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OPTIMIZATION OF HEALTHCARE PATHWAYS IN COVENANT UNIVERSITY HEALTH CENTRE USING LINEAR PROGRAMMING MODEL

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Abstract

A care pathway in healthcare practice is to enhance the quality of care by improving patient outcomes, enhancing patient safety, increasing patient satisfaction and optimizing the use of resources. In this paper, linear programming technique is applied to healthcare pathways in order to maximize healthcare delivery. It was observed that some constraints can hinder healthcare delivery; this research focuses on identifying those constraints and optimizing resources to aid effective decision-making in a health centre. The resulting linear programming model is solved manually and shown on tables. It was noticed that, minimum number of patients who need to visit Covenant University Health Center for treatment, number of patients that should be protected from kidnapping, number of staff needed for the center and

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minimum number of patients impressed with healthcare facilities are major factors for optimizing healthcare pathways in Covenant University Health Centre.

1. Introduction

There is a general saying that "health is wealth", over the years this has proven to be true as good health enables people to engage in desired activities with required energy and vitality. People who fall short of this health privilege patronize the service of hospitals in order to get better, it is therefore important for hospitals to render healthcare services effectively to people in order to enable them stay healthy. Care pathway involves improving quality in healthcare, cooperation among health professionals, efficiency and patient satisfaction [1, 8, 9]. Thus, the purpose of care pathway is the enhancement of care processes in three major areas of healthcare delivery: quality, safety and efficiency [2]. Care pathway development is a promising and widely used approach to the problem of integrating the clinical quality improvement and resource management efforts. Care pathways can reduce resource use while maintaining or improving clinical care quality [1, 10]. A good health system delivers quality services to all people, when and where they need them. However, there may be some factors hindering quality healthcare in hospitals. Linear programming model is a planning technique which uses mathematical model in maximizing or minimizing appropriate measure to optimize the value of some objective after identifying some constraints [3]. This study focuses on using linear programming model to maximize healthcare pathways by identifying constraints and obtaining optimal result for a quality healthcare service delivery. Linear programming is a technique in operations research and is one of the most versatile, powerful and useful techniques for making managerial decisions [5]. This study uses Covenant University as a case study. Over the years, care pathways have proven to be very useful in the following areas: care pathways help ensure efficient and quality delivery in healthcare for a population: once a pathway is established, the information is used for monitoring the quality of service delivered to a hospital's patients and targeting areas in need of improvement. Care pathways help service providers to identify appropriate steps to take: As each patient's health needs differ, the pathway would indicate the most appropriate interventions which would assist the client and worker to identify a desirable next step [3, 6, 7]. Care pathways are an excellent tool for educating and informing new staff: They provide visual representation of the care plan and the expected course of quality care. Care pathways are used for organizing care around patient needs [4]. Care pathways enhance decision making among management concerning extending business and health competencies, reducing staff costs, providing greater access to human resources and new business opportunities [7]. Linear programming technique may be used for solving broad range of problems in different sectors of an economy such as business, government, industry, hospital, libraries, etc. [6, 8]. This study shows how linear programming can be used to maximize healthcare quality which is termed as "care pathway". Linear programming is considered the technique to be used for this study because of the following characteristics it possesses: The relationship between variables and constraints is linear, the model has an objective function, the model has structural constraints, and the model has non-negativity constraint. Dantzig invented the simplex algorithm for solving a linear programming problem [6].

2. Formulation of Problem

2.1. Objective

To maximize healthcare pathway.

2.2. Decision variables

Let x_{ij} represent number of i type of patient requirement needed to use up j resource in order to maximize healthcare in Covenant University healthcare for a period of 1 year, c_j represents the contribution to x_{ij}.

2.2.1. Patient outcome: x_{ij}

x_{11} represents minimum number of patients who need to visit Covenant University Health Center for treatment in order to maximize healthcare,

x_{12} represents minimum number of patients who should be successfully treated for their ailment in Covenant University Health Center,

x_{13} represents maximum number of death cases within one year,

x_{14} represents maximum number of patients referred to other medical centers.

The data collected from Covenant University Health Center show that the contributions c_j are as follows:

$$c_1 = 17482.4,$$

$$c_2 = 17119.2,$$

$$c_3 = 11.6,$$

$$c_4 = 351.6.$$

The performance as regards patient's outcome can be stated as follows:

$$\sum_{j=1}^{H} c_j x_j = 17482x_{11} + 17119x_{12} + 12x_{13} + 352x_{14}.$$

2.2.2. Patient safety: x_{2j}

Let

x_{21} represent number of patients that should be protected from accident domestic accidents expected,

x_{22} represent number of patients that should be protected from theft,

x_{23} represent number of patients that should be protected from kidnapping,

x_{24} represent number of patients that should be protected from mistakes.

From the data gathered the contributions c_j as regards patient safety are as follows:

$$c_1 = 37.6,$$

$$c_2 = 0,$$

$$c_3 = 0.4,$$

$$c_4 = 70.4.$$

The performance as regards patient safety is as follows:

$$\sum_{j=1}^{4} c_j x_{2j} = 37.6x_{21} + 0x_{22} + 0.4x_{23} + 70.4x_{24}.$$

2.2.3. Medical resources: x_{3j}

Let

x_{31} represent number of staff needed for the center,

x_{32} represent number of new special equipment needed for the center,

x_{33} represent number of specialized doctors needed for the center.

From the data gathered at the Covenant University Medical Center, the contributions c_j as regards medical resources are as follows:

$$c_1 = 20,$$

$$c_2 = 5,$$

$$c_3 = 4.$$

Therefore, the performance as it affects medical resources can be written as follows:

$$\sum_{j=1}^{u} c_j x_{3j} = 20x_{31} + 5x_{32} + 4x_{33}.$$

2.2.4. Patient satisfaction: x_{4j}

Let

x_{41} represent minimum number of times Covenant University Health Center should be opened to patients,

x_{42} represent minimum number of patients who should be comfortable with the location of health center,

x_{43} represent minimum number of patients who should be happy with the customer care,

x_{44} represent minimum number of patients impressed with healthcare facilities.

From the data collected from Covenant University Health Center, the contributions c_j are as follows:

$$c_1 = 0.5,$$

$$c_2 = 0.6,$$

$$c_3 = 0.6,$$

$$c_4 = 0.7.$$

Therefore, the performance as regards patient's satisfaction is

$$\sum_{x=1}^{4} c_j x_{4j} = 0.5x_{41} + 0.6x_{42} + 0.6x_{43} + 0.7x_{44}.$$

2.3. Constraints

$$\frac{160000000}{87412} x_{11} \leq 160000000,$$

$$x_{11} - x_{13} - x_{14} \leq \frac{1}{5}(87412 - 58 - 1758),$$

$$x_{21} + x_{22} + x_{23} + x_{24} \leq \frac{1}{5} \text{ of } 874,$$

$$\frac{480000000}{5} \times \frac{1}{100} \times x_{31} + \frac{1}{5}(160000000 + 210000000) x_{32} + 160000000 x_{33}$$

$$\leq \frac{1}{5}(480000000 + 160000000 + 21000),$$

$x_{12} \geq 70\% \text{ of } \frac{87412}{5},$

$x_{41} + x_{42} + x_{43} + x_{44} \leq \frac{1}{2} \text{ of } \frac{87412}{5},$

$x_{ij} \geq 0, \quad i = 1, 2, 3, 4; \quad j = 1, 2, 3, 4.$

2.4. The model

Maximize

$$Z = \sum_{j=1}^{4} c_j x_{ij} + \sum_{j=1}^{4} c_j x_{2j} + \sum_{j=1}^{4} c_j x_{3j} + \sum_{j=1}^{4} c_j x_{4j}$$

$$= \sum_{i=1}^{4} \sum_{j=1}^{4} c_j x_{ij}.$$

Subject to:

$$\sum_{i=1}^{4} \sum_{j=1}^{4} a_{ij} x_{ij} \leq b_i,$$

where a_{ij} and b_i are the technological coefficients and resource levels, respectively,

$$x_{ij} \geq 0; \quad i = 1, 2, 3, 4; \quad j = 1, 2, 3, 4.$$

That is:

Maximize

$$Z = 17482x_{11} + 17119x_{12} + 12x_{13} + 352x_{14} + 37.6x_{21}$$

$$+ 0x_{22} + 0.4x_{23} + 70.4x_{24} + 20x_{31} + 5x_{32} + 4x_{33}$$

$$+ 0.5x_{41} + 0.6x_{42} + 0.6x_{43} + 0.7x_{44}.$$

Subject to:

$$x_{11} \leq 0.087,$$

$$x_{11} - x_{13} - x_{14} \leq 85.6,$$

$$x_{21} + x_{22} + x_{23} + x_{24} \leq 0.87,$$

$$48x_{31} + 150x_{33} \leq 850,$$

$$-x_{12} \leq 12.2,$$

$$-x_{41} - x_{42} - x_{43} - x_{44} \leq -43.7.$$

3. Model Solution

3.1. Standardized model

Maximize

$$Z = 17482x_{11} + 17119x_{12} + 12x_{13} + 352x_{14} + 37.6x_{21}$$

$$+ 0x_{22} + 0.4x_{23} + 70.4x_{24} + 20x_{31} + 5x_{32} + 4x_{33}$$

$$+ 0.5x_{41} + 0.6x_{42} + 0.6x_{43} + 0.7x_{44}.$$

Subject to:

$$x_{11} + S_i = 0.087,$$

$$x_{11} - x_{13} - x_{14} + S_2 = 85.6,$$

$$x_{21} + x_{22} + x_{23} + x_{24} + S_3 = 0.87,$$

$$4.8x_{31} + 15x_{33} + S_4 = 850,$$

$$-x_{12} + S_5 = -12.2,$$

$$-x_{41} - x_{42} - x_{43} - x_{44} + S_6 = -43.7,$$

$$x_{ij} \geq 0,\ i = 1, 2, 3, 4;\ j = 1, 2, 3, 4;\ S_j \geq 0,\ i = 1, 2, 3, 4, 5, 6.$$

3.2. Simplex method of solution

In this research work, we adopted simplex method algorithm to solve the standardized linear programming model and came up with the following tables:

Table 1 (Initial simplex table)

Solution Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{33}	x_{41}	x_{42}	x_{43}	x_{44}	S_1	S_2	S_3	S_4	S_5	S_6	Solution Quantity
S_1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.087
S_2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	-85.6
S_3	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0.87
S_4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	850
S_5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-12.2
S_6	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	-1	43.7
Z	17482	17119	12	352	37.6	0.4	70.4	20	5	4	0.5	0.6	0.6	0.7	0	0	0	0	0	0	

Table 2

Solution Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{33}	x_{41}	x_{42}	x_{43}	x_{44}	S_1	S_2	S_3	S_4	S_5	S_6	Solution Quantity
X_{11}	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.087
S_2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	-12	-1	0	0	0	0	-85.6087
S_3	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0.87
S_4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	850
S_5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-12.2
S_6	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	-1	43.7
Z	0	17119	12	352	37.6	0.4	70.4	20	5	4	0.5	0.6	0.6	0.7	-17482	0	0	0	0	0	-1520.934

Table 3

Solution Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{33}	x_{41}	x_{42}	x_{43}	x_{44}	S_1	S_2	S_3	S_4	S_5	S_6	Solution Quantity
X_{11}	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.087
S_2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	-85.6087
S_3	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0.87
S_4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	850
X_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-12.2
S_6	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	-1	43.7
Z	0	0	12	352	37.6	0.4	70.4	20	5	4	0.5	0.6	0.6	0.7	-17482	0	0	0	17119	0	207330.87

Table 4

Solution Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{33}	x_{41}	x_{42}	x_{43}	x_{44}	S_1	S_2	S_3	S_4	S_5	S_6	Solution Quantity
X_{11}	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.087
X_{14}	0	0	1	1	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	-85.6087
S_3	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0.87
S_4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	850
X_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-12.2
S_6	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	-1	43.7
Z	0	0	-340	0	37.6	0.4	70.4	20	5	4	0.5	0.6	0.6	0.7	-177130	352	0	0	0	17119	237465.13

Table 5

Solution Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{33}	x_{41}	x_{42}	x_{43}	x_{44}	S_1	S_2	S_3	S_4	S_5	S_6	Solution Quantity
X_{11}	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.087
X_{14}	0	0	1	1	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	-85.6087
X_{23}	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0.87
S_4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	850
X_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-12.2
S_6	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	-1	43.7
Z	0	0	-340	0	-32.8	-70	0	-50.4	5	4	0.5	0.6	0.6	0.7	-17130	352	-70.4	0	0	17119	237403.88

Table 6

Solution Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{33}	x_{41}	x_{42}	x_{43}	x_{44}	S_1	S_2	S_3	S_4	S_5	S_6	Solution Quantity
X_{11}	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.087
X_{14}	0	0	1	1	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	-85.6087
X_{23}	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0.87
X_{31}	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	850
x	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-12.2
S_6	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	-1	43.7
Z	0	0	-340	0	-32.8	-70	0	-504	0	-1	0.5	0.6	0.6	0.7	-17130	-352	-70.4	-5	0	17119	233153.88

Table 7

Solution Variable	x_{11}	x_{12}	x_{13}	x_{14}	x_{21}	x_{22}	x_{23}	x_{24}	x_{31}	x_{33}	x_{41}	x_{42}	x_{43}	x_{44}	S_1	S_2	S_3	S_4	S_5	S_6	Solution Quantity
X_{11}	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.087
X_{14}	0	0	1	1	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	-85.6
X_{23}	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0.87
X_{31}	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	850
X_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	-12.2
X_{44}	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	-1	43.7
Z	0	0	-340		-32.8	-70	0	-504	0	-1	-0.2	-0.1	-0.1	0	-17130	352	-70.4	-5	0	17119	233123.29

4. Result and Discussion

From the tables above, it can be seen clearly that the four major decision variables that maximize healthcare pathway are X_{11}, X_{23}, X_{31} and X_{44}; which represent, respectively, minimum number of patients who need to visit Covenant University Health Center for treatment in order to maximize healthcare, number of patients that should be protected from kidnapping, number of staff needed for the center and minimum number of patients impressed with healthcare facilities. Among these decision variables, X_{31} is very critical in determining the optimal healthcare at the Covenant University Health Centre. It is worthy of note that the four major thins that needed to be enhanced in order to optimize healthcare are represented by X_{11}, X_{23}, X_{31} and X_{44}. The patient outcome is represented by X_{11}. The patient safety is represented by X_{23}, patient satisfaction is represented by X_{31} and the resource is represented by X_{44}. This implies that all these four areas have to be enhanced before optimization of healthcare can be achieved at the Covenant University Health Centre. It is important to note, also, that x_{12} representing minimum number of patients who should be successfully treated for their ailment in Covenant University Health Center, and x_{14} representing maximum number of patients referred to other medical centers, are important but cannot determine the optimality of healthcare at Covenant University Health Centre. Finally, the factors capable of hindering quality healthcare as a result of enhancing the four decision variables mentioned above, should be guided against seriously if optimality of healthcare pathway is to be achieved.

5. Conclusion

Interest is on maximizing healthcare pathway in Covenant University Health Centre. The analysis is carried out using simplex method. The peculiar situation is modelled as a linear programming problem. It is shown that all the four categories of factors leading to optimization of healthcare pathway are significant in the process of maximization. Specifically the number of quality staff working at the centre has to be sufficient, because this plays a very important role in attaining optimality of healthcare pathway.

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