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An Integer Programming Based Decision Support System for Pharmacy On-Duty Assignment

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Abstract— As long as the world exists people will constantly seek solutions to health problems. It is not enough for the people to reach the hospitals and doctors; at the same time, they need to reach medicine when they need it. Excluding exceptional cases, medicines are available from private pharmacies. These pharmacies must be easily accessible when needed. For this reason depending on the population and size of the city, at least the determined number of pharmacies have to be kept open all the time in any city center. As the population of the city increases, the demand for access to the pharmacy also increases. Organizations responsible for the rights and duties of pharmacies must ensure that access is sustained and fair. In this study, a decision support system is presented to make pharmacy assignment task easy and clean. A mathematical model containing all the necessary constraints has been created and solved using mixed integer programming. Penalty scores are established for all on-duty pharmacies for formal holidays, weekend delays and after regular hours in order to compensate inequality among the pharmacies. Assignments of duty pharmacies are made based on these scores in ascending order. According to the result of the proposed model, the pharmacies must have equal or very close penalty scores for any preferred time period. The usefulness of the used method and the benefits provided by the decision support system are denoted.

Index Terms—Integer Programming; Pharmacy Assignment; Decision Support Systems; Linear Model

1 Introduction

Pharmacies have a great deal of precaution to meet the medicine needs of the community. In this sense, they operate with an active and under governance according to the population density of the region where they are located. These pharmacies have to be open for seven days and twenty-four hours, as people may encounter a health problem at any time. It is not possible for all of the pharmacies to operate 7/24. For this reason, the pharmacy on-duty system is required. The pharmacy in the area where the pharmacy is affiliated, including the shopping malls, has to comply with the working day and opening and closing times. In locations with more than one pharmacy, only on-duty pharmacies remain open during scheduled business hours and on official holidays. Pharmacies outside the pharmacy on-duty can’t operate during seizure hours. The working order of the pharmacies on-duty is as follows. Considering the characteristics of the places where the pharmacists are located and the current pharmacy capacity by the pharmacists' chambers or the representative; pharmacy working hours, if the on-duty task will be performed the number of days of duty and working hours on-duty and how many pharmacists will be remaining on duty will be determined and a schedule will be prepared. These lists shall be sent to the district and provincial health directorate on time, in such a way as not to cause any disruption to the service. It is put into practice with the acceptance and approval of the district and provincial health directorate. Assignment problems in health systems have been widely studied. Zaerpour et al. proposed a tactical assignment model for lab-clinics [1]. Laesanklang et al. studied a linear model for healthcare planning [2]. Hampe presented a simulation approach for assignment of health administration students [3]. Healthcare staff assignment problems are often encountered in literature [4], [5], [6]. Many solution approaches are proposed for other healthcare topics like vaccine scheduling [7]. The assignment of duty pharmacies is usually carried out by a board designated by the provincial pharmacists' chambers. The pharmacies in shopping malls closed at night are exempt from duty. Pharmacies located in airports open to international flights may be open 24 hours outside the pharmacy working day and time. In this case, it is obligatory to have a pharmacist for every 8 hours, one of whom is a pharmacist. On-duty pharmacy lists are announced by the pharmacy chambers to all relevant places in the area. The aim of this study is to establish a decision support system that determines the assignment of duty pharmacies more easily, objectively and quickly, while adhering to the specific criteria of the assignment system implemented by the pharmacists' chambers.

2 Methods

One of the most common problems in the Operations Research is assignment problem. It is desirable to make an appointment plan with the lowest total cost, provided that each task is absolutely given one candidate and only one entity is assigned. Sequencing is the processing of jobs according to their specific characteristics. When sequencing gives different results, the problem is evolved to scheduling. Scheduling is a decision-making process that is used regularly in many manufacturing and service industries. It is using of scarce sources to optimize their objectives by taking time into account. Assignment of a certain number of activities in a limited number of sources and time periods to provide certain conditions. Pour et al introduced a practical generalization of the standard personnel assignment problem [8]. Binder et al. proposed an analytic model for capacitated passenger assignment problem by taking into account passenger priority lists [9]. Lai et al. examined the task assignment problem by using particle swarm optimization techniques and compared them through their different aspects [10]. Wang and Sitters considered some special cases of restricted assignment problem by Linear Programming models [11]. Pavlin presented a solution for classical continuous assignment problem by a linear model in order to make service pricing [12]. A neighborhood search heuristic algorithm is used for robust ate assignment in airports by Yu et al [13]. Another heuristic is proposed for Mixed Integer Programming (MIP) by Andrade et al [14]. They used biased random key genetic algorithm and for LP relaxation. A self-learning approach is given by Haoran et al. [15] to solve multi-product pipeline problem which is modeled as Mixed Integer Linear Programming problem. A mixed Integer Linear programming model is presented by Chassein and Goerigk [16] for robust optimization with uncertainties. They aimed to find a set of robust solutions. Workforce assignment problem which known as NP Hard for a paced assembly line was solved by conventional and randomized heuristics on the simulated data [17]. A bi-objective Mixed Integer Linear Programming model is developed for health service network design with Hybrid Robust Possibilistic Programming (HRPP) [18]. They used this model for three level healthcare service. An adaptive Kernel search is developed by Guastaroba et al. for solving Mixed Integer Linear Programs [19]. A network design problem under random demand is considered by [20]. They used more than one approach for Mixed Integer Linear Programming model and compared the performances through parameters, network and cost setting. Decisions have to be made about more than one objective, such as flexibility, speed, security, economics, and productivity. A scientific method like decision support system should be followed to support and strengthen these decisions. Malmir et al. developed a decision support system for disease diagnosis under uncertainty [21]. McNamara [22] proposed a decision support system for personal assignment. A student group assignment problem is designed as a multi criteria decision support system by Weitz et al.[23]. In this study a deterministic mixed integer programming model is developed. The model is settled into proposed decision support system. Pharmacy on-duty assignment decision support system is written in C# programming language using SQL database..

3 Problem Definition and Model

The aim of the study is to develop a more objective and more useful system instead of the current pharmacy assignment system in city centers. In this system, the distances between the pharmacies and the neighborhoods are taken into consideration. Population densities that they cover while assigning pharmacies on-duty are also included in the model. Also the penalties to be given to the pharmacists according to the days when the pharmacies are on- duty and the days and intervals will be determined. Penalty scores are established for all on-duty pharmacies for formal holidays, weekend delays and after regular hours in order to compensate inequality among the pharmacies. X penalty point is given to the pharmacies who are on-duty in regular days, 3X penalty points are given to the pharmacies who are on-duty on Sundays, and 7X penalty points are added to the pharmacies who are on-duty on official holidays like religious holidays and etc. This study was carried out on 12 regions and 86 pharmacies in Erzurum province.

Distances among regions, pharmacies in regions and the populations of the regions are added individually to the model. Pharmacies in the regions are usually based on a health center or neighborhood centers because they are clustered around a hospital. The purpose of determining these distances is due to the fact that there must be a certain distance between pharmacies on-duty. The purpose of determining the population of the regions is to have the highest proportion of the population to be covered by the pharmacies on-duty to be appointed on a day-to-day basis.

In the illustrated example for Erzurum province, the distance between the regions where the pharmacists on-duty are accepted as at least 5 km and the pharmacies on-duty are defined to cover at least 60,000 people and at most 130,000 people in the regions. According to these definitions, the number of pharmacies on-duty will be determined for each day and the names of these pharmacies will be determined as the result of the mathematical model. The mathematical model was constructed as a mixed integer programming model that would give the results 0-1.

$$MIN \sum SA_i + \sum SB_i + \sum SC_i + \sum SD_i + \sum SE_i + \sum SF_i + \sum SG_i$$

Subject to:

$$R_3 + R_6 + R_7 + R_{10} + R_{11} + R_{12} \geq 1$$

$$R_1 + R_2 + R_4 + R_5 + R_6 + R_7 + R_8 + R_9 + R_{10} + R_{11} + R_{12} \geq 1$$

$$R_3 + R_6 + R_7 + R_{10} + R_{12} \geq 1$$

$$R_3 + R_7 + R_{10} + R_{12} \geq 1$$

$$R_2 + R_3 + R_4 + R_{10} \geq 1$$

$$R_1 + R_2 + R_3 + R_4 + R_5 + R_8 + R_9 + R_{10} + R_{11} \geq 1$$

$$R_3 + R_7 \geq 1$$

$$R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_7 \geq 1$$

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$$R_2 + R_3 + R_7 \geq 1$$

$$R_1 + R_2 + R_3 + R_4 \geq 1$$

$$\sum_{i=1}^{12} R_i P_i \geq 60000, \sum_{i=1}^{12} R_i P_i \leq 130000,$$

$$R_i + R_j \leq 1, \forall i, j: D_{i,j} \leq 5,$$

$$\sum_{i=1}^{7} SA_i \geq R_1, \ \sum_{i=1}^{3} SB_i \geq R_2, \ \sum_{i=1}^{6} SC_i \geq R_3, \ \sum_{i=1}^{7} SD_i \geq R_4$$

$$\sum_{i=1}^{8} SE_i \geq R_5, \ \sum_{i=1}^{5} SF_i \geq R_6, \ \sum_{i=1}^{4} SG_i \geq R_7, \ \sum_{i=1}^{18} SH_i \geq R_8, \ \sum_{i=1}^{14} SJ_i \geq R_9$$

$$\sum_{i=1}^{2} SK_i \geq R_{10}, \ \sum_{i=1}^{5} SL_i \geq R_{11}, \ \sum_{i=1}^{7} SM_i \geq R_{12}$$

$$P_1 = 23255, \quad P_2 = 30156, \quad P_3 = 34280, \quad P_4 = 28281, \quad P_5 = 46993, \quad P_6 = 12276, \quad P_7 = 32835, \quad P_8 = 24104, \quad P_9 = 13433, P_{10} = 19465, P_{11} = 18853, P_{12} = 38335$$

$$SA_i, SB_i, SC_i, SD_i, SE_i, SF_i, SG_i, SH_i, SJ_i, SK_i, SL_i, SM_i, R_i = 0 \text{ or } 1$$

4 Results

The aim of the scoring system is to ensure equality in pharmacy assignments. The assignment is made by the increasing order of the scores. Pharmacies with a minimum penalty score among the penalties they are assigned on a daily basis, subject to the defined limitations of pharmacies. This process is repeated for 400 days. The pharmacy assignment schedule is obtained by using the mixed integer programming algorithm.

Date	Pharmacy	Region	Score	Population Served
10.12.2017	Yıldızkent	Region9	181	112358
10.12.2017	Tuğra	Region8	181	125390
10.12.2017	Çamlıca	Region11	182	109458
10.12.2017	Hilalkent	Region12	182	104398
11.12.2017	Erdoğan	Region3	182	110003
11.12.2017	Köşk	Region7	182	98312
11.12.2017	Deniz	Region10	182	101276
11.12.2017	Yağmur	Region12	183	97854
12.12.2017	Kaya	Region4	183	125876
12.12.2017	Pınar	Region2	183	99943
12.12.2017	Serpil	Region6	183	91782
12.12.2017	Ağırman	Region5	185	98332
13.12.2017	Cengiz	Region1	185	97629
13.12.2017	Selvi	Region11	185	103555
13.12.2017	Gölbaşı	Region4	185	98275
13.12.2017	Alkazan	Region7	185	112879
14.12.2017	Fulya	Region10	186	126095
14.12.2017	Güven	Region5	186	102245
14.12.2017	Şifa	Region9	186	99556
14.12.2017	Gürcükapı	Region3	186	96772

5 Conclusions

This paper touches on a practical application of the standard task assignment problem under completely deterministic conditions. Addition to many scheduling problems, pharmacy on-duty problem is introduced with the literature. The originality of this work is that, the problem wasn't studied before. The model's implementation in practice shows that pharmacies in city are assigned to the duties equally and other constraints like population covered and distance limitation are satisfied sleekly. Adding penalty points to pharmacies according to duties they performed, provides a clear work for schedule makers.

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