Nurse Scheduling and Rostering Shift Sequence Using Linear Programming Problem. A Case Study of Insurgency Related Area Borno State Specialist Hospital Maiduguri, Northeast-Nigeria

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Abstract: **This paper is to study and analyzed the Nurse scheduling and rostering shift sequence (NSRSS) process, in one of the most renowned Hospital in Borno State, located in central area called Borno State Specialist Hospital Maiduguri the case study. The most difficult task of shift sequence when considered the services rendered during the crisis period at the peak of Military hostility and subsequent Government declaration and pronouncement of curfew on all sorts of movements between the 1800hours to 0600hours without any provision for alternative arrangement for the special health-care workers, apart from their effort of modernizing or providing an improved local arrangements on the rostering shift sequence for night shift personnel from the normal period of 2200hours to 0700hours, changed to 1700hours to 0700hours, with minimum of 14 hours working time, instead of the normal 8 hours period. We proposed a model to improve both the process and the quality of rostering schedules. A numerical illustration and example of nurse scheduling and rostering shift sequence for normal 8 hours shift is solved by correct linear programming model, by Echelon elementary row operation. The hospital needs more personnel (nurses) to meet up with global standard of a hospitals to be more effective.**

Keywords: **Nurse scheduling and rostering shift sequence (NSRSS); Linear programming problem (LPP); Constraints; Objective function; Insurgency related area (IRA); Borno State Specialist Hospital (BSSH).**

I. INTRODUCTION

Nurse scheduling and rostering, simply refers to a working timetable for a special group of health-care workers for its staff(s) so that a certain activity can meet up and satisfy the requirements of patients or an employer, within a time need framed. Borno State Specialist hospital, Maiduguri Northeast-Nigeria, as a case study, has suffered enough from patients and victims of Insurgency attacked by Boko Haram between April, 2009 to September, 2019 which has culminated in Military hostility and Government declaration and pronouncement of Curfew on all sorts of movements., without any re-curse on such essential services of Nurses. In the domain of health-care, shift sequence and rostering, is so challenging because of the presence of various requirements on different days, more especially when the terrorist heat their required targets, such as markets place, worship centers, clubs etc, the nurses has to call a teamwork to be able to attend to the victims appropriately. They try to make a lot of sacrifices during the period of insurgency by providing high level of quality and efficiency services, teamwork and required result, from their available way of scheduling and rostering. The labor force that always received commendation from the less privilege Internally Displaced Person(s)-IDPs in Maiduguri are the Nurses. In addition, the scheduling and rostering shift sequence problem has to do with seniority level, knowledge and skills of the personnel are always taking into consideration, and form the point of view for shift sequence in the hospital.

Constraints are usually divided into two groups among the nurses of Borno State Specialist Hospital Maiduguri: Nurses on permanent morning based on seniority level, knowledge, skills, experience and medication, then the second group comprises of all other personnel (nurses). We can conveniently classified the constraints as hard and soft**.** All the feasible weekly shift patterns were pre-defined and associated with seniority level, knowledge and skills concerning preferences and sequence of successive weeks, etc. The objective also includes the conduct of practical study on the process of Nurse Scheduling and Rostering Shift Sequence (NSRSS), in hospital under Borno State Government, then we introduce the basic concept of operation research / Linear Programming that can be easily implemented in each hospital in the Northeast-Nigeria at no extra cost and finally, use the method and the software to generates most fairness and balanced nurse scheduling and rostering shift sequence.

In this paper, Borno State Specialist Hospital Maiduguri, has 269 Nurses, 15 nurses on part-time studies leave, 110 nurses on permanent morning shift based on seniority level and other cases of medical advice and the hospital has a total of 16 ward for admitting patients and another 12 sections/units for daily routine diagnosis, which are all inclusive during the manual scheduling and rostering, (1) Female medical ward. (2) Male medical ward (3) Female Surgical ward (4) Male Surgical ward. (5) Gynecology ward. (6) Post-natal ward (7) Labour ward (8) Antenatal ward (9) Nursery ward (10) VVF ward (11) Female Orthopedic ward (12) Male orthopedic ward (13) Pediatric ward (14) EPU ward (15) ICU ward (16) Accident and Emergency A&E ward. In addition we have some units that received nurse shifting (1) Injection Unit Male (2) Injection Unit Female (3) Pediatric Unit (4) Theater Unit (5) Labour theater Unit. (6) Staff clinic Unit. (7) DOT clinic (8) HDU clinic (9) Family planning Unit (10) Counseling Unit (11) ENT Unit (12) Antenatal clinic.

In the hospital, the 28 section/wards listed are all interrelated in-terms of services required simultaneously. In practice, the rostering shift sequence are scheduled on weekly basis, besides the provision of knowledge, skills, experience and request are very necessary in each shift.

In second part of this work, we examined scheduling and rostering shift and we present the problem formulation through correct linear programming problem (LPP). The area of implementation is described in part three, while literature review is in section 4, and Section 5 shows the structure of linear programming problem (LLP) and., Finally, we present nurse scheduling modeling problems in section 6 and conclusion in section 7.

II. PROBLEM FORMULATION

The situation in which the nurses in Maiduguri, Borno State, Northeast-Nigeria found themselves between April, 2009 to September, 2019 is very critical, crucial and complex in nature., under the crisis period of the insurgency. We can equally say that., Nurse scheduling and rostering shift sequence during these period of Insurgency is a complex exercise with series of unrealistic objectives. At the planning stage / period, seniority level, knowledge, skills and experience are much important elements, while certain activities attached to scheduling process such as work, rest, eating, tea breaks, week/declared holidays, proximity to work place, maternity leave, and annual leave are also not feasible. Minimizing the total cost is not feasible, while maximizing the nurse preferences and all request to actualized certain target, and equally scheduling and rostering of workload is highly recognized and very important.

Work constraint and equitable balanced of personnel to the rostering shift sequence during the insurgency is more worrisome and most serious source of concerned and challenges, on scheduling process. As much as the process is fairly balanced, the second constraint, is the requirements for each shift without any hitches on seniority level, knowledge and skills on permanent morning shift by others.

> *If this is our goal [to solve real nurse scheduling problems in real hospitals], then we must address the full range of requirements and demands that are presented by modern hospital workplaces.- Burke et al. (2004)*
>
> *It is hard to avoid the conclusion that, in the united state at least, practitioners do not accept academically produced management and*

computer science solution to the nurse-scheduling problem. –Kellogg and walczak (2007)

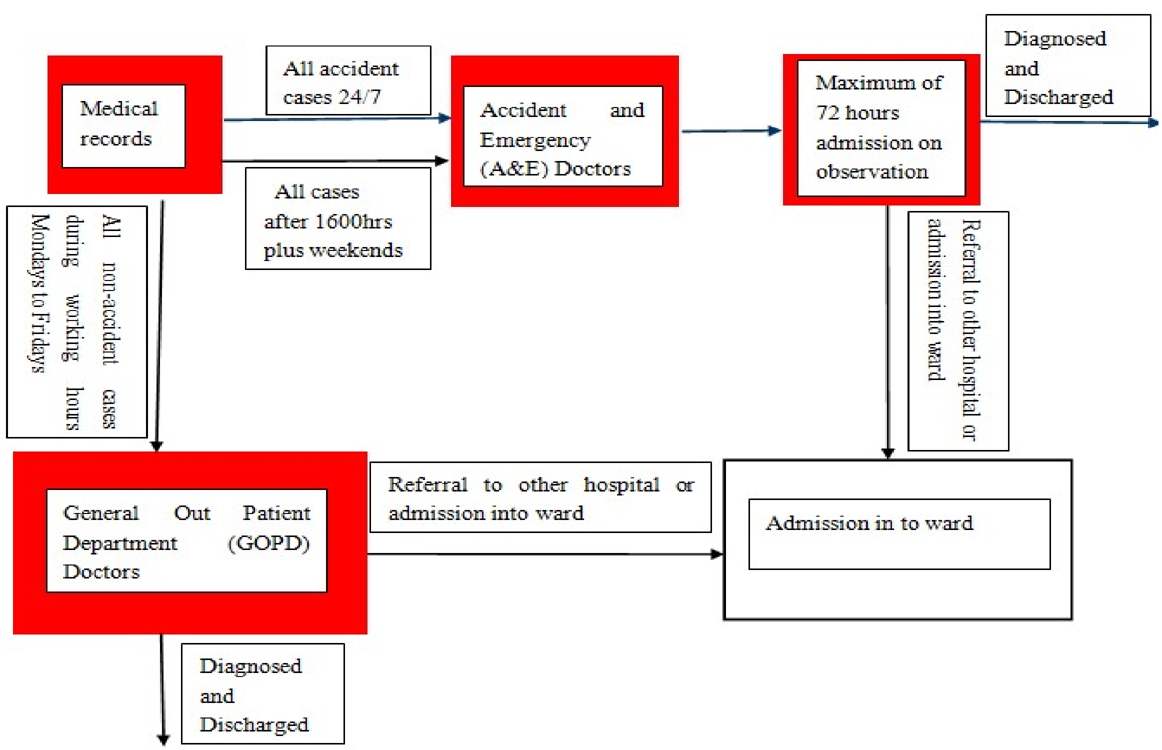
A Shift Sequence for Nurse Scheduling Using Linear Programming Problem, -Kumar,B.*S,et al (2014)*

The algorithm under the analytic scheduling provides maximum number of 5days-on work with 2days-off duty, minimum period of rest time between shifts and days-off work period. From the work paper, we can conveniently describe the general rostering and shift sequence characteristics as; (1). Fixed planning period (2). Fixed number of shift (3). Fixed number of required days of work in a week. (4). Fixed combination of on/off days work weekly. (5). Fixed shift transition days-on / days-off (6). No nurse working for two consecutive weekends. (7). First week, night shift between 1700hours to 0700hours nurse will spend 98hours and allows only 25hours the following shift sequence, afternoon shift, between 1200hours to 1700hours. On all work days, Monday to Sunday, at least one of the nurses was also on duty a day before, minimize the number of different shift in each roster, first week with 98hours allows only 25hours the following shift, if work night shift, then proceed on night off shift of 7days-off., unless there is a long' off-stretch in between, some nurses have a weekly off day called a zero day. For each nurse, it is preferred that the zero days are always on the same day of the week, a special shift type must be covered by the same employee for a whole week before end of the month.

III. AREA OF IMPLEMENTATION

Hospital and Health-care Location: - The nurse rostering and shift sequence study in health-care system in Borno State Specialist Hospital, Maiduguri, Northeast-Nigeria a case study of insurgency related area (IRA) couple with Military hostility and Government placement of curfew on all sorts of movements is more worrisome. The paper focus has been on nurse scheduling. The structured put in placed as normal routes in the hospital includes;

(1). The medicals records, as first point of call for all patients. (2). General Out-patient Department (GOPD) is open only during working days and working hours Mondays to Fridays between 0700hours to 1600hours. (3). Accident and Emergency (A&E) working round 24/7 (4). Ref-feral and Admission into ward.



The Doctors at GOPD and A&E, they are both clinical and cost imperatives associated in nature with appropriate levels of staff in different medical wards with at least three nurses in each shift. The rostering must always provide suitably qualified nurses to cover the demands arising from the causalities of the insurgent attacked, in addition to normal numbers of patients in the wards, also ensuring that, night shift begins at 1700hours to 0700hours with a minimum of 98hours weekly, and the following week shift of afternoon begins 1200hours to 1700hours with periods of 25hours a week, and weekend shift are distributed fairly, allowing for casual leave, maternity leave, annual leave, 2days-off weekly, and 7days-off night shift., as range of employee preferences.

The constraints resulting from scheduling and rostering shift sequence problems are, in most cases on seniority level, part-time studies, knowledge and skills.

Recommendation and journals approaches in early, 1970s and 1980s was able to discussed and addressed an alternative solution to problem formulations and implementation techniques to the nurse scheduling and rostering shift. The aim and objectives as sustained in this paper was to provide alternative approach or support tools to reduce the need for manual scheduling and rostering of nurse shift. Some papers looked into the problem of determining required personnel and staff levels, knowledge and skills based on the number of patients and their medical demand. In some cases other presenters adopted mathematical programming, goal programming, mix programming and various techniques. Others use analytic / iterative algorithms to generate shift rostering in which a balanced and fairness scheduling can be achieved. In the 1990s a reasonable number of papers that provided classification of nurse scheduling and rostering shift systems and the reviews of methods for solving different classes of problems. Further advances on paper work were made in applying linear programming, integer programming, mix programming and network optimization techniques for developing nurse rosters. The method applied to problems involving cyclic and non-cyclic rosters, which also considered the nurse on part-time study, maternity leave, annual leave and casual leave., but the papers was unable to focused or predicted to take-care of Insurgency related areas as the case study of Borno state specialist hospital Maiduguri, Northeast-Nigeria.

The compound nurse are strictly in charge of all nurses during a particular shift period, also responsible for Doctors on-call invitation. The most senior nurse is called Chief Nursing Officer (CNO) also responsible for scheduling and rostering. Some researchers have provided approaches which included a simulation techniques. In an attempt to deal with more complex nurse rostering and clinical service problem., the seniority level, knowledge and skills, while nurse on part-time and those released officially on training, are considered for simulation model augmented by analytic method is used to incorporate nurse training into rostering shift sequence.

Nurse Scheduling and Rostering Shift Sequence Using Linear Programming Problem; concerted effort by different researchers on the best approaches to deal with rostering and shift sequence to have fairly balanced roster, each employee must work five consecutive days and then received two days off, as can be illustrated. Formulate the linear programming to minimize the number of employees must be able to meet up with the demand and need of patients, which includes seniority level, knowledge and skills.

Let $x_i =$ number of the required nurse beginning to work on each day, where $i = 1,2,......,7$

DAYS	x_1	x_2	x_3	x_4	x_5	x_6	x_7	Required Nurse
Monday	1	0	0	1	1	1	1	b_1
Tuesday	1	1	0	0	1	1	1	b_2
Wednesday	1	1	1	0	0	1	1	b_3
Thursday	1	1	1	1	0	0	1	b_4
Friday	1	1	1	1	1	0	0	b_5
Saturday	0	1	1	1	1	1	0	b_6
Sunday	0	0	1	1	1	1	1	b_7

Min $Z = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$

Subject to constraint

$$
\begin{aligned}
&x_1 + x_4 + x_5 + x_6 + x_7 >= b_1 \\
&x_1 + x_2 + x_5 + x_6 + x_7 >= b_2 \\
&x_1 + x_2 + x_3 + x_6 + x_7 >= b_3 \\
&x_1 + x_2 + x_3 + x_4 + x_7 >= b_4 \\
&x_1 + x_2 + x_3 + x_4 + x_5 >= b_5 \\
&x_2 + x_3 + x_4 + x_5 + x_6 >= b_6 \\
&x_3 + x_4 + x_5 + x_6 + x_7 >= b_7
\end{aligned}
$$

$x_i >= 0, i = 1,2,....7$ and $b_1, b_2, ..., b_7$ are the number of required nurses working on a particular day. We can now use linear programming as our simulation modeling, and also we made an attempt to develop a knowledge based system for generating weekly nurse rosters and then adjusting the rostering to uphold the hospital and the patients daily demand based on availability of personnel. These algorithms are designed to overcome one of the basic problems associated with using a complex nurse scheduling and rostering shift sequence problems.

IV. LITERATURE REVIEW

In the Literature, there are many comprehensive studies on nurse scheduling and rostering shift sequence that are very extensive. In [1], Gungor proposes an integer linear model for nurses scheduling in hospital that is open for 24 hours and 7 days a week, where all the nurses worked for 40 hours per week. The model consist of two stages in his proposal. First, the minimum number of nurses that need to be fulfilled, and how many of them are on training as student are determined., then, work on-days and work off-days for a period of two weeks is also designed. Wong and Chung [2] examined the nurse scheduling problem using a probability-based techniques. As a result of their work, a required solutions to the problem in a short time framed and presented appropriate charts. Azaiez and Shariff [3] developed a model for a computerized 0-1 Goal programming method for nurse scheduling. This method is adopted in almost all hospitals in Saudi Arabia. The model was able to prevents unnecessary overtime costs. The various researchers that study and employed optimization methods to solve the NSRSS, like linear, integer or mixed integer programming, goal programming or constraint programming. We believe the resolution techniques involving the use of solvers are more easily transferable to hospital-services. Hence our contribution, related to existing approaches, is focused on the linear programming problem, which seeks to satisfy the demand coverage while minimizing the salary cost and maximizing the nurses preferences as well as team and work balance.

Different objectives are studied in this literature are to decrease manual scheduling, to increase demand covering in terms of workforce size but also according to required skills, to obtain equity between the schedules. Sungur, et al.[2], using the integer programming method, aimed to reduced labor costs and enabled employers to assign shifts in the most appropriate way.

The Borno State Specialist Hospital, identified 4 levels of seniority among the working classes of nurses within the hospital. We have (1). the Chief Nursing Officer, in charged of all nurse. (2). compound nurse are in charged of a particular shift sequence. (3). the nurse in charge of wards (4). lastly the routing nurses in various wards. Any emergency case brought to hospital, the Compound Nurse is responsible of reporting or calling the attention of Doctors on-call and no any other person.

V. STRUCTURE OF LINEAR PROGRAMMING MODEL

The basic structure of a Linear Programming model consists of three components.

1. The activities (variables) and their relationships
2. The objective functions and
3. The constraints

The activities are represented by $x_1, x_2, x_3, ..., x_n$ these are known as decision variables.

The objective functions of a Linear Programming Problem

(LPP) is a mathematical model that gives the objective in terms of or as its relates to a measurable quantity such as profit, cost, revenue, etc.

Optimization (Max or Min)

$$Z = c_1x_1 + c_2x_2 + c_3x_3 + \ldots\ldots. + c_nx_n$$

Where Z is the measure of performance variable of the required function,

$c_1x_1 + c_2x_2 + c_3x_3 + \ldots\ldots + c_nx_n$ are the decision variables

and $c_1, c_2, c_3, \ldots\ldots, c_n$ are the parameters or the coefficients of the decision variables.

The constraints are the set of linear inequalities and/or equalities which impose restriction of the limited resources

5.1 Mathematical Model and Parameters:

n: number of nurses working in the hospital, $n = 269$

m: number of days in a week, $m = 7$

s: number of section in the hospital, $s = 28$

t: number of shifts in the hospital, $t = 6$

i: number of nurses on permanent morning shift, $i = 110$

j: number of nurses on study leave, $j = 15$

k: number of nurses for rostering and shift, $k = 159$

p: personnel index, $p = 1,2,\ldots..k$

q: Day index, $q = 1,2,\ldots\ldots.., m$

r: Section index, $r = 1,2,\ldots\ldots, s$

f: Shift index, $f = 1,2,\ldots\ldots., t$

5.2 The decision variables

$$x_{pqrf} = \begin{cases} 1 & \textbf{1, if personnel on shift.} \quad p=1,2,\ldots,n, q=1,2,\ldots\ldots,m, f=1,2,\ldots.,t \\ 0 & \textbf{0, otherwise} \end{cases}$$

$$y_{pq} = \begin{cases} 1 & \textbf{1, if nurse on annual leave} \quad p=1,2,\ldots.,n, q=1,2,\ldots.,m \\ 0 & \textbf{0, otherwise} \end{cases} \qquad (2)$$

5.3 Constraints

To meet the daily and weekly personnel needs of the 21 wards in fairly balanced manner of the scheduling and the rostering shift sequence.

Number of required nurses for each shift in (1). Female medical ward

$$\sum_{p=1}^{n} (X_{pq1f}) = 5, q = 1,2,\ldots, m, f = 1,2,\ldots, t \qquad (3)$$

Number of required nurses for each shift in (2). Male medical ward

$$\sum_{p=1}^{n} (X_{pq2f}) = 5, q = 1,2,\ldots, m, f = 1,2,\ldots, t \qquad (4)$$

Number of required nurses for each shift in (3). Female surgical ward

$$\sum_{p=1}^{n} (X_{pq3f}) = 3, q = 1,2,\ldots, m, f = 1,2,\ldots, t \qquad (5)$$

Number of required nurses for each shift in (4). Male surgical ward

$$\sum_{p=1}^{n} (X_{pq4f}) = 3, q = 1,2,\ldots, m, f = 1,2,\ldots, t \qquad (6)$$

Number of required nurses for each shift in (5). Female orthopedic ward

$$\sum_{p=1}^{n} (X_{pq5f}) = 3, q = 1,2,\ldots, m, f = 1,2,\ldots, t \qquad (7)$$

Number of required nurses for each shift in (6). Male orthopedic ward

$$\sum_{p=1}^{n} (X_{pq6f}) = 3, q = 1,2,\ldots, m, f = 1,2,\ldots, t \qquad (8)$$

Number of required nurses for each shift in (7). Gynecology ward

$$\sum_{p=1}^{n}(X_{pq7f}) = 4, q = 1,2,...,m, f = 1,2,..,t \qquad (9)$$

Number of required nurses for each shift in (8). VVF ward

$$\sum_{p=1}^{n}(X_{pq8f}) = 2, q = 1,2,...,m, f = 1,2,..,t \qquad (10)$$

Number of required nurses for each shift in (9). Labour ward

$$\sum_{p=1}^{n}(X_{pq9f}) = 5, q = 1,2,...,m, f = 1,2,..,t \qquad (11)$$

Number of required nurses for each shift in (10). Post-natal ward

$$\sum_{p=1}^{n}(X_{pq10f}) = 3, q = 1,2,...,m, f = 1,2,..,t \qquad (12)$$

Number of required nurses for each shift in (11). Nursery ward

$$\sum_{p=1}^{n}(X_{pq11f}) = 4, q = 1,2,...,m, f = 1,2,..,t \qquad (13)$$

Number of required nurses for each shift in (12). Pediatric ward

$$\sum_{p=1}^{n}(X_{pq12f}) = 2, q = 1,2,...,m, f = 1,2,..,t \qquad (14)$$

Number of required nurses for each shift in (13). EPU ward

$$\sum_{p=1}^{n}(X_{pq13f}) = 2, q = 1,2,...,m, f = 1,2,..,t \qquad (15)$$

Number of required nurses for each shift in (14). ICU ward

$$\sum_{p=1}^{n}(X_{pq14f}) = 4, q = 1,2,...,m, f = 1,2,..,t \qquad (16)$$

Number of required nurses for each shift in (15). Accident and Emergency ward

$$\sum_{p=1}^{n}(X_{pq15f}) = 5, q = 1,2,...,m, f = 1,2,..,t \qquad (17)$$

Number of required nurses for each shift in (16). Injection Unit Male

$$\sum_{p=1}^{n}(X_{pq16f}) = 3, q = 1,2,...,m, f = 1,2,..,t \qquad (18)$$

Number of required nurses for each shift in (17). Injection Unit Female

$$\sum_{p=1}^{n}(X_{pq17f}) = 5, q = 1,2,...,m, f = 1,2,..,t \qquad (19)$$

Number of required nurses for each shift in (18). Theater Unit

$$\sum_{p=1}^{n}(X_{pq18f}) = 2, q = 1,2,...,m, f = 1,2,..,t \qquad (20)$$

Number of required nurses for each shift in (19). Labour Unit

$$\sum_{p=1}^{n}(X_{pq19f}) = 4, q = 1,2,...,m, f = 1,2,..,t \qquad (21)$$

Number of required nurses for each shift in (20). Pediatric Unit

$$\sum_{p=1}^{n}(X_{pq20f}) = 3, q = 1,2,...,m, f = 1,2,..,t \qquad (22)$$

Number of required nurses for each shift in (21). Labour Theater Unit

$$\sum_{p=1}^{n}(X_{pq21f}) = 5, q = 1,2,...,m, f = 1,2,..,t \qquad (23)$$

Number of required nurses for each shift in (22) Staff clinic Unit.

$$\sum_{p=1}^{n}(X_{pq22f}) = 1, q = 1,2,...,m, f = 1,2,..,t \qquad (24)$$

Number of required nurses for each shift in (23) DOT clinic

$$\sum_{p=1}^{n}(X_{pq23f}) = 1, q = 1,2,...,m, f = 1,2,..,t \qquad (25)$$

Number of required nurses for each shift in (24) HDU clinic

$$\sum_{p=1}^{n}(X_{pq24f}) = 1, q = 1,2,...,m, f = 1,2,..,t \qquad (26)$$

Number of required nurses for each shift in (25) Antenatal clinic

$$\sum_{p=1}^{n}(X_{pq25f}) = 3, q = 1,2,...,m, f = 1,2,..,t \quad (27)$$

Number of required nurses for each shift in (26)Family planning Unit

$$\sum_{p=1}^{n}(X_{pq26f}) = 2, q = 1,2,...,m, f = 1,2,..,t \quad (28)$$

Number of required nurses for each shift in (27) Counseling Unit

$$\sum_{p=1}^{n}(X_{pq27f}) = 2, q = 1,2,...,m, f = 1,2,..,t \quad (29)$$

Number of required nurses for each shift in (28) ENT Unit

$$\sum_{p=1}^{n}(X_{pq28f}) = 1, q = 1,2,...,m, f = 1,2,..,t \quad (30)$$

5.4 Assumptions of Linear Programming Certainty

In all Linear Programming models it is a reality that, all the model index such as availability of resources, such as profit or cost contribution of a unit of decision variable and consumption of resources by a unit of decision variable must be known and constant. In case of Borno state specialist hospital Maiduguri, Northeast-Nigeria, crisis period of insurgency attacked by Boko Haram, sacrifices by the nurses cannot be quantified.

Linearity

The relationships in the Linear Programming model (i.e. in both objective function and constraints) must be linear.

5.5 General Mathematical Model Of an Linear Programming Problem

Optimize (maximize or minimize)

$$Z = c_1x_1 + c_2x_2 + c_3x_3 + ... + c_nx_n$$

Subject to constraints

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + ... + a_{1n}x_n (<=>) b_1$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + ... + a_{2n}x_n (<=>) b_2$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + ... + a_{3n}x_n (<=>) b_3$$
$$......+......+......+........+.......$$
$$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + ... + a_{mn}x_n (<=>) b_n$$

$$x_1, x_2, x_3, ..., x_n > 0$$

5.6 Personnel (Nurses) Scheduling Problem

The Borrno state specialist hospital Maiduguri, requires different skills, experience, knowledge and senior nurses on different days of the week., to handle the patients requirements as follows.

DAY	Nurses Roster (Holding)
Monday	230
Tuesday	235
Wednesday	195
Thursday	205
Friday	245
Saturday	85
Sunday	65

Each employee must work for five consecutive days and then proceed to two days off. Which is not applicable to nurse on night shift, that has seven days off.

To formulate the linear programming (LPP) to minimize the number of nurses needed for the week, excluding the nurses on seven days night shift off.

Day	x_1	x_2	x_3	x_4	x_5	x_6	x_7	Required Nurse
Monday	1	0	0	1	1	1	1	230
Tuesday	1	1	0	0	1	1	1	235
Wednesday	1	1	1	0	0	1	1	195
Thursday	1	1	1	1	0	0	1	205
Friday	1	1	1	1	1	0	0	245
Saturday	0	1	1	1	1	1	0	85
Sunday	0	0	1	1	1	1	1	65

The correct linear programming, 1 refers to nurse on shift, while 0 otherwise

$$x_1 + x_4 + x_5 + x_6 + x_7 = 230$$
$$x_1 + x_2 + x_5 + x_6 + x_7 = 235$$
$$x_1 + x_2 + x_3 + x_6 + x_7 = 195$$
$$x_1 + x_2 + x_3 + x_4 + x_7 = 205$$
$$x_1 + x_2 + x_3 + x_4 + x_5 = 245$$
$$x_2 + x_3 + x_4 + x_5 + x_6 = 85$$
$$x_3 + x_4 + x_5 + x_6 + x_7 = 65$$

using echelon row elementary operation, Optimal (Min) $Z = 252$

VI. NURSE SCHEDULING AND ROSTERING SHIFT SEQUENCE PROBLEMS MODELING

Nurse scheduling is a known problem all over, but the alternative improved rostering under the insurgency period by the personnel has actually contributed immensely. Improving self-scheduling, that can be describe in the technical way.

Assembled the requirements of each ward and the preferences. Spirit of teamwork was introduced on the schedule, in case of insurgents got their targets with several causalities.

Nurse scheduling and rostering shift sequence in Borno state specialist Maiduguri, Northeast-Nigeria, the study aim is to minimize changes to the on the manual original schedule while minimizing costs, rebuilding the schedule with current staff is usually a simple way ,by changing the schedule will alter other nurse schedules as well. One of the Coimbatore city hospitals has the following minimal daily requirements for nurses.

Roster /Scheduled	**Recommended Clock time (24hours) day**	**Required Nurses**
1	07:00am – 11:00am permanent morning	110
2	11:00am – 3:00pm morning shift	250
3	3:00pm – 7:00pm afternoon shift	180
4	7:00pm – 10:00pm evening shift	150
5	10:00pm - 4:00am night shift	170
6	4:00am - 07:00am early morning shift	90

From the manual rostering shift sequence timetable as obtained in the hospital, Nurses report at the hospital at the beginning of each period and work for such hours, seniority level, knowledge and skills all considered as preference. In other to determine the minimum required number of nurses to be employed so that there will be a sufficient of nurses available for each period. We are going to formulate this as a linear programming problem by setting up appropriate constraints and objective function from [5.6]. The guidelines for formulating the linear programming model.

- Identify and define the decision variable of the problem

  Let $x_1, x_2, x_3, x_4, x_5, x_6$ be the number of nurses on-duty and off-duty at the beginning of periods 1,2,3,4,5,6 respectively.

- Define the objective function

  Minimize $Z = x_1 + x_2 + x_3 + x_4 + x_5 + x_6$

- State the constraints to which the objective function should be optimized. The above rostering or the objective function is subject to the following constraints.

$$x_1 + x_2 >= 110$$
$$x_2 + x_3 >= 250$$
$$x_3 + x_4 >= 180$$
$$x_4 + x_5 >= 150$$
$$x_5 + x_6 >= 170$$
$$x_6 + x_1 >= 90$$

$$x_1, x_2, x_3, x_4, x_5, x_6 >= 0$$

We can easily observe that, the model has 6 variables by using the simplex method by adding a slack variables $0s_1, 0s_2, ..., 0s_6$ and applying echelon elementary row operations to decomposed the variable, the linear programming problem (LPP), the feasible solution is Minimum $Z = 530$ as required nurses that can handle the hospital demand effectively.

$$Z = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + 0s_1 + 0s_2 + 0s_3 + 0s_4 + 0s_5 + 0s_6$$

Subject to constraints

$$x_1 + x_2 + s_1 = 110$$
$$x_2 + x_3 + s_2 = 250$$
$$x_3 + x_4 + s_3 = 180$$
$$x_4 + x_5 + s_4 = 150$$
$$x_5 + x_6 + s_5 = 170$$
$$x_6 + x_1 + s_6 = 90$$

The solution found by applying echelon elementary row operation $Z = 530$ shows that, Borno state specialist hospital Maiduguri, Northeast-Nigeria are in need of more staff to meet up the patients needs.

VII. CONCLUSION

The paper shows an overview of Borno State Specialist Hospital, Maiduguri Northeast-Nigeria nurse scheduling and rostering shift sequence problem, during the Insurgency attacked by Boko Haram between April, 2009 and September, 2019. The paper reveals the minimum number of nurses can handle the hospital needs at this critical time. Nurse scheduling and rostering shift sequence is a complex scheduling problem that affects hospital nurses on a daily basis most especially during the crisis period and the daily exit of some workforce on retirement on age and transfer of services to NGOs higher emoluments to the young nurses.

RECOMMENDATION AND ACKNOWLEDGEMENT

We advanced the recommendation of lifting embargo on employment in health-care sector and the employment of additional nurses by the Borno State Government under the leadership of His Excellency Prof. Engr. Babagana Umara Zulum mni to bridge the gab. We also acknowledge the performance of the entire workforce in the hospital, especially the Chief Nursing Officer, Deputy Chief Nursing Officer, Compound Nurses for teamwork spirit and the provision of alternative arrangement of shift roster during the insurgency period.

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