Optimal Staffing Level of Network Operations and Management Centers

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Abstract— **In this paper, we try to monitor and optimize the productivity of network operations and management centers in a big telecommunication company. To achieve this goal, we apply linear programming and simulation techniques and propose a system architecture. Linear programming and simulation are most frequently used techniques in management science field. We apply these techniques to obtain the best staffing level of network operations and management centers and verify the result. We also propose a system architecture that implements the linear programming model in the real situation and monitor the productivity of network operations and management centers. This research will help to increase the competitiveness of a telecommunication company as well as other organizations by reducing the operating expenditure in today's fierce competitive environment.**

Index Terms— **Optimal Staffing Level, Network Operations and Management, Linear Programming, Simulation, Management Science, Operating Expenditure**

I. Introduction

IN current telecommunication industries the companies try to survive in recent market saturation and fierce competition by reducing operating expenditure and creating new customer values [2, 3]. In this paper, we consider how to reduce operating expenditures that is one of key survival factors for a telecommunication company. Among various efforts to reduce the operating expenditures in a large telecommunication company optimizing staffing level in operations and management centers is a very important problem for the next generation operations and management paradigm [3]. Therefore, in this paper, we are going to introduce how to optimize operations staffing level in operations and management centers and how to verity the result. Moreover, we propose a system architecture to implement the result.

To obtain the optimal staffing level this paper proposes linear programming (LP) technique and to verify the result we propose simulation. Here, 'verify' means that we use LP result into simulation model as one part of inputs. These two methods are most frequently used in management science discipline and have been applied in various areas such as telecommunication design, supply chain design, call center design, etc. In this paper, with LP, we minimize daily labor cost of the operations and management staff under the constraints of daily activity limits for each worker type, number of each worker type, and the number of each daily task. With simulation, we verify the result that is obtained by using LP. Finally, to implement the result, we propose a system architecture which is based on service-oriented architecture.

For literature review of this paper, we first review telecommunication and network operations and management trends [2, 3]. Then we introduce the concept of management science [4, 5], LP [6], simulation [7, 8] and a literature related to staff optimization in various application fields [9]. However, there are few literature considering the staff optimization in network operations and management centers in a telecommunication company even though there are plenty of literature in call center and operator optimization [9—22].

In this paper we apply LP to optimize the staffing level in operations and management centers and give a simple example to explain the model developed. Because the model is a general formulation, it can be applied to other operations and management centers for a telecommunication company. We also apply a stochastic simulation model to verify the result. Unlike the deterministic optimization model a simulation model is dynamic over time. Therefore we can model the more realistic situations of network operations and management centers over time. Finally to implement the result in operations and management centers we propose a system architecture to monitor and optimize the productivity of operations and management centers.

In the next section, we provide the review of trends of current telecommunication industries and network operations and management paradigm, and introduce the concept of management science including LP and simulation, and finally

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give a brief review of previous research about the optimization of the staffing level. We subsequently present a linear programming model for optimizing the staffing level of operations and management centers and give a simple example for illustration. Then we develop a simulation model to verify the result. In the remaining sections of the paper, we present a system architecture to implement the model in a telecommunication company and conclude the research and suggest future research issues.

II. Literature Review

In this section, we present the trends of current telecommunication industries and network operations and management paradigm. We also introduce the concept of management science including LP and simulation, and some previous research literature for a staffing level optimization.

A. Trends of telecommunication industries and network operations management

In this subsection, we provide a review of trends of current telecommunication industries and network operations and management paradigm based on the papers [2, 3] that were published in IEEE Communication Magazine in 2007 and 2008, respectively.

First, the paper, "Telco 2.0: A new role and business model", provided new directions for telecommunication companies' customer creation. These directions are explained in terms of four frameworks, customer innovation, business value migration, technology open innovation and collaborative and creative management infrastructure after analyzing future lifestyle of customers, ICT Trend, business and market trend. The paper also implemented four frameworks in Korea Telecom. These four frameworks were defined as Telco 2.0 that is the new direction that every telecommunication company if it wants to survive in the new IP world should be a total solution provider to create new customer value.

Second, to operate and manage new services creating new customer values the telecommunication companies need new paradigm of network operations and management field. That is "NOM 2.0: Innovative network operations and management for business agility [3]." Its new directions were explained in terms of automation and intelligence, remote control and network surveillance, virtual office for unmanned operations with robot, multi dimensional quality management and self customizable user interface. Also, from the environmental change, network operations and management needs the operators satisfying various needs from the companies while having multiple skills to cope with future technologies such IP Multimedia Subsystem and Service Delivery Platform and decrease of the operators in future. Therefore, to increase the competitiveness of the telecommunication companies it is mandatory to assign optimal number of operators in network operations and management centers.

B. Management science and staffing level optimization

Management science is generally a scientific approach to design and operate a system under some constraints such as insufficient resource [4, 5]. Broadly it can be divided by two categories, deterministic models and probabilistic models. Deterministic models include Linear Programming, Dynamic Programming, Integer Programming, etc. Probabilistic models include Markov Chain, Queueing Theory, Simulation, etc. In this paper, we apply LP to optimize operations and management centers' staffing level and simulation to verify the result. LP is a mathematical tool to optimize a linear objective function under linear constraints. Simulation is to use a computer to imitate the operation of an entire process or system. Here the system is usually a stochastic system. For more detail explanations of these techniques and management science models, refer to [4--8].

In the literature related to management science field there are various application problems pertaining to staffing level optimization. The main application areas are Transportation Systems, Call Centers, Health Care Systems, Protection and Emergency Services, Civic Services and Utilities, Venue Management, Financial Services, Hospitality and Tourism, Manufacturing, etc [9]. Among these areas the staffing optimization problems pertaining to telecommunication industries are mainly the optimization of operator, especially, call center operators [10--22]. There is few literature in the staffing level optimization of network operations and management centers.

TABLE I: INPUT PARAMETERS

Input Parameters	Explanation or Examples
Types of Tasks	Ex) AS, BS, Fulfillment, Surveillance/Mgmt, Operations/Maintenance Mgmt
Types of Workers	Ex) Manager, Officer, Master, Pre Master, A, B, C, D grade workers
Task Categories for each type of worker	- Upper and low limits of daily activity amount for each worker type - Ex) A manager can work for AS more than 60% and less than 70% among daily tasks.
Labor cost for each worker type	Daily labor cost for each worker type
Max # of workers in each NOMC	Information about maximum number of workers for each network operations management center
Min # of task in each NOMC	Information about minimum number of activity for each task type

III. STAFFING LEVEL OPTIMIZATION AND SIMULATION

In this section we apply LP to optimize the number of operations personnel in network operations and management centers in a telecommunication company. In addition, we develop a simulation model to verify the optimization result.

In an LP model, we consider the following input parameters.

To formulate the LP model that optimizes the staffing level in the operations and management centers, we first visited some selected centers and examined the types of tasks and task details of the centers. Then we decided input parameters as in Table 1.

With the input information of Table 1, we can have the following mathematical model to optimize the staff level of network operations and management centers.

A Mathematical Model

$$\text{Min } Z = \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij} X_{ij}$$

s.t. (subject to)

$$\frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \geq L_{ij} \text{ for each } i \text{ and } j \text{(Max \# of Each Task)}$$

$$\frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \leq U_{ij} \text{ for each } i \text{ and } j \text{(Min \# of Each Task)} \qquad (1)$$

$$\sum_{i=1}^{n} X_{ij} \leq b_j \text{ for each } j \text{(Max \# of Each Type of Worker)}$$

$$\sum_{j=1}^{m} a_{ij} X_{ij} \geq TL_i \text{ for each } i$$

(Min # of Each Task for Each Worker Type)

All $X_{ij}^{'}s \geq 0$.

For the above mathematical model (1),

Decision Variables

- Xij: ratio of worker type j who processing task type i

Objective Functions

- Z: Total cost of daily labor

Constraints

- Upper and low limits of daily activity amount for each worker type
- Upper limit of the number of each worker type
- Low limit of the number of each daily task
- Sign Restriction

The mathematical model (1) is an LP since the objective function is linear and constraints are linear. In the model (1), if we add the assumption that Xij's are integer, then the model is IP (integer programming). If the problem size is not too big, we can apply IP to optimize the staffing level in the operations and management centers. However, since in real problems we have to estimate parameters in the model (1) and consider other factors that may not be included in the model (1), we proposed LP model.

To use the above mathematical model (1), we need to figure out or estimate the information in Table 1. Then putting the information into the mathematical model, we can figure out the optimal staffing plan for network operations and management centers.

For illustration, let us consider 2 worker types and 2 task types. Table 2 indicates upper and low limits of the amount of daily activities for each worker type.

TABLE 2: THE RATIO OF ACTIVITY FOR EACH WORKER TYPE

	Task 1	Task 2
Worker Type 1	(60,70)	(30,50)
Worker Type 2	(30,50)	(60,70)

Unit: %

In Table 2, for example, the worker type 1 processes activity 1 more than 60% and less than 70%. For other entries in Table 2, we can interpret in a similar way. For the information of the daily labor cost, we estimate ₩190,000 and ₩150,000 for worker type 1 and 2, respectively. Also, because of the limitation of expenditure cost, we cannot hire more than 1 and 2 workers for type 1 and 2 worker, respectively.

Finally we need to figure out the minimum number of each task to be processed as in Table 3. In Table 3, for example, the worker type 1 processes 30 numbers of task 1 if he/she works for only task 1. And, the worker type 1 processes 20 numbers of task 2 if he/she works for only task 2. For worker type 2, we can interpret in a similar way. Thirty and twenty numbers of tasks 1 and 2, respectively, should be processed on average daily.

TABLE 3: THE NUMBER OF TASKS TO BE PROCESSED

	Task 1	Task 2
Worker Type 1	30	20
Worker Type 2	20	40
Min # of Tasks to be done	30	20

With these input information incorporated into the mathematical model (1) and after a little algebra, we have the following mathematical formulation in the next page.

Then using a software package such as Lindo or Excel, we can easily get the optimal solution for the decision variables. In this paper, we explain how to formulate the above example using Excel since if we can formulate the mathematical model into Excel, then in real companies they can easily apply LP models into their operations and management support systems.

$$\text{Min } 19x_{11}+19x_{12}+15x_{21}+15x_{22}$$

s.t.

$$\left.\begin{aligned} -0.4x_{11}+0.6x_{12} &< 0 \\ 0.3x_{11}-0.7x_{12} &< 0 \\ -0.5x_{11}+0.5x_{12} &< 0 \\ -0.7x_{21}+0.3x_{22} &< 0 \\ 0.5x_{21}-0.5x_{22} &< 0 \\ 0.6x_{21}-0.4x_{22} &< 0 \end{aligned}\right\}$$

Upper and low limits of daily activity amount for each worker type

$$\left.\begin{aligned} x_{11}+x_{12} &< 1 \\ x_{21}+x_{22} &< 2 \end{aligned}\right\}$$

Upper limit of the number of each worker

$$\left.\begin{aligned} 30x_{11}+20x_{21} &> 30 \\ 20x_{12}+40x_{22} &> 50 \end{aligned}\right\}$$

Low limit of the number of each daily

$$\text{All } X_{ij} \geq 0$$

The following figure 1 shows the optimal solution of our previous example.

Optimal Solutions of a Network Opeations Management Center

	Type 1	Type 2	unit:₩10,000									
Cost Per Peo. (Day)	₩19	₩15										
	Req. of # of Tasks											
	Type 1	Type 2										
Task 1	30	20										
Task 2	20	40										
	Fraction of People for Tasks			Total		Min.	Req. Tasks Pro.					
	Type 1	Type 2		Num. Tasks		Tasks	For Peo. 1		Min. Pro.			Max. Pro.
Task 1	0.7	0.45		30	>=	30	0.1	>=	0	2.40918E-14	<=	0
Task 2	0.3	0.675		33	>=	20	-2.40363E-14	>=	0	-0.2	<=	0
Total Num. Peo.	1	1.125										
	<=	<=					Req. Tasks Pro.					
Max. Num. Peo.	1	2					For Peo. 2		Min. Pro.			Max. Pro.
							0.1125	>=	0	-0.1125	<=	0
			Total Cost	₩36			1.70874E-12	>=	0	-0.1125	<=	0

Figure 1: The optimal staffing level for a network operations management center

By the result, for worker type 1, we need 0.7+03=1 people. That worker will spend 70% of his time for task 1 and 30% for task 2. For worker type 2, we need 0.45+0.675=1.125 people. However, generally as we mentioned just before, the number of worker should be integer. So, you can use integer programming instead of linear programming. We use here linear programming because it is easy to get solution and implement a system when the problem size is big. Also, we give more room to manipulate optimal decision about the staffing level based on LP solution depending on the situation of network operations management centers that is not considered here in the mathematical model.

In the real situation, number of variables is about 7 and constraints could be 35. Therefore, it is reasonable using LP and simplex algorithm. In case that we have many constraints, we may consider using dual problem.

For the next step, we can develop a simulation mode to verity the result from the optimization model. In this paper, we developed our simulation model using Arena [8]. The simulation model can be developed with similar inputs from the above optimization model. However, the characteristics of the simulation models are different from the deterministic optimization models because they are dynamic over time in nature. As an example, in the simulation model in this paper we created two tasks arrivals, task A and B. Task A's interarrival time is an exponential distribution with mean 0.8 (hour) and task B's interarrival time is an exponential distribution with mean 1.2 (hour). In addition, the processing time for task A is a triangle distribution with minimum 0.5, Mode 0.8, Max 1 (hour) and the processing time for task B is a triangle distribution with minimum 0.8, Mode 1.2, Max 1.5 (hour). Before processing tasks A and B, they will stay in servers A and B, respectively. The waiting time for servers A and B is an exponential distribution with mean 20 (minutes). The simulation model and the results are in Figure 2, Table 4 and 5.

In the simulation model, worker type 1 and 2 consists of two workers for each type and the number of replication is 30. In the results 95% confidence interval for waiting time for server A is (0.2535, 0.5135) hours and 95% confidence interval for waiting time for server B is (0.2453, 0.5453) hours. We can see that the average and half width of waiting time for server B is a little greater than those of waiting time for server A. In Table 5, we can see the similar results for numbers of waiting in queues to Table 4. The average number of waiting for worker type 1is a little less than the average number of waiting for worker type 2, but the half width is a little greater.

IV. System Architecture

This section provides a system architecture that includes the optimization solver described in the previous section. The system has an enhanced network assurance and remote connection technology support functions. Through the system the company can reduce operators' dispatch time and have the optimal number of operation personnel. Also, it can reduce operating expenditures through reduction of dispatching ratio. Figure 3 and 4 describes the system's operating environment and the system architecture, respectively.

In figure 3, the system is interoperated with fault management system, authentication management system, remote simple message service system, and human resource system. The operators, technicians, security managers can access the system and they can find the most proper field workers and dispatch them when there are some problems in telecommunications networks.

In figure 4, the optimization function in the previous section is included in achievement analysis module. We are currently developing this module and if the system has input information such as in Table 1 it can use the linear programming model in Equation (1) to provide the best optimal staffing level.

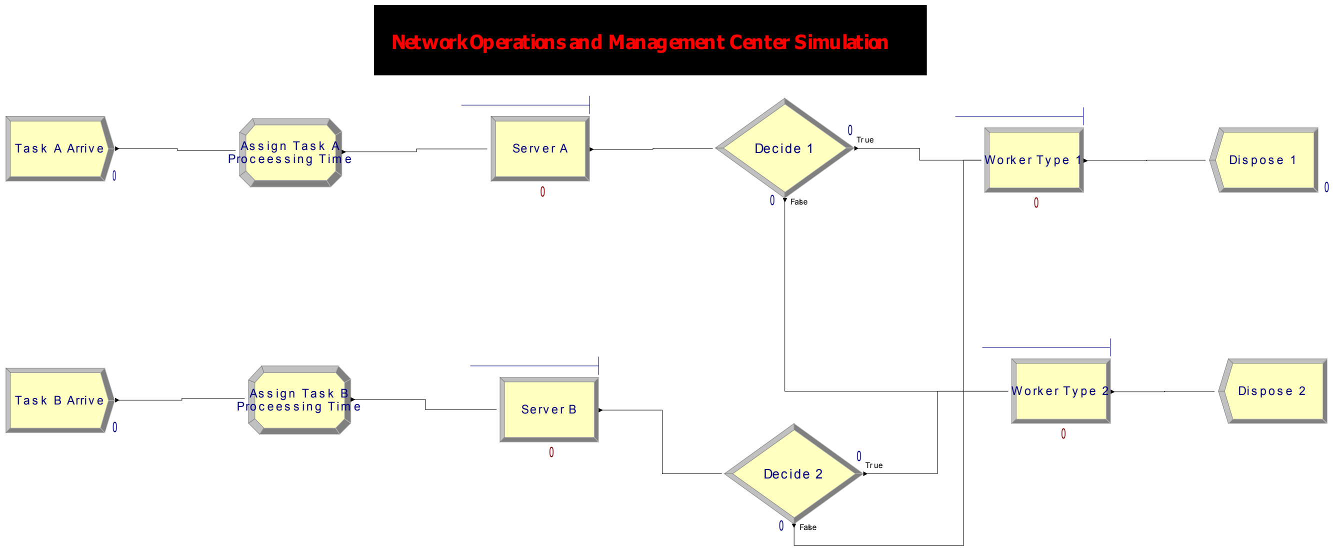

Figure 2: Network Operations and Management Center Simulation Model

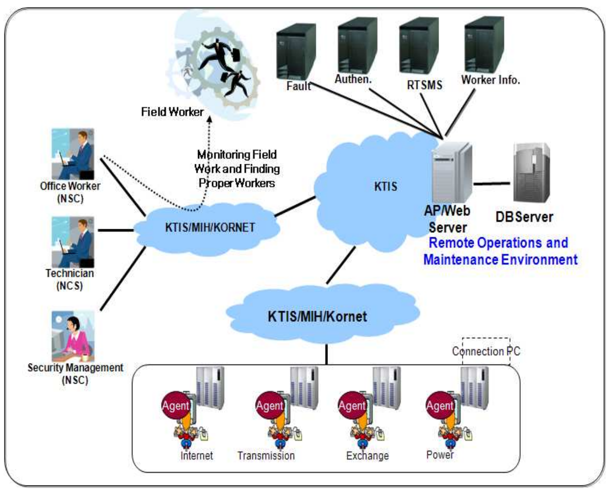

Figure 3: Remote Operations and Maintenance Environment (ROME)

TABLE 4: Waiting Time Results for Server A and B Queues

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Server A. Queue	0.3835	0.13	0.00	1.3861	0.00	3.3671
Server B. Queue	0.3953	0.15	0.0484	1.8943	0.00	3.1055

TABLE 5: Number of Waiting Results for Servers and Work Types Queues

Number of Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Server A. Queue	0.5351	0.21	0.00	2.1166	0.00	5
Server B. Queue	0.3336	0.14	0.0303	1.5542	0.00	5
Worker Type 1. Queue	3.9321	0.57	1.5551	7.5701	0.00	15
Worker Type 1. Queue	4.0629	0.46	1.2150	7.6618	0.00	14

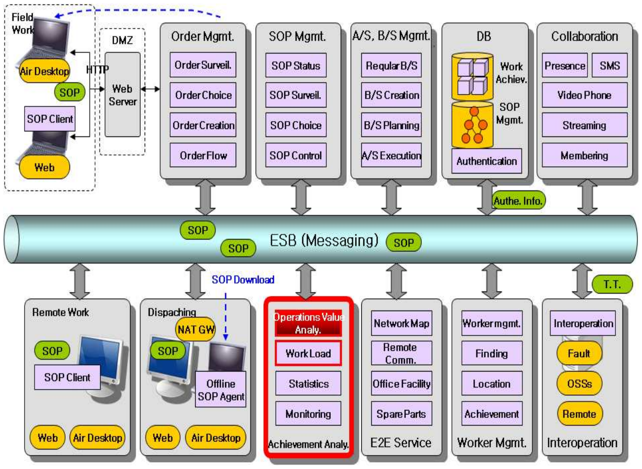

Figure 4: System Architecture of ROME

I. Conclusions

In this paper we provide a linear programming model to optimize the staffing level of network operations and management centers and a simulation model to verify the result. Also, we present a simple example to explain the linear programming formulation. Because the optimization model is a kind of general formulation, it can be applied to other operations and management centers in a telecommunication company. Applying the model to the field will reduce the operating expenditures for the company so that it can contribute to increase the competiveness. We also provide a simulation model to verify the result. However, because simulation model is dynamic over time in nature we need to get more data to make the model. Finally we present the implementation architecture of the linear programming model in a system. All of this process can also contribute to process analysis and improvement of a telecommunication company as well as a general organization such as hospital, government, and manufacturing company.

In the linear programming model, we assumed that the objective function and constraints are linear. We can relax this assumption for further research and develop more complex models and compare the results with those of this paper. Also, we can develop more complex simulation models.

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