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Article

Binary Programming Model for Rostering Ambulance Crew-Relevance for the Management and Business

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Abstract: The nature of health care services is very complex and specific, thus delays and organizational imperfections can cause serious and irreversible consequences, especially when dealing with emergency medical services. Therefore, constant improvements in various aspects of managing and organizing provision of emergency medical services are vital and unavoidable. The main goal of this paper is the development and application of a binary programming model to support decision making process, especially addressing scheduling workforce in organizations with stochastic demand. The necessary staffing levels and human resources allocation in health care organizations are often defined ad hoc, without empirical analysis and synchronization with the demand for emergency medical services. Thus, irrational allocation of resources can result in various negative impacts on the financial result, quality of medical services and satisfaction of both patients and employees. We start from the desired staffing levels determined in advance and try to find the optimal scheduling plan that satisfies all significant professional and regulatory constraints. In this paper a binary programming model has been developed and implemented in order to minimize costs, presented as the sum of required number of ambulance crews. The results were implemented for staff rostering process in the Ambulance Service Station in Subotica, Serbia. Compared to earlier scheduling done ad hoc at the station, the solution of the formulated model provides a better and equable engagement of crews. The developed model can be easily modified and applied to other organizations with the same, stochastic, nature of the demand.

Keywords: decision making; binary programming; scheduling; ambulance service; health care organizations

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1. Introduction

Organization and management of health care systems are highly significant and complex activities in every society because of the special and extremely important nature of health care services. Thus, managing operations in health care organizations is a question of extraordinary social relevance. Health care systems in modern societies are facing an extreme challenge to improve efficiency, quality, and satisfaction of provided services in spite of the global economic crisis, budget limitations and rapidly changing environment. There is a growing trend in terms of share of employment in the service economy over the last few decades [1]. Accordingly, demand for health care services is permanently increasing and the same trend is expected in the future [2–5]. Increased demands for the quality and extent of health care usually coincide with reduced spending on health care systems, thus various countries face the same challenges of limited resources, increasing costs and heightened demands for services [6]. As the largest share of health care expenditure is financed by public sources, the efficient decisions are not only a purely technical and financial problem but may be seen as an issue of public interest in broader terms [7]. The intention of health care management is quantitative and qualitative optimization of organization and its financial and human resources. The main task of operations research is to manage scarce resources in the best possible way, so practical implementation of these methods can surely be of great interest for achieving business objectives and desired quality of services in all health care organizations [8,9]. However, practical implementation of operations research models in health care sector in our region is quite rare. There are numerous reasons for this situation, but probably the main are: lack of available and useful data formatted for modelling, low level of quantitative knowledge among specialist who work in health care organizations and high cost of hiring external consultants [10]. Many health facilities lack information and experience in process management; therefore, the existing internal rules do not address all problem areas and do not eliminate all known risks [11]. As well, health systems of low- and middle-income countries are often characterized by the lack of reliable data, which greatly hinders workforce-planning efforts. Without a reliable information system that allows accurate reporting and measuring workforce capacity, countries cannot assess the scope and magnitude of the gap between the number of health workers needed and the number that is available [12]. One of the aims of this paper is to improve awareness about the benefits that can be achieved by application of operations research methods, and their practical relevance to business development.

Despite the fact that all developed countries established public health care system a long time ago, some research results [13] indicate a lack of systematic analysis, long term capacity planning and resource allocation. Countries all around the world are facing an enormous challenge to improve health care systems on the efficient and equitable way at affordable costs. However, costs are not an only threat for structuring an efficient health care system. The nature of health care services is very complex and specific, thus delays and organizational imperfections can lead to serious and irreversible consequences, especially when dealing with emergency medical services. In life-threatening situations every second is important. Therefore, constant improvements in various aspects of managing and organizing provision of emergency medical services are vital and unavoidable. Breakdowns in information flow, discontinuity of care and delays in delivering medical services also represent serious drawbacks that should be resolved [14].

By synchronization of management activities on operational, tactical, and strategic levels, health care organizations aim to achieve predefined business objectives and provide high quality services with respect to all the specifics that characterize a health care system. Health care management attempts to satisfy and balance interests of all participants in the health care system. Due to the core similarities with economic systems, in the developed countries health care systems are treated as a health industry, led by specialists who are not medical doctors, but experts that possess distinctive knowledge and skills for managing health care organizations. General conditions regarding organizational performances in the province of Vojvodina can be found in paper Grubor et al. [15]. The main characteristics that differentiate management in health care organizations from management activities in business organizations are:

- Uncertainty and uniqueness—risk and uncertainty are an unavoidable part of any decision-making processes, but seriousness and the weight of possible bad outcomes in the health care sector make these activities even more complex;
- Quality of services—services are the main output of health care institutions, but their outcome depends also on the patient, and this makes it extremely hard to quantify and compare the quality of services. The main output of health care services is health, which is almost an immeasurable category;
- Human resources management—this is a very complex process in health care organizations due to the necessity of coordination of different professionals. The autonomy and superior status of medical experts make it even more challenging;

- Cooperation and communication—good relationships are the main prerequisite for satisfaction of both patients and the medical staff, which leads to efficiency of the whole health care system.

This paper deals with modelling human resources allocation in health care organizations. We start from inserting observed regularities in demand for emergency medical services into human resources allocation process. Therefore, the balance between demand and supply can be obtained, which consequently leads to improvement of quality of medical services and increased satisfaction for both patients and medical staff. This survey was realized in order to make improvements in the workforce allocation in the ambulance service station in Subotica, Serbia.

The common organizational problem of the ambulance services in Serbia is that the number of disposable ambulance crews has been determined despite of the variations in demand and system load. The necessary staffing level and human resources allocation is defined ad hoc, without empirical analysis and synchronization with demand for emergency medical services. Irrational allocation of resources results in various negative impacts on the financial result, quality of medical services and satisfaction of both patients and employees. Managers need to automate routine tasks in order to limit the time and other resources they spend on daily basis [16]. We start from the previously determined desired staffing levels and try to find the optimal scheduling plan that satisfies all necessary constraints. The novelty lies in the fact that those staffing levels are based on detailed quantitative analysis of demand for emergency medical services [17]. Following the work of Li and Kozan [18] we built a binary programming model that comprises all significant professional and regulatory constraints for rostering ambulance services. Furthermore, the model minimizes the required number of ambulance crews per planning period, which enables significant savings of both financial and human resources.

The next chapter focuses on the previous studies in the field of operations research, scheduling and health care management that highly motivated us for this research. Chapter three describes specifics of scheduling of employees in health care organizations and presents the applied methodology and formulation of the model. In the fourth chapter the results are presented, followed by main conclusions and guidelines for future research.

2. Literature Review

Scheduling employees in health care organizations is a very challenging task and should be perceived from different angles. In this section a short review of papers dealing with all aspects of a scheduling process is given. In order to enable the development of an optimal plan for human resources allocation, it is necessary to possess accurate information on demand for observed services. Analysis of emergency medical services demand can be divided into two categories. The first one is dealing with spatial distribution, vehicle routing and redeployment problems in order to find location with the best spatial coverage that provides the shortest time of response. Further articles dealing with location problems are [19]; another group of models investigates how demand for ambulance services evolves over time, which provides reliable basis for development of a scheduling plan [20,21]. Baker and Fitzpatrick [22] first applied Winters exponential smoothing model to predict the daily number of calls at the ambulance service of South Carolina; they applied goal and quadratic programming to select exponential smoothing parameters. Finally, authors compared the forecasts obtained by multiple regression model and Winters exponential smoothing model and concluded that the forecast obtained by the exponential smoothing model was more accurate.

Interesting study compared various time-series models used to forecast the number of calls in the ambulance service in Calgary, Canada [23]. The study showed that an autoregressive model of the number of daily calls and a multinomial distribution for the vector of number of calls in each hour conditional on the total volume of calls during the day, had the best goodness of fit and forecasting a accuracy for observed data.

Zuidhof [24] performed complex analysis of the demand of ambulance services in Amsterdam, The Netherlands. Holt-Winters exponential smoothing models, seasonal autoregressive integrated moving average models and multiple regression models were applied to forecast the daily demand in this health care organization. In this study, the superior prediction has been achieved by the multiple regression model.

It is important to point out that artificial neural network can also generate successful forecast for health care services with stochastic demand [25,26].

When time and space dependent variations of demand are known, various groups of models can be applied to generate an optimal scheduling plan. The detailed review of different groups of staff scheduling and rostering models is presented by Ernst [27] and other authors [28].

Elkhuizen [29] developed complex capacity management model that calculate the number of nurses needed for a hospital ward and suggest ways to improve capacity utilization on a ward. The model gives the chance to define staffing requirements for wards based on accurate ward-specific data. The necessary capacity can be calculated on an annual basis and for each shift using this model. There is also a new way of human resource management such as Electronic Human Resource Management (e-HRM) [30] and the New Rural Cooperative Medical Scheme (NCMS) of employing which has been implemented in rural China [31]. For the group of authors, the one of the most important thing about healthcare system is the balanced mix of financial, economic, political, and social sustainability with the mentioned models of management [32].

The queuing theory models are often applied in health care organizations to improve patients' and employees' satisfaction by reducing the time spent in waiting lines [33–36]. It is possible to identify daily patterns and conclude which hours of the day are more frequent than the others. Furthermore, the number of available ambulance crews should be adjusted to the demand fluctuations. This is usually achieved by application of Erlang B model [24,37,38]. It is also important to state that many studies came to the conclusion that the demand for ambulance services follows a non-homogeneous Poisson process [23].

Li and Kozan [18] developed a model for rostering ambulance crew in order to maximize the coverage and minimize the number of ambulance crew. The two-stage models are developed using the nonlinear integer programming technique to determine the shift start times, the number of staff required to work for each shift and a balanced schedule of ambulance staff.

Kwak and Li [39] used goal programming model to support strategic planning and allocation of limited workforce in a health care organization. The main goal was to assign the workers to the proper shift hours that enable organization to meet the goal of minimizing the total payroll costs while patients are satisfied.

Kumar [40] presented the application of linear programming model for scheduling nurses in hospital and showed how both nurses and managers can benefit from application of this model.

Saaty et al. [41] accentuate the importance of intangible criteria and their incorporation into the decision-making model. They used Analytic Hierarchy Process and Linear Programming to rate and derive the best combination of people assigned to jobs.

Jasim [42] in his project developed a computerized system that makes use of optimization techniques that allow for the efficient allocation of staff to roster periods while meeting shift requirements and staff objectives. The rostering problem was modelled as a set partitioning problem, which is a zero-one integer-programming problem. The fatigue model, which has been used to predict the impact of working hours on the fatigue that is experienced by the staff member, was applied to the optimal solution.

Simulation is also a mathematical technique that can be successfully used to aid staffing and rostering processes in health care organizations [43–45].

3. Methodology

3.1. Problem Definition

Employee scheduling in health care organizations is a very complex task due to the nature of vital medical services that must be provided 24 h every day. Besides that, there are numerous legal and business regulations and agreements, which have to be complied during this process. For this reason, scheduling is one of the most common areas of application of operations research methods, whose main objective is to achieve optimal allocation of scarce resources. Efficient and effective allocation of human resources is one of the biggest challenges faced by managers of health care organizations. Compared to business organizations, determination of the optimal staffing level and scheduling employees is more complex in health care institutions, which are faced with very variable demand, chronic lack (or excess) of workforce for certain profiles and a limited budget. A great challenge for health care managers is also balancing between satisfaction of patients and satisfaction of employees.

When creating a schedule, it is important to take into account the impact of five main factors: patients' satisfaction, quality, stability, flexibility and costs. Taking into account all these features, creating a schedule is not a simple task. It is extremely difficult to find a good solution to these highly constrained and complex problems and even more difficult to determine optimal solutions that minimize costs, meet preferences, distribute shifts equitably and satisfy all the workplace constraints [25]. In developed countries, leading health care organizations use advanced information systems, modern software solutions and quantitative analysis in order to achieve the best way of staff scheduling. In Serbia rostering is mainly done ad hoc by the executives of small organizational units. In order to improve the organization of health care institutions in this paper we present a binary programming model for rostering ambulance crew.

3.2. Binary Programming Model

As well as other types of services, emergency medical services are characterized with significant increase of demand in recent years and the same trend is expected for the future. In current situation, improved rostering of ambulance staff can help reduce their fatigue levels and increase the quality of provided services [18]. Ambulance services operate 24 h every day, which require employees to work night shifts, and also on weekends and holidays. In order to improve scheduling process a binary programming model has been developed for the Ambulance Service Station in Subotica (Serbia).

Detailed statistical analysis of the demand for emergency medical services at the Ambulance station in Subotica has been conducted for the period three years prior to the formulation of binary programming model for scheduling. Results of the performed nonparametric Mann-Whitney U test (U statistic value 107995.5) show the existence of significant difference in the demand for ambulance services depending on the day of the week. During the weekend, the demand for emergency medical services is considerably higher than the number of interventions during the workdays. In the Figure 1 the demand for emergency medical services at the Ambulance station in Subotica is presented depending on the hours of the day and days of the week. The demand for ambulance services is higher during the day than during the night hours, and majority of interventions are concentrated between 8 a.m. and 8 p.m.

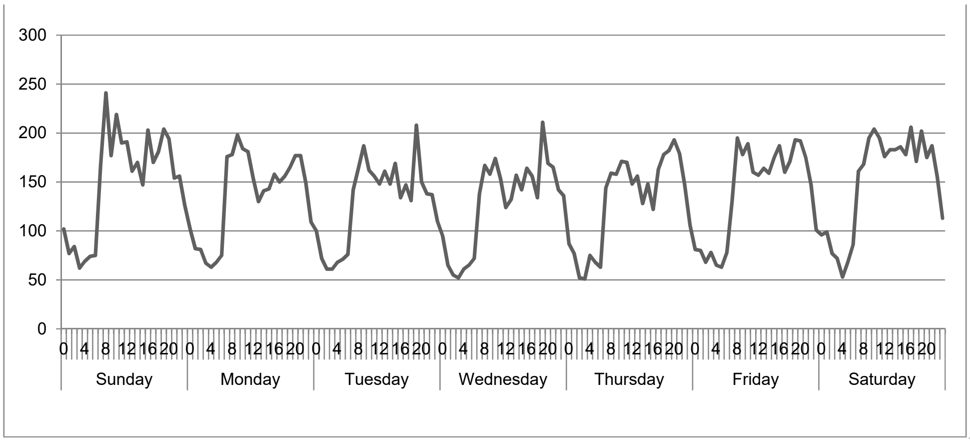

Figure 1. Mean hourly volume of the emergency medical services in Ambulance station Subotica.

Binary programming is a special class of integer linear programming, where the primary variables can take values 1 or 0, depending on whether the event is realized or not. Binary programming models have very frequent use in staff deployment tasks, so in this paper we develop binary models for scheduling ambulance crew. The model generates the optimal schedule of crews for the period of four weeks, with respect to all necessary constraints. The model has been solved by Lingo 14.0 optimization modelling software. Examples of various models used for scheduling staff in health care organizations are given in papers such as [33,38,46,47].

Notations:

d	Morning shift
n	Night shift
l	The set of shifts; $l = d, n$
i	Week, $i = 1, 2, 3, 4$
j	The set of crews
J	Total number of crews
k	Day of the week, $k = 1, 2, 3, 4, 5, 6, 7$
S_{kl}	The number of ambulance crew required to be assigned to shift l on day k
M_{min} and M_{max}	minimal and maximal number of shifts per crew per period
N_{min} and N_{max}	minimal and maximal number of night shifts per crew per period
W_{min} and W_{max}	minimal and maximal number of shifts per crew per week
N_{min} and N_{max}	minimal and maximal number of night shifts per crew per period
W_{min} and W_{max}	minimal and maximal number of shifts per crew per week

$$x_{ijkl} = \left\{ \begin{array}{ll} 1, & \text{if crew j is assigned to shift l on day k in week i} \\ 0, & \text{otherwise} \end{array} \right\}$$

$i = 1, 2, 3, 4, j = 1, 2, \ldots, J, k = 1, 2, \ldots, 7, l = d, n.$

Objective function:

In order to minimize total costs, objective function is defined as the minimal number of crews in a four week period.

$$Z = \sum_{i=1}^{4} \sum_{j=1}^{J} \sum_{k=1}^{7} \sum_{l=d}^{n} x_{ijkl} \tag{1}$$

Constraints:

Since the current schedules in health care organizations in Serbia are static and made ad hoc, previous research [17] provide insight in dealing with randomness in the ambulance service planning, by linking demand and supply to obtain the optimal resources allocation. Based on the Erlang B model, staffing models were used to determine the optimal staffing level, according to the variations of number of emergency calls over time. Thus, the number of necessary ambulance crews for morning and night shifts has been defined for every day of the week S_{kl}, based on the optimal staffing level. Equation (2) ensures that the total number of available crews in every shift per day has to be equal to the minimum required level.

$$\sum_{i=1}^{4}\sum_{j=1}^{J} x_{ijkl} = S_{kl}, \;\; k = 1,2,\ldots,7 \; and \; l = d,n \tag{2}$$

Since the wages of employees depend on the number of night shifts, the total number of night shifts should be uniformly distributed between the crews. This is provided by upper and lower limit for number of night shifts per crew.

$$\sum_{i=1}^{4}\sum_{k=1}^{7} x_{ijkl} \geq N_{min}, \quad j = 1,2,\ldots,J \; and \; l = n \tag{3}$$

$$\sum_{i=1}^{4}\sum_{k=1}^{7} x_{ijkl} \leq N_{max}, \quad j = 1,2,\ldots,J \; and \; l = n \tag{4}$$

The total number of shifts should be evenly distributed to each crew, in order to achieve approximately equal number of working hours. This is ensured by Equations (5) and (6).

$$\sum_{i=1}^{4}\sum_{k=1}^{7} x_{ijkl} \geq M_{min}, \quad j = 1,2,\ldots,J \; and \; l = d,n \tag{5}$$

$$\sum_{i=1}^{4}\sum_{k=1}^{7} x_{ijkl} \leq M_{max}, \quad j = 1,2,\ldots,J \; and \; l = d,n \tag{6}$$

It is important to arrange a uniform distribution of shifts to each crew, in order to avoid excessive fatigue, which can lead to poor quality of provided medical services. For this reason, the constraints on minimal and maximal number of weekly shifts for each team have been included in the model (Equations (7) and (8)).

$$\sum_{k=1}^{7}\sum_{l=d}^{n} x_{ijkl} \geq W_{min}, \;\; i = 1,2,..4 \; and \; j = 1,2,\ldots,J \tag{7}$$

$$\sum_{k=1}^{7}\sum_{l=d}^{n} x_{ijkl} \leq W_{max}, \;\; i = 1,2,..4 \; and \; j = 1,2,\ldots,J \tag{8}$$

Equation (9) ensures that each crew can only be assigned to the maximum of two shifts during three consecutive days.

$$\sum_{k=b}^{b+2}\sum_{l=d}^{n} x_{ijkl} \leq 2, \quad i = 1,2,\ldots,4 \; and \; j = 1,2,\ldots,J \; and \; b = 1,2,\ldots,5 \tag{9}$$

The previous constraint ensures that ambulance staff cannot work more than two shifts within three days. Since we need to specify the schedule for four weeks period, it is necessary to add a transitional constraint that connects two consecutive weeks. Thus, the crew may be assigned to maximum two shifts during the current weekend and on Monday the next week.

$$x_{ij6d} + x_{ij6n} + x_{ij7d} + x_{ij7n} + x_{i+1,j1d} + x_{i+1,j6n} \leq 2, \;\; i = 1,2,3 \; and \; j = 1,2,\ldots,J \tag{10}$$

A similar constraint should be added to link the Sunday of the current week with Monday and Tuesday of the next week.

$$x_{ij7d} + x_{ij7n} + x_{ij7d} + x_{i+1,j1n} + x_{i+1,j2d} + x_{i+1,j2n} \leq 2, \ \ i = 1,2,3 \ and \ j = 1,2,\ldots,J \quad (11)$$

If it is the fourth weekend of the current period, the next restriction is necessary to link it with the first week of the next four weeks period, so the constraint is:

$$x_{4j6d} + x_{4j6n} + x_{4j7d} + x_{4j7n} + x_{1j1d} + x_{1j1n} \leq 2, \ \ i = 1,2,3 \ and \ j = 1,2,\ldots,J \quad (12)$$

Ambulance staff is eligible to work only one shift during 24 h, which is ensured by Equation (13).

$$\sum_{l=d}^{n} x_{ijkl} \leq 1, \ \ i = 1,2,3, \ j = 1,2,\ldots,J \ and \ k = 1,2,\ldots,7 \quad (13)$$

If the ambulance crew works the night shift at the current day, the same crew cannot work the morning shift on the next day and vice versa.

$$x_{ijkl} + x_{ij,k+1,d} \leq 1, \ \ i = 1,2,3, \ j = 1,2,\ldots,J \ and \ k = 1,2,\ldots,6 \quad (14)$$

The same constraint is presented by Equations (15) and (16) as a transitional constraint that links two consecutive weeks and periods.

$$x_{ij7n} + x_{i+1,j1d} \leq 1, \ \ i = 1,2,3, \ and \ j = 1,2,\ldots,J \quad (15)$$

$$x_{4j7n} + x_{1j1d} \leq 1, \ \ i = 1,2,3, \ and \ j = 1,2,\ldots,J \quad (16)$$

4. Results and Discussion

4.1. Results

Specified model has been solved in Lingo 14.0 optimization modelling software and the results are implemented for staff rostering process in the Ambulance Service Station in Subotica. Compared to earlier scheduling done ad hoc at the Station, the solution of the formulated model provides a better and equable engagement of crews. All specified constraints have been satisfied, which means that the model meets the requirements for rational staff engagement and at the same time provides the best possible allocation of human resources at the lowest costs.

Values of the required number of crews for this ambulance station are given in Table 1 in order to present the relationship between the imposed constraints and the results obtained. This ambulance station has 13 crews that are available for dealing with life threatening situations and part of the results is presented in Tables 2 and 3.

Table 1. Required number of crews for Ambulance Service Station.

S_{kl} Weekdays Morning Shift	S_{kl} Weekdays Night Shift	S_{kl} Weekend Morning Shift	S_{kl} Weekend Night Shift	M_{min}	M_{max}	N_{min}	N_{max}	W_{min}	W_{max}
2	2	4	3	10	11	4	5	2	4

Table 2. Results of binary programming model for scheduling ambulance crew.

Ambulance Crews	Schedule	
	Total Number of Shifts	Total Number of Night Shifts
1	11	5
2	11	5
3	11	5
4	10	4
5	10	5
6	10	5
7	11	5
8	11	5
9	11	5
10	10	5
11	10	6
12	10	5
13	10	4
Total	136	64

Table 3. An example of the weekly schedule (*d*—morning shift, *n*—night shift).

Ambulance Crews	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
	d	*n*	*d*	*n*	*d*	*n*	*d*	*n*	*d*	*n*	*d*	*n*	*d*	*n*
1		1								1				1
2						1				1		1		
3					1		1				1		1	
4				1									1	
5	1												1	
6				1										1
7						1		1			1			
8	1		1						1			1		
9									1				1	
10			1											1
11					1		1					1		
12								1			1			
13		1									1			
Total	2	2	2	2	2	2	2	2	2	2	4	3	4	3

The importance of this schedule is that it links demand (through determinate staffing levels) and supply (available ambulance staff) which ensures better organization of work and higher level of satisfaction. At the current stage it is difficult to transfer models from one organization to another one without significant changes. In the future, it is also important to make the schedule more adaptable to constant changes and personal preferences.

Compared to the previous research presented in the abovementioned literature review, the results of proposed binary programming model provide useful basis to aid scheduling process in this particular ambulance service station. Until now, the schedule has been created manually, without any quantitative analysis of the demand and available staff. Therefore, it was hard to adequately manage this process and often two borderline cases have been seen: there very too many available crews at one time or there were not enough available ambulance services. Those situations negatively influence both satisfaction of staff and patients. Proposed model is simple and small scale, but efficiently helps the manager to improve current situation. The computational time of this programming running in Lindo is few minutes which is significantly shorter that the schedule generated manually. Felici and Gentile [48] developed a very general weekly staff scheduling problem using binary programming. They describe integer programming approach for a class of such problems, where solutions have to obey a number of constraints related to workload balancing, shift compatibility, and distribution of days off. Authors Li and Kozan [18] presented an interesting solution for the rostering ambulance crew by implementing two stage nonlinear integer programming model to determine the shift start times, the number of staff required to work for each shift and a balanced schedule of ambulance staff. Authors also concluded that most of the rostering problems did not consider personal preferences which is also the case with the model developed in this paper. Further research will follow this direction and we aim to expand the current local scope to a regional level.

4.2. Discussion

This paper sought to make a positive step in solving the problem and to point out the needs and possibilities of an appropriate approach. In a real-world environment, the rostering ambulance crew process cannot be based solely on intuition and free design. Practice proves the justification of formalized system management, as well as decision-making—for which it is necessary to develop adequate tools for more exact qualitative modelling and dynamically harmonize strategic and operational management.

The problem of scheduling service occurs very often in various types of organizations, so therefore the need to systematize knowledge in this area cannot be denied, as well as further development of methods and models to cover the problem and formulate better solutions. These conditions and situations occur in such diverse forms and so often that at first glance they seem out of the question of formalization. It is possible that it is empirically clear that one business activity is more rational than another, that there are business decisions that are decisive in relation to others that are less important. Only such a comparison has some mathematical characteristics, and thus suggests the possibility of mathematical analysis. The most important effect of binary programming is that in simple situations it provides a conceptual framework for describing and analyzing such problems. There is a very big difference, however, between what this model can manage and what occurs in practice in most cases. Therefore, the binary programming technique can only have a partial role in the scheduling service process, it is an indirect aid. However, due to the significance of the mentioned general problem, further investigations in this domain are continued with the aim of covering even more complex problems. Based on the achievements of binary programming so far, this paper performs a critical analysis and sets such combinations and modifications of methods, which provide a more effective management and decision-making instrument, and which can be a factor in solving the problem of inefficiency.

One of the goals of this research was to provide incentives for the most intensive application of quantitative methods in healthcare practice. In the paper itself, the possibility of applying binary programming is presented through a real numerical example. It follows from the nature of the method that it can handle data, which does not have to adapt much to the method but can be inserted into a model with relatively small changes. The obtained results indicate the positive effects of decisions made on the basis of such provided quantitative support in relation to other more complex methods. We can consider this method simpler, most often and much more understandable and accessible to the user due to its deterministic character, and in fact for these reasons it reflects reality sufficiently. It can provide solutions, which are most favorable in certain situations, especially when it comes to a longer time horizon for the decision to take effect.

5. Conclusions

This paper presents a possible solution for one of numerous problems in health care organizations. It can be concluded that the complex combination of quantitative methods, human resources management and medical sciences is crucial for the improvement of the whole health care system. The goal of this study was to present and encourage practical implementation of quantitative methods in order to aid planning, organization, and management of ambulance stations in Serbia. This paper represents an economic research in which quantitative models for workforce allocation are developed in order to improve the performance of health care organizations. The proposed model is easily applicable to various aspects of the human resources planning process in organizations with stochastic demand.

In this paper we tried to present a possible application of the integer programming in human resources allocation in health care organizations; the presented methodology is applicable in all of the organizations that possess similar constraints and characteristics of demand (e.g., police and fire departments, etc.). An interesting topic that maybe subject of future investigations is the incorporation of fatigue levels in the scheduling model, which could significantly improve both patients' and employees' satisfaction. Adding personal preferences to the model would also be a very challenging task for the future research that could improve the quality, but also increase the complexity of scheduling. Changes in the health care are necessary and require more attention, as well as financial and human investments considerably higher than the existing. However, it is not possible to optimize business processes in health organizations without adequate human resources management, which is the most complicated segment in the work of health organizations.

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