significance of our study.

1.5 Scope of the study:

The study is limited to finite planning horizon and employee learning through experience is not considered in the study. The computational study and the empirical data collection for it are just to illustrate how capacity decisions can be taken using the network flow models we developed. Behaviour of the model was analysed using a simple computer programming coded in Java language and hence the scope of the analysis of the data is limited.

1.6 Outline of the study:

An overview of our study and a flowchart representation of it are given for easy reference (Fig. 1.1). Our work aims at providing a model that minimizes costs while maintaining quality performance, say, for example limiting client's expected waiting time before the service request is attended to. We consider the problem over a finite planning horizon of length T . The horizon is divided into discrete time periods of equal intervals. We analyze the system performance by using Queuing techniques. To facilitate the application of Queuing concepts, we assume that the system is in

steady-state conditions. The application of queuing concepts leads to non-linear equations in our mathematical formulation of the problem. Since the workforce level is integer valued, the model we propose will be a non-linear integer optimization model that minimizes the total cost along with a prefixed level of system performance to maintain quality.

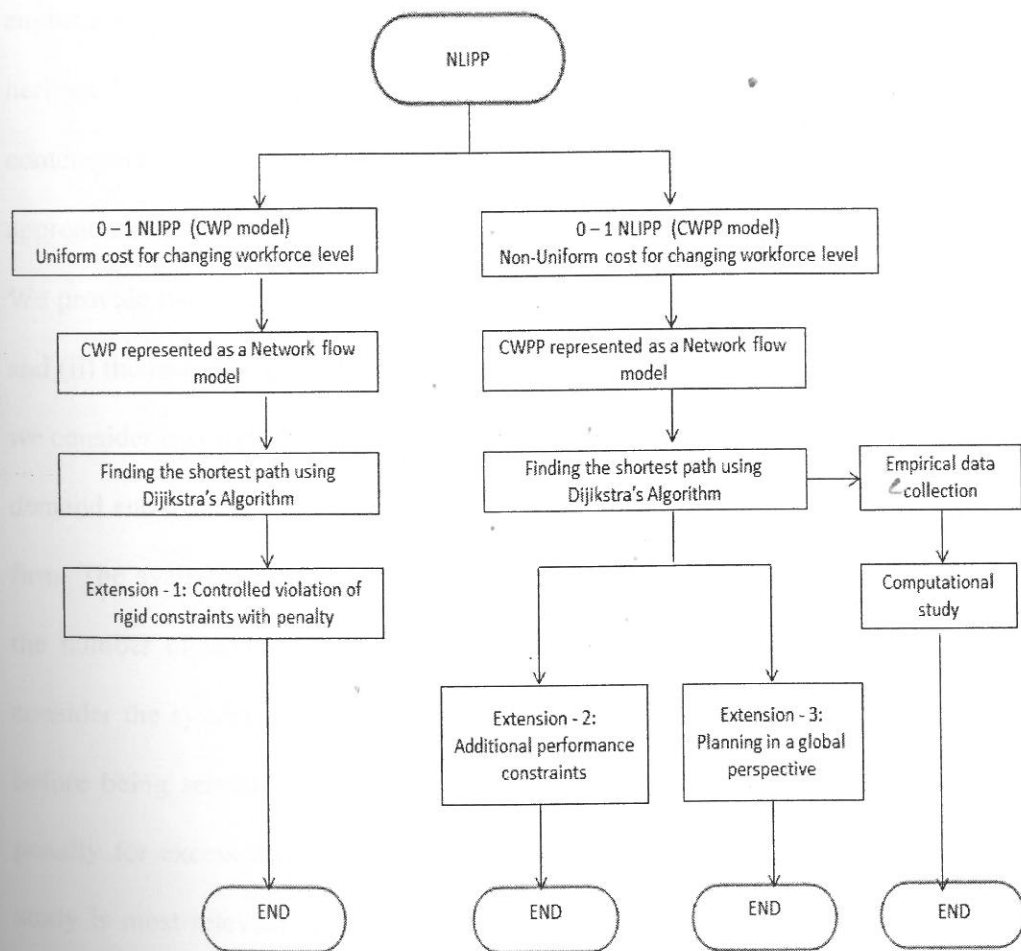


Fig. 1.1 Flowchart representation of the study

The formulation that we framed is then simplified, taking into consideration of some practical approach of capacity increase or decrease in batches of some base value so that there will be a limited number of alternatives for changing capacity in each

period of the planning horizon. This leads our original problem into a non-linear zero-one integer programming problem.

To solve the problem, we use network flow approach, an exciting field that 'couples deep intellectual content with a remarkable range of applicability, covering thousands of applications in wide ranging fields like computer networking, engineering, manufacturing, scheduling and routing, telecommunications etc.' Its heritage is rooted in the traditional fields of Applied Mathematics as well as the contemporary fields of Computer Science and Operations Research. Network flow approach helps us to solve the optimization problem we framed in polynomial time. We provide two models: (i) a model in which cost for changing capacity is uniform and (ii) the model where capacity changing cost is not uniform. In the second model we consider two concepts, viz., essential capacity which is just sufficient to meet the demand and available capacity which is the amount of workforce on the rolls of the firm. The available capacity level can be changed to essential capacity by reducing the number of existing employees or hiring new employees. In both models we consider the system performance by giving a constraint for customer waiting time before being served. We then give a relaxation to this constraint by introducing penalty for excess waiting time as an extension of the models in this study. The study is most relevant to service providers who desire to maintain enough labour force to deliver effective service to their clients and wish to avoid shortages.

Chapter 2 is devoted for a brief survey of literature related to Workforce Management. As we stated earlier, the literature on workforce management using network flow approach is less in number. In chapter 3, we provide the preliminary concepts and notions that will form the theoretical foundations of optimization and network flow. In chapter 4 we developed a basic network flow model to represent