ISSN No. 0976-5697

Volume 3, No. 3, May-June 2012

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

Incorporation of Quality Metrics in Workforce Management Model for Service Industries With Special Reference to Catering Sector - A Network Flow Approach

Varughese T.C*
Professor, Management Studies,
Mount Zion College of Engineering,
Kadammanitta, Pathanamthitta, Kerala, India
tcv747@rediffmail.com

Dr. Mendus Jacob
Professor and Director, MCA Dept.,
Marian College, Kuttikanom,
Kerala, India
mendusjacob@yahoo.com

Abstract: The number of service industries is growing tremendously in the majority of countries. The increase of competitors compels firms in this sector to improve their efficiency and productivity which require adequate management of available manpower and other resources. Relating staffing decisions with quality is not so frequent in manpower planning models. The goal of manpower planning model shall be to establish minimum capacity levels below which quality may be affected. The current study is an extension of the authors' work on workforce planning models using network flow approach. The models developed earlier incorporate the main issues concerning with the determination of workforce size in a service organization, such as the duration of the planning horizon, average time a customer has to wait before his demand is attended to and monetary issues in connection with the changing of workforce strength. The models also accommodated workforce reduction through temporary closing and expansion of workforce strength through new capital investment. In the current study, we incorporate a constraint related to quality aspects of the service delivered with special reference to catering industry scenario and has seen that addition of new constraints fit well in the network flow models developed.

Keywords: workforce, quality metrics, planning horizon, network flow, catering sector.

I. INTRODUCTION

Planning of Workforce management is central to the pursuit of balancing the quality of services delivered by an organization with the cost of providing those services. Relating staffing decisions with quality is highly essential in any capacity planning model. In this research line, van Looy et al [1] studied the relationship between productivity and quality. To them, assigning staff based on productivity is a difficult task. For example in the high-contact services such as health care sectors, looking for better productivity will usually imply a reduction of the contact time and hence lower quality indices. Miller and Adam also expressed the same view in their work [2]. This trade-off must be considered by the decision managers when assigning human resources to different departments, especially in high-contact services.

Catering is a very active service sector that is socially necessary because of its employment opportunities and the effects it generates in the general economy of a country. The role it plays in the development of tourist sector, a back bone of the economy of many countries, is worth to be highlighted. The goal of any workforce planning model is to establish minimum capacity levels below which quality may be affected. The model must be able to assign short-term resources (such as temporary employees) on the basis of demands arise. Catering services is a service sector where we normally have flexible workforce with limited staff and variable activities to be carried out depending on the type of customers. Workforce is flexible in the sense that they are multi-skilled to perform different tasks. Adequate allocation of workforce is required to maximize the perceived quality.

Varughese and Mendus [3] have developed two models for workforce management in service industries. These models, suitable for all type of service industries, minimize capacity cost while maintaining a desired level of quality performance, say, for example limiting clients' expected delay before being served. In their work, they considered the problem over a finite planning horizon of length T which was divided into discrete time periods of equal intervals and analyzed the system performance by using Queuing techniques. The non-linear zero-one integer programming formulation that they framed was converted into a network flow model taking into account of some practical considerations and using Dijkstra's algorithm the problem was solved in polynomial time. The study is most relevant to service providers who desire to maintain enough workforces to deliver effective service to their clients and wish to avoid shortages. In that study, they considered two system performance constraints, namely, the client's waiting time constraint and the budgetary constraint.

In the current study, we examine how to incorporate an additional constraint related to quality measures in the network flow model described in [3]. We consider the nature and requirements of a restaurant service and frame the quality constraint accordingly. We then examine how this constraint can be added to the network flow model. This paper is organized as follows: In section II, we present a brief discussion of network flow techniques applied in our work. Section III is devoted for presenting an overview of some of the literatures in the relevant field including a reasonable discussion of the model we developed in [3]. In section IV, we frame the quality constraint pertaining to a restaurant service and examine how to incorporate it in the network flow model. Section V concludes the study with some suggestions on future research.

II. CONCEPTUAL FRAMEWORK OF THE STUDY

Network flows is a topic that has evolved in the best tradition of applied mathematics. It unites ideas from the abstract world of mathematics and concrete world of computation. It is a subject that has had numerous applications in a wide variety of practical problem settings.

A network, as defined in [4], is a collection of capacitated or non-capacitated nodes and directed or undirected arcs that are capacitated or non-capacitated. Let N be the set of nodes and A the set of arcs. If there be n nodes and m arcs, then $|N| = n$ and $|A| = m$. The arcs of a network are ordered pairs (i, j) of nodes. We assume that there is at least one arc from node i and that there is no self-loop (i.e., there exists no arc (i, i)). The arc (i, j) is an outgoing arc of node i and an incoming arc of node j. The degree of a node is determined by the number of arcs incoming to and outgoing from that node. We distinguish two special nodes, the source node s and the sink node d with no incoming node to the source node and no outgoing node from the sink node.

Let $G(N, A)$ be a finite directed network in which every arc $(i, j) \in A$ has a non-negative real valued capacity $C(i, j)$. If (i, j) is not an element of A, we assume that capacity $C(i, j) = 0$. Let s be the source node and d the sink node. We define a real valued function $f: N \times N \rightarrow R^+$ such that $\forall\ i, j \in N$,

(i). $f(i, j) \leq C(i, j)$ (Capacity constraint).

(ii). For any intermediate node *k*, $\sum_{j\in N} f(j, k) = \sum_{i\in N} f(k, i)$ (Flow conservation) or equivalently, $\sum_{j\in N} f(k, j) = 0$, unless $k = s$ or $k = d$.

(iii). For any arc (u, v) incident to source node s or incident from sink node d, we have $f(u, v) = 0$. f is called a flow. Thus a flow in a network is a function f that assigns to each arc (i, j) a non-negative real number $C(i, j)$ satisfying the conditions *(i)*, *(ii)* and *(iii)* above.

Condition *(i)* ensures that the flow along an arc cannot exceed its capacity. Condition *(ii)* states that for any node other than the source node and the sink node, the total flow into that node equals the total flow out of it. i.e., the net flow at an intermediate node is zero. Generally, this condition need not be true. In the general sense, the out flow minus inflow must be equal to the supply/demand of the node. If the out flow and the inflow are equal, the node is called a *transshipment node*. Condition *(iii)* ensures that the flow moves from source node to sink node and not in the opposite direction. The *value of a flow* is the net amount of the flow per unit of time leaving the source node or equivalently, that entering the sink node. Thus value, $val(f)$, of flow f is given by

$$val(f) = \sum_{j\in N} f(s, j) = \sum_{j\in N} f(j, d),$$

where s is the source node and d is the sink node.

There are different models of network flow problems of which the *Shortest Path Problem* is perhaps the simplest one and it is a core model central to network optimization. The main objective in a Shortest Path problem is to find a path of minimum weight (weight may be cost, computer time or some other entity) from a specified node (source node) to another specified node (sink node), assuming that each arc $(i, j) \in A$ has an associated weight c_{ij}. There are powerful algorithms like Dijkstra's algorithm [4] to find the shortest path in a directed network.

III. LITERATURE SURVEY

Diaz and Torre [5] studied the problem of capacity management in service sector, proposing a model for calculating minimum staffing levels that guarantees a predefined level of quality for the customer. The model is formulated on the basis of historical data kept in a restaurant with a total capacity of 2000 customers and 130 staff. They identified certain tasks the waiters have to undertake. It relates quality indices collected in service to the relationship between theoretical staff level (using a system for evaluating workloads) and the actual staff employed to carry out this service. It gives a minimum value beyond which the selected quality measures in a specific one will be in danger. The model can be used only in service industries where historical registers are maintained.

Nankervis and Debra [6] have studied different policies of human resource management in hotel settings. To them, the models developed by fast food restaurants for managing their capacity, the efficient process by which customer's orders are dealt with at low cost etc. are remarkable.

Mill [7] explains the external quality indices which are to be obtained from the customer survey system, a widespread practice very common in catering sector. Some of the external indices chosen are: the general rating of the services rendered; the rating of the temperature of the dishes; the number of complaints received from the customers etc.

Lam et al [8] furnishes some of the internal indices defined and generated by the staff of the firm, with the aim of controlling the production process and the offering of services. Some of the internal indices are: reports of the services prepared by the heads of dining room, average waiting time for the dishes to be received from the kitchen, average duration of each service etc.

The study using network flow optimization method in Workforce Management is rare and one of the noted works in this domain using network flow optimization is due to Batta et al [9]. In their work, they studied the problem of balancing staffing and switching costs in a service centre with multiple types of customers and time dependent service demand. Workers are assumed to be flexible and can be switched from one type of customer to another type. Their model aims at minimizing total staffing and switching costs subject to service level constraints. They use the network flow approach to solve the problem. Worker's skill level is different for different types of customer demand. They tackled this problem by introducing a skill level coefficient that varies between 0and1. But there may arise some practical difficulties at the implementation level such as accuracy of the skill level coefficient allotted to a worker.

Varughese and Mendus developed two models for workforce management [3] using network flow approach. In their works, they considered optimum workforce level change to cope with the fluctuations in service demands. Workforce will be increased when demand increases and will be decreased when demand decreases. Both models take measures to preserve quality of services rendered by the firms. In the first model they considered uniform cost for workforce level change. In the second model the discussion was based on non-uniform cost for workforce level change. In both models shortest path method is used to get the optimum solution.

We now discuss in brief the first model and examine the possibility of incorporating a new quality constraint in the model. Following symbols and notations are used as in [10] to represent the various parameters and decision variables of the problem formulation and solutions of the model developed:

- T : Length of the finite planning horizon which is divided into equal time periods *t = 1, 2,........,T*; *t* can be a hour, a day, a week, a month, a quarter of a year or a year.
- λ_t : Arrival rate of service demand in period t. Since demand is uncertain, for the purpose of planning, λ_t can be forecasted using trend lines.
- μ_t : Service rate over period *t*.
- α_t : Maximum allowable expected delay for a customer before the customer's service demand is attended to, after receiving the order, pre-fixed by the organization as a policy decision to maintain system performance.
- β_t : Budget limit of monetary resources fixed for the period *t* for the purpose of workforce level increase/decrease in period t (excluding wages).
- x_t : Number of employees (work-force level) in period *t*.
- x_t^+: The amount of increase in workforce level at the beginning of period *t*
- x_t^-: The amount of decrease in workforce level at the beginning of period *t*.
- η (x_t) :Staffing cost (both salaries and operating cost) in period *t*.
- $\Phi\ (x_t, \lambda_t, \mu_t)$: Expected waiting cost function for a client. It depends on capacity level, arrival rate of service demand and service rate in time period t
- W (x_t, λ_t, μ_t): Expected waiting time for a service demand is to be served in time t
- Ψ (x_{t-1}, x_t) : Cost of changing workforce level from x_{t-1} to x_t (assumed to be uniform).

A. Problem Setting:

The total expected cost during the planning horizon for meeting the service demands of the clients is

$$\sum_{t=1}^{T} \Phi(x_t, \lambda_t, \mu_t) + \sum_{t=1}^{T} \psi(x_{t-1}, x_t) + \sum_{t=1}^{T} \eta(x_t)$$

Thus we have the non-linear integer programming problem:

Minimize

$$\sum_{t=1}^{T} \Phi(x_t, \lambda_t, \mu_t) + \sum_{t=1}^{T} \psi(x_{t-1}, x_t) + \sum_{t=1}^{T} \eta(x_t) \qquad (1)$$

subject to

$$x_{t-1} + x_t^+ - x_t^- = x_t \qquad (2)$$

$$x_0 = c_0 \qquad (3)$$

$$\psi(x_{t-1}, x_t) \leq \beta_t \qquad (4)$$

$$W(x_t, \lambda_t, \mu_t) \leq \alpha_t \qquad (5)$$

$x_t,\ x_t^+,\ x_t^-$ are non-negative discrete variables,

$$t = 1, 2, \ldots\ldots T \qquad (6)$$

Constraint (2) states that the workforce level available in a period is equal to the amount of workforce available at the previous period plus the amount of increase in the workforce minus the amount of decrease and thus it gives a flow balance equation. Constraint (3) sets the initial workforce level to c_0 and constraint (4) is a budgetary constraint limiting the amount of funds allocating to reduce or increase the capacity level. Constraint (5) ensures the level of system performance. It gives a maximum available limit on the expected waiting time for meeting the service demands, beyond which the service organization has to pay penalty (damage to the goodwill can also be considered as penalty).

Constraint (6) ensures that the decision variables are integer valued. This non-linear integer programming formulation is now converted into a non-linear 0-1 integer programming model as explained below.

The number of integer variables associated with the formulation (1) could be large as we have no restriction on the number of additions or deletions in the total workforce. We can alleviate this difficulty to a great extent by a practical approach. In practice, workforce level is increased in batches. Usually the changes will be some integer multiple of a base value, say 20 or 50, depending on the size of a unit. Approaching in this way, we see that there are only a limited number of alternatives for changing workforce level in each period. The change in capacity can be enforced by hiring or firing the contingent/temporary staff. Using this practical approach the change in capacity can be replaced by a set of alternative discrete constraints, requiring only one alternative to be chosen in the solution for each period. This approach can transform our original NLIPP (1) into a nonlinear zero-one integer programming problem.

B. NLIPP as a non-Linear zero-one Integer Programming Model:

Let θ be a given base value, in multiples of which the workforce level can be increased or decreased from one period to the next period. Let $n$be the number of possible distinct levels of workforce increase or decrease and π be the given workforce level at time t.

We now define

$$(\pi - r\theta)^{max} = max\{0, \pi - r\theta;\},\ \ r = 0,1,2, \ldots, n$$

Thus for a given workforce level π in period t, the workforce level in period $t+1$ shall be one of

$$(\pi - r\theta)^{max},\ \pi + r\theta; r = 0,1,2, \ldots \ldots, n.$$

We also assume that there is *no lead time* for the new capacity added to the existing one. i.e., all newly acquired additional workforces, if any, will be readily available for service in the same period. Let us define two new variables y_{rt}^{+} and y_{rt}^{-}, as in [10], such that
y_{rt}^{+} = 1, if the existing workforce level is increased by $r\theta$ at the beginning of t; r= 0,1,2,..,n and
= 0, otherwise.
y_{rt}^{-} = 1, if the existing workforce level is decreased by $r\theta$ at the beginning of t; r= 0,1,2,..,n and
= 0, otherwise.

We call these variables as *workforce level selection decision variables*.

Thus we have the non-linear zero-one integer programming model:

Minimize:

$$\sum_{t=1}^{T} \Phi(x_t,\lambda_t,\mu_t) + \sum_{t=1}^{T} \psi(x_{t-1},x_t) + \sum_{t=1}^{T} \eta(x_t) \quad (7)$$

subject to

$$x_{t-1} + \sum_{r=1}^{n} r\theta y_{rt}^{+} - \sum_{r=1}^{n} r\theta y_{rt}^{-} = x_t \quad (8)$$

$$x_0 = c_0 \quad (9)$$

$$\psi(x_{t-1},x_t) \le \beta_t \quad (10)$$

$$W(x_t,\lambda_t,\mu_t) \le \alpha_t \quad (11)$$

$$\sum_{r=1}^{n} y_{rt}^{+} + \sum_{r=1}^{n} y_{rt}^{-} \le 1 \quad (12)$$

$$x_t \ \ge\ 0,\ \forall\, t \text{ and } y_{rt}^{+},\ y_{rt}^{-} \in \{0, 1\},\ \forall\ t \quad (13)$$

Objective function (7) minimizes the total cost of customer's delay, change in workforce level and the operating cost. Constraint (8) is a flow balance equation. While constraint (9) sets the initial workforce level toc_0, constraint (10) is a budget constraint on the amount of money allotted to changing workforce level. Constraint (11) gives a measure of system performance by imposing a maximum allowable limit on the expected customer delay. Constraint (12) shows that workforce level change is permitted only once in each period.

C. Conversion to a Network flow Model:

We can develop a network flow representation for this problem which will enable us to solve the problem easily. The process is described below.

Consider a T partite graph with T layers. Each layer represents a time period in the planning horizon. If the workforce level in period t is π, the system can be denoted by (t, π). Let s be the source node and d the sink node. The node $(0, x_0)$ represents the initial state of the system with initial capacity x_0 at t = 0. The source node s is connected to the node $(0, x_0)$ with arc length 0. If the capacity of the current period is π, we define $X(\pi)$ = the set of all reachable workforce levels in the next period.

i.e. $X(\pi) = \{ (\pi - r\theta)^{max}, \pi + r\theta; r = 0,1,2,\dots\dots,n\}$

Let the node $(0, x_0)$ be connected to all nodes $(1, x')$ for all $x' \in X(x_0)$. If the waiting time constraint and the budgetary constraint are not violated,

i.e., if $W(x',\lambda_1,\mu_1) \le \alpha_1$ and
$\psi(x_0,x') \le \beta_1$,

assign $\Phi(x',\lambda_1,\mu_1) + \psi(x_0,x') + \eta(x')$; $x' \in X(x_0)$ as lengths of the arcs joining the node $(0, x_0)$ with all nodes $(1, x')$; $x' \in X(x_0)$. If any of the two constraints is violated by any arc, the length of the corresponding arc will be fixed as a very large number, say, K. Let $R(t)$ = the set of reachable capacity levels in period t from all capacity levels in period $(t-1)$. By allowing t to run from 1 to $T-1$, we cover the entire planning horizon. Let each node(t,x), $x \in R(t)$ be connected to $(t+1, x')$, $x' \in X(x)$ with arc length equal to the total cost in the respective periods as $\Phi(x',\lambda_{t+1},\mu_{t+1}) + \psi(x,x') + \eta(x')$, $t = 1,2,\dots.,(T-1)$, provided the budgetary constraint and the waiting time constraint are satisfied. If either constraint is violated by any arc, its length will be assigned as a very large number K. The node (T,x), $x \in R(t)$ is connected to the sink node d with arc length 0. Thus we complete the proposed network flow model. The shortest path from the source node to the sink node, without having any arc of length K, gives the workforce plan with minimum total cost, satisfying the waiting time and budgetary constraints. We can easily prove that the size of the network will be $nT^2 + (n+1)T + 3$ and the shortest path can be obtained in $O(n^2T^4)$ time using Dijkstra's algorithm. Fig. 1 depicts a sample network model. We now examine how to incorporate an additional constraint related to quality measures in the network flow model developed above.

IV. INCORPORATION OF QUALITY RELATED CONSTRAINT

When we analyze the functioning of an organization, we will realize that waiting time constraint and budgetary constraints are not the only metrics to assess system performance. It may be required to include more constraints. We consider the case of catering sector. Suppose we need to incorporate a constraint with regard to the total quality of the restaurant services offered in a hotel in addition to the two constraints we provided in the above model. Let us frame a quality constraint and incorporate it in the model. Some of the various activities in restaurant services as stated in [5] are:

Change place settings, Receive and seat customer, Hand out menus and offer suggestions, Place water on the table, Refill glasses and take orders, Serve the different courses in succession, Clean the table during service, Serve desert, Serve coffee, Prepare bill, Returning customer's belongings kept in the cloak room, Accompany and see off customer.

In this type of services, one of the main difficulties is the establishment of quality indices. We assume that the hotel has been working with general quality indices, the use and analysis of which are consolidated and integrated in its Quality Management System. The various indices are grouped into two categories (1) External indices and (2) Internal indices. The first category is resulting from customer survey system, a wide spread practice in the catering sector. Internal indices are defined and generated by the staff of the firm with the aim of controlling the production process and offering of services. Indices that are directly dependent on the services offered by the waiters are: *Externals:-* the general rating of the service received, rating of the temperature of the dishes and the number of the complaints received from the customer and *Internals:-* average waiting time of dishes received from the kitchen, report of the service presented by the heads of the dining rooms, average duration of each service and the number of incidents occurred such as staining customer's cloth, mistake in the bills etc. The firm may assign more weights to external indices compared to internals. The total quality function depends on workforce level, customer demand rate and the external and internal quality indices at any time period t. If the firm sets a pre-specified value δ for the quality function Q, below which the service is not satisfactory, we have the quality constraint

$$Q(x_t, \lambda_t, E_t, I_t) \geq \delta, \qquad (14)$$

where x_t is the work force level, λ_t is the customer arrival rate and E_t and I_t are the external and internal quality indices for period t. We can include this constraint in our model as a third system performance constraint without increasing the time for getting optimal solution significantly. If the constraint (14) is not satisfied in period t by any particular workforce level, we attach a large number K as arc length to the corresponding arc. The shortest path without having any arc of length K gives the workforce plan with minimum total cost, satisfying the waiting time constraint, budgetary constraint and quality constraint. In case the shortest path contains an arc with length K, the problem is infeasible and no solution that satisfies the constraints can be obtained.

V. CONCLUSION

This study tackles the problem of workforce management in service sector in general and restaurant services in particular. We presented a model for calculating minimum staffing level that guarantees a pre-specified level of quality service for the customer on the basis of network flow approach. Same model could be used in other service industries, especially in those where personalized demands of customers are warranted. We can easily add more performance constraints to the formulations. Inclusion of additional constraints does not increase the time for obtaining the optimal solution significantly because we need only to take these new constraints into consideration in setting up the network. Finding the shortest path from the source node to the sink node using Dijkstra's algorithm will determine the optimal solution. In case of any constraint violation, we need to assign a large arc cost K to the corresponding arc.

As a suggestion for future research, new calculation methods for the global quality function and what quality should be considered in each case must be analyzed in detail. Development of new models to manage several units simultaneously must also be investigated for assigning scarce human resources to all of them.

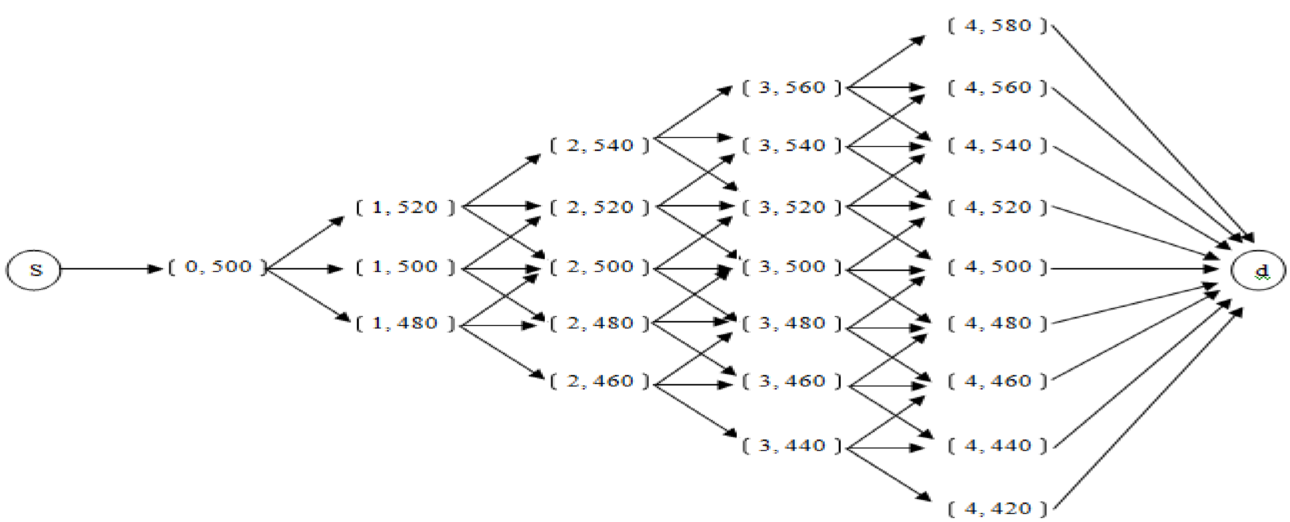

Figure 1. Network with $x_0 = 500$, $\theta = 20$, $T = 4$ and $n = 1$

VI. REFERENCES

[1]. van Looy, B., Gemmel, P., Desmet , S., van Dierdonck, R., Serneels. S. (1998) "Dealing with productivity and quality indicators in a service environment: some field experiences", International Journal of Service Industry Management, vol. 9 No 4. pp. 359-76

[2]. Miller, J. L, Adam E.E (1996) "Slack and performance in health care delivery", International Journal of Quality and Reliability Management, Vol. 13, No.8, pp. 63-74

[3]. Varughese, T. C. & Mendus Jacob (2011) "Managing Workforce in a Service Industry under Non-uniform cost for changing Workforce Level", Proc. National conf. on Emerging Trends in Technology and Management (NCETTM 11), Mount Zion College of Engineering, Kadammanitta, Pathanamthitta, Kerala, India, May 2011, p. 25

[4]. Ahuja, Ravindra. K.., Magnanti, Thomas. L. & Orlin, James. B. Network Flows: Theory, Algorithms and Applications, 1993, Prentice- Hall, NJ, pp. 24-112

[5]. Diaz, Adenso.B. & Torre, Gonzalez.P. (2002) “A capacity management in service industries”, International Journal of Service Industry Management, 13, No.3, pp. 288-302

[6]. Nankervis, A.R., Debrah, Y. (1995) “Human resource management in hotels: a comparative study” Tourism Management, Vol. 16 No.7, pp. 507-13

[7]. Mill. R (2001) Restaurant Management: Customers, Operations and Employees, Prentice-Hall, NJ

[8]. Lam, T., Baum, T., Pine, R. (2001) “Study of managerial job satisfaction in Hong Kong’s Chinese restaurants”, International Journal of Contemporary Hospitality Management, Vol.13 No.1, pp. 35-42

[9]. Batta, Rajan, Berman, O. & Wang, Qian (2007) “Balancing Staffing and Switching Costs in a Service center with Flexible Servers”, European Journal of Operational Research, 177, pp. 924-938.

[10]. Akcali, E., Cote, M.J. &Lin, C. (2006) “A network flow approach to optimizing hospital bed capacity decisions”, Health Care Management Science, 9, pp. 391-404.

