Gwoza Former Boko Haram Caliphate Borno State Northeast-Nigeria, General Hospital Under Mèdecins Sans Frontières MSF-Spain Nurse Scheduling Using Simplex Method

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Abstract: **This paper is to study the contributions, analyze the professional handling of patients needs by the globally recognized European, non governmental organization Médecins Sans Frontiéres MSF-Spain, on Nurse Scheduling, through the most less cost effective and workload sharing techniques, in former Boko Haram stronghold that was formally declared as the insurgents headquaters referred as the Caliphate on the 7th August, 2014 by their Leadership. This hospital is located in central area of the local government called Gwoza General Hospital. The most difficult and highly volatile, risk area in Borno State Northeast-Nigeria, that was classified as a red zone by the security intelligence reports. The task of Nurse Scheduling to meet up with the community counseling, traumatized patients by the armed gunmen, hetherto the hectic and herculean task patients needs when considered the services rendered during the crisis period at the peak of the insurgency, Military hostility and subsequent Government declaration and pronouncement of curfew on all sorts of movements sometimes between the 1600hours to 0700hours without any provision for alternative arrangement for the special health-care workers. We proposed a model to improve both the process and the quality of scheduling techniques. The objective is to maximize the fairness of the schedule among personnel. A numerical illustration and example of workload scheduling for a maximum of 8 hours is obtained and solved by correct simplex method, through Gauss-Jodan elementary row operation, the hospital needs a minimum of 30 professional nurses to meet up with the patients needs to be more effective and efficient.**

Keywords: **Nurse Scheduling Programming(NSP); Simpleaux Method; Médecins Sans Frontiéres (MSF-Spain); Constraints; Objective function; Boko Haram Caliphate (BHC); Gwoza General Hospital (GGH).**

I. INTRODUCTION

Médecins Sans Frontìeres (MSF-Spain), a European non governmental organization that offers humanitarian services on areas engulfed by violence, conflicts, communal clashes, floods, epidemic, insurgency, etc. The NGO are simply called "Doctors Without Borders". The continued violence and insurgency attacked on Gwoza Local Government, Borno State, Northeast-Nigeria on the 5th August, 2014, has uprooted more than four hundred thousand inhabitants of the area to a various destination within Nigeria, Cameroon and Tchad Republic. The presence of MSF-Spain has been responding to diseases outbreaks and many other emergency health-care needs in the area, also focusing on maternal and paediatric health-care, vaccination campaigns against diseases such as measles, meningitis, pneumonia and providing enough seasonal malaria chemoprovention /nets. Workload Distribution is a process of effective and efficient distribution of schedules across staffers of an organization, when successfully achieved and workload scheduling management maximizes employee performance, then it helps the team to feel great and satisfied at the end of each working day. Nurse Scheduling is also part of the workload distribution by the management, which simply has to do with timetable for a special group of health-care workers for its personnel so that a certain activity and desired needs of patients can be achieved, by satisfying the requirements of an employer (MSF-Spain). Our field sport assesments reveals that, Gwoza people that stayed under the Boko Haram Caliphate have really suffered and were traumatized until when, *Médecins Sans Frontìeres (MSF-Spain) surfaced. The professional n*urses working with the MSF-Spain have given there best, offered a lot of sacrifices, during the period of insurgency, through high level of commitment, selflessness, dedication and efficient services, teamwork and required result were achieved, from the professional master plan design by MSF-Spain, on scheduling of workload. In addition, the NGO has recorded a marvelous commendation from the less privilege Internally Displaced Person(s)-IDPs. Constraints are always normal in all organization, but we clasified them into two parts among the nurses working under *Médecins Sans Frontìeres (MSF-Spain) in Gwoza General* Hospital, Borno State, Northeast-Nigeria; in-charge nurse of each shift based on seniority level, knowledge, skills and experience, then the second part, which 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. Thus,

we introduce the basic concept of operation research / linear programming problem (LPP) using simplex method that can be easily implemented in each hospital under the European non governmental organization NGOs in the Northeast-Nigeria at zero extra cost and finally, we use the method and the software to generate most fairness and balanced nurse scheduling and shift roster. In this paper, *Médecins Sans Frontìeres (MSF-Spain)*, has up to 30 professional nurses when we paid visit to the hospital, with a total of 4 ward for admitting patients; (1) Maternity ward. (2) Paediatric ward (3) Adults ward (4) Emergency ward. In practice, the scheduling and shift roster are on weekly basis, besides the provision of knowledge, skills and experience, the preferences request are very necessary in each shift through the in charge to the field coordinator.

In second section 2 Literature review, while section 3 of this work, we examined scheduling and shift, we present the problem formulation through correct linear programming problem (LPP) using simplex method. Section 4, we examined the area of implementation. while Section 5 shows the structure of linear programming problem (LLP) using simplex method, Finally, we present nurse scheduling modeling problems in section 6 and conclusion in section 7.

II. LITERATURE REVIEW

Literature on nurse scheduling and shift roster is extensive and have been solved by different researchers using variety of alternative programming methods. Several papers used optimization methods to addressed the nurse scheduling problem, which are mainly mathematical programming, like linear programming, integer programming, mixed integer programming, 0-1goal programming. Empirical solutions always shows that the modeling method is more superior over the manual scheduling method in terms of efficiency and time consuming. First, the mathematical programming, analytic approaches for nurse-scheduling problem introduced. Meanhout and Vanhoucke [13] proposed an integrated analysis methods to solve human resource planning and shift scheduling problem of nurse on the long run. Azaiez and Shariff [2] developed a model for a computerized 0-1 goal programming method for nurse scheduling which takes into consideration the ratio of nurses working night shifts or having days-off on weekends, trying to avoid cost implications that might arised from overtime schedules where applicable. This method is adopted in almost all hospitals in Saudi Arabia. The model was able to prevent unnecessary overtime costs. Kumar, B.S., Nagalasshmi, G., Kumaraguru, S [12] A shift sequence for nurse scheduling using linear programming problem As a result of their work, a required solutions to the problem in a short time framed and presented appropriate charts. Varli, E., Ergisi, B., Eren, T. [10] Nurse scheduling problem with special constraints; Goal programming approach, Erciyes University. In addition we have an integer linear model for nurses scheduling in hospital that is open for 24/7 a week, where all the nurses worked for 48hours per week. The model consist of two stages in his proposal. First, the minimum number of nurses that need to be engagged and those to be on days-off. 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.

Second, the heuristics for nurse-scheduling problems are introduced. Hadwan et al [5] proposed a harmony search algorithm for the nurse-scheduling problems, which was tested and varified in Malaysia and proven to be more acceptable than the genetic algorithm approach. Aickelin and Dowsland [1] proposed an indirect genetic algorithm for the nurse scheduling problem. The objectives of the research in this literature are to decrease manual scheduling and to recommend upward review on increase demand covering in terms of workforce size but also according to required skills and to obtain equality between the schedules. Jaumard et al [7] proposed a model generalized linear programming for nurse scheduling. European Journal of operational research. We also aimed to reduced labor costs and enabled employers to assign shifts in the most appropriate way.

The Gwoza General Hospital (GGH) Borno State Northeast-Nigeria under *Médecins Sans Frontìeres MSF-Spain*, identified 3 levels of seniority among the categories of nurses within the hospital. Thus, (1) Field coordinator (2) In-charge (3) The ward nurse. Any emergency case brought to hospital as a result of gunshot or bomblast, bomb explosive, a standy response team through helicopter services are readily available between 0600hours to 2000 hours, the Field coordinator is the leader and responsible for all ref-ferrals and the In-charge nurse is the head of all nurses.

III. PROBLEM FORMULATION

The professional master plan design brought by the experts, *Médecins Sans Frontìeres MSF-Spain* has improved the workload distribution modelling and shift rotations of nurses in Gwoza General Hospital, Borno State Northeast-Nigeria. In the actual sense, when it comes to nurse shift scheduling, the personnel have a wide and diverse preferences on shift rotations and work-days off. The satisfaction of nurse shift sequence always depends on preferences for work shifts and days-off to be given to a personnel and their time to take proper rest that will enable the personnel to increase the quality of their work input and to minimize medical cost in most fairly balanced manner. It is apparentely very useful to take the preferences of all nurses and their demands before any modelling on nurse scheduling and is very critical, crucial and complex in nature, under the violence area. We can equally say that, the exercise basic objective was full of series of unrealistic fundamentals because its output. At the planning stage, seniority level, knowledge, skills and experience are much important elements, that all the combinations of shifts and work days-off meet the manpower requiremens of each nurse within a shift.

The design master plan type of MSF-Spain for nurse shift and days-off workload distributions techniques includes; the 2-shft rotation for Medical Doctors from 0800hours to 1800hours and 1800hours to 2200hours while the nurses shift rotations was put on 3-shifts rotations from 0800hours to 1500hurs as morning shift, 1500hours to 2100hours as afternoon shift and 2100hours to 0800hours as night shift. Work days-off is attached to scheduling process and rest, eating, tea breaks, are all entitle of nurses. Minimizing the total cost is not feasible, while maximizing the nurse preferences and all request to actualized certain target, equal scheduling of workload is highly recognized and very important.

Work constraint and equitable balanced of personnel for 3-shift rotations during the insurgency is more worrisome and most serious source of concerned and challenges, on scheduling process. The night shifts is 11hours due to curfew on all movements and has became unfairly balanced rotations against the original planned of 8hours shift rotations, the second constraint, is the requirements for each shift without any hitches on seniority level, knowledge and skills shift by other personnel.

It is hard to avoid the conclusion that, in the united state at least, practitioners do ot 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)*

Modelling a Nurse Shift Schedule with Multiple Preference Ranks for Shifts and Days-Off -Chun-Cheng Lin et al (2014)

Nurse Scheduling and Rostering Shift Sequence Using Linear Programming Problem. A Case Study of Insurgency Related Area Borno State Specialist Hospital Maiduguri, Northeast-Nigeria - BMT Hambagda et al (2019)

The mannual presentation of the analytic scheduling provides maximum of 48hours work with 2days-off, minimum period of rest time between shifts and days-off work period from the master plan design by the MSF-Spain. From the work paper, we can conveniently describe the general rostering and shift sequence patterns as; (1) Normal planning period (2) Normal number of shifts rotations (3) Normal period of 48hours of work in a week. In fact, because of individual lifestyles and level of tolerance among the nurses, each personnel is entitle to the same number of days-off [5-7] as minimum rest period after a shift is required, 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 arranged to covered by the same employee for a whole week before end of the month.

IV. LOCATION FOR CONSIDERATION

Health-care Location: - The nurse scheduling problems have been solved by so many researchers using various methods, which are mainly introduced by different mathematical programming problems. This paper focuses on professional handing of Gwoza General Hospital (GGH) Borno State Northeast-Nigeria under *Médecins Sans Frontìeres MSF-Spain*, military offensive operations and Government placement of curfew on all sorts of movements on this Local Government is more worrisome. The structured put in placed as new designed by MSF-Spain for the hospital includes;

(1) The medicals records. (2) General Out-patient Department (GOPD) open 24/7. (3) Accident and Emergency (A&E) 24/7.

The medical doctors at GOPD and A&E are highly skillful and experience personnel, likewise the professional nurses also, handling of traumatized patients associated with appropriate levels of staff in different medical wards with at least three nurses in each shift is highly observed during our courtesy visitation to Gwoza under high military escout, unless otherwise. The shifts always consider suitably qualified nurses to cover the demands arising from the causalities of the insurgent attacked, in addition to normal traumatized patients undergoing counseling in the hospital, nurse schedule is 48hours a week, and weekend shift are distributed fairly and allowing for 2days-off weekly as employee preferences.

The constraints emanating from nurse scheduling and shifts problems are, in most cases on seniority level, knowledge and skills.

Different journals and alternative approaches in early, 1970s and 1980s addressed variety of problem formulations with regard to nurse scheduling techniques and was able to discussed, addressed analytic and numerical solution to problem formulations and implementation techniques to the nurse scheduling and shift roster. The aim and objectives as sustained in this paper is to provide alternative approach or support tools to reduce the need for manual scheduling and nurse shift. Some papers have already looked into the problem of determining the 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, linear programming (LPP) 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 in charge nurse are strictly considered during a particular shifts under MSF-Spain, morning period, also responsible for Doctors on-call invitation. 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 as an index.

Nurse Scheduling Programming Problem Using Simplex Method; 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 48hours 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 as the basic requirements.

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	$\mathbf{b_1}$
Tuesday	1	1	0	0	1	1	1	$\mathbf{b_2}$
Wednesday	1	1	1	0	0	1	1	$\mathbf{b_3}$
Thursday	1	1	1	1	0	0	1	$\mathbf{b_4}$
Friday	1	1	1	1	1	0	0	$\mathbf{b_5}$
Saturday	0	1	1	1	1	1	0	$\mathbf{b_6}$
Sunday	0	0	1	1	1	1	1	$\mathbf{b_7}$

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

Subject to constraint

$$x_1 + x_4 + x_5 + x_6 + x_7 >= b_1$$
$$x_1 + x_2 + x_5 + x_6 + x_7 >= b_2$$
$$x_1 + x_2 + x_3 + x_6 + x_7 >= b_3$$
$$x_1 + x_2 + x_3 + x_4 + x_7 >= b_4$$
$$x_1 + x_2 + x_3 + x_4 + x_5 >= b_5$$
$$x_2 + x_3 + x_4 + x_5 + x_6 >= b_6$$
$$x_3 + x_4 + x_5 + x_6 + x_7 >= b_7$$

$x_i >= 0, i = 1,2,..7.$ and $b_1, b_2, ..., b_7$ are the number of required nurses working on a particular day. We can now use linear programming problem (LPP) by simplex method as our simulation modelling, and also we made an attempt to develop a Knowledge Based System (KBS) for generating weekly nurse rosters and then adjusting the shift 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 nurse preferences using a complex nurse scheduling and shift problems.

V. STRUCTURE OF LINEAR PROGRAMMING MODEL

In this section, we construct a mathematical model, the basic structure of a Linear Programming Problem (LPP) using simplex method consists of three components.

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

The activities are denoted by $x_1, x_2, x_3, ..., x_n$ and are called decision variables.

The objective functions of a Linear Programming Problem (LPP) using simplex method is a mathematical model that gives a measurable quantity.

Optimization (Maximize or Minimize) $Z = c_1x_1 + c_2x_2 + c_3x_3 + ... \pm c_nx_n$

Where Z is the measure of performance variable of the required function, $c_1x_1 + c_2x_2 + c_3x_3 + ... + c_nx_n$ are called the decision variables, where $c_1, c_2, c_3, ..., c_n$ are the parameters /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, $n = 30$

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

s: number of section in the hospital, $s = 4$

t: number of shifts in the hospital, $t = 3$

k: number of nurses for rostering and shift, $k = 30$

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

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

r: Section index, $r = 1,2,....., s$

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

5.2 The decision variables.

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

$$y_{pq} = \begin{cases} 1 & \text{1, if nurse on annual leave} \quad p=1,2,\ldots n, q=1,2,\ldots m \\ 0 & \text{0, otherwise} \end{cases} \tag{2}$$

5.3 Constraints

To meet the daily and weekly personnel needs of the 4 ward in most fairly balanced manner of the scheduling and shift rotations and days-off based on the preference ranks of the nurses.

5.4 Assumptions of Linear Programming Certainty

In all Linear Programming models it is feasible to observed that, all the model index such as availability of resources, 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 Gwoza General Hospital (GGH) Borno State Northeast-Nigeria under *Médecins Sans Frontìeres MSF-Spain*, high risk, violence by armed gunmen *(*Boko Haram), sacrifices by the NGO and their contract staffers (nurses) cannot be quantified.

Linearity

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

5.5 General Mathematical Model Of an Linear Programming Problem

Optimize (maximize or minimize) $Z = c_1x_1 + c_2x_2 + c_3x_3 + \ldots . \therefore c_nx_n$

Subject to constraints

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

$$x_1, x_2, x_3, \ldots\ldots\ldots, x_n > 0$$

VI. NURSE SCHEDULING PROBLEMS UNDER MSF-SPAIN

In this section, we are presenting a correct linear programming (LPP) using simplex method on required days/ 48hours period under MSF-Spain. The performance and the feasibility of the nurse scheduling modeling is a known problem all over and has been evaluated by various researchers. Nurse scheduling and rostering shift under MSF-Spain, Gwoza General hospital, Borno State Northeast-Nigeria. 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,

- Identify and define the decision variables.
  Let $b_1, b_2, b_3, b_4, b_5, b_6, b_7$ be the number of nurses on-duty from Monday to Sunday respectively.
- Define the objective function

  Minimize

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

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

$$x_1 + x_4 + x_5 + x_6 + x_7 >= b_1$$
$$x_1 + x_2 + x_5 + x_6 + x_7 >= b_2$$
$$x_1 + x_2 + x_3 + x_6 + x_7 >= b_3$$
$$x_1 + x_2 + x_3 + x_4 + x_7 >= b_4$$
$$x_1 + x_2 + x_3 + x_4 + x_5 >= b_5$$
$$x_2 + x_3 + x_4 + x_5 + x_6 >= b_6$$
$$x_3 + x_4 + x_5 + x_6 + x_7 >= b_7$$

$$x_i >= 0, i = 1,2,\ldots 7.$$

6.1 Personnel (Nurses) Scheduling Problem

Gwoza General Hospital (GGH) Borno State Northeast-Nigeria under *Médecins Sans Frontìeres MSF-Spain*, nurse preferences and requirements to meet up the daily counselling, traumatized patients and patients on admission, the skills, experience and knowledge on different days of the week to handle the hospital as follows.

DAY	Nurse Roster (Holding)
Monday	23
Tuesday	28
Wednesday	21
Thursday	23
Friday	20
Saturday	17
Sunday	18

Each personnel (nurse) must work for 48hours per week within five consecutive days and then proceed to two days-off. To formulate the linear programming (LPP) using simplex method algorithm to minimize the number of nurses needed for the week.

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	23
Tuesday	1	1	0	0	1	1	1	28
Wednesday	1	1	1	0	0	1	1	21
Thursday	1	1	1	1	0	0	1	23
Friday	1	1	1	1	1	0	0	20
Saturday	0	1	1	1	1	1	0	17
Sunday	0	0	1	1	1	1	1	18

Min

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

Subject to Constraints

$$x_1 + x_4 + x_5 + x_6 + x_7 = 23$$
$$x_1 + x_2 + x_5 + x_6 + x_7 = 28$$
$$x_1 + x_2 + x_3 + x_6 + x_7 = 21$$
$$x_1 + x_2 + x_3 + x_4 + x_7 = 23$$
$$x_1 + x_2 + x_3 + x_4 + x_5 = 20$$
$$x_2 + x_3 + x_4 + x_5 + x_6 = 17$$
$$x_3 + x_4 + x_5 + x_6 + x_7 = 18$$

using simplex method by applying Gauss-Jodan elementary row operation, the feasible solution, Optimal (**Min**) $Z = 30$ the minimum required nurses to meet up the schedule.

VII. CONCLUSION

The paper shows an overview of nurse-scheduling under *Médecins Sans Frontìeres MSF-Spain at Gwoza general hospital*, Borno State Northeast-Nigeria. It is impossible to obtain a correct nurse-scheduling shift mannually but the designed master planned brought by MSF-Spain has assisted in reaching a relatively required result. The paper reveals the exact minimum number of professional nurses can handle the hospital needs as 30 without povision for unforesing circumstance of any additional nurse to provide preferences that might come up from the nurses, for annaul leave, maternity leave and compossionate leave.

In future, we intend to extend our work on comparrison of nurse scheduling and rostering shift sequence in Government hospitals and NGO hospitals in Notheast-Nigeria. Therefore it will be of interest to integrate them to be solved in a single stage to enlarge possible solutions of the nurse-scheduling process.

VIII. RECOMMENDATION AND ACKNOLEDGEMENT

We recommend addional contract employments of professional nurses by the *Médecins Sans Frontìeres MSF-Spain* to ensure adequate arrangement for nurse preference and to meet up with request that might come up on annual leave, maternity leave and compossionate leave from the personnel (nurses) when the need arises.

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