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Article

Weight Calculator for Graphical Presentation of Nurse Rostering

Vrushali Omkar Salunkhe[1], Pallavi Prasad Jamsandekar[2]

Bharati Vidyapeeth (Deemed to be University), Institute of Management and Rural Development Administration, Sangli, Maharashtra, India.
Email: vrushali.salunkhe12@gmail.com
[2]Bharati Vidyapeeth (Deemed to be University), Institute of Management and Rural Development Administration, Sangli, Maharashtra, India.
Email: pallavi.jamsandekar@bharatividyapeeth.edu

Abstract: - The nurse scheduling problem (NSP), also called the nurse rostering problem (NRP), is the operations research problem of finding an optimal way to assign nurses to shifts, typically with a set of hard constraints which all valid solutions must follow, and a set of soft constraints which define the relative quality of valid solutions. The nurse scheduling problem involves the assignment of shifts and holidays to nurses. Each nurse has their own wishes and restrictions, as does the hospital. The problem is described as finding a schedule that satisfies not only the constraints of the nurses available but also the requirements of the hospital. Conventionally, a nurse can work 3 shifts because nursing is shift viz: day shift, night shift, late night shift. After reviewing various literature, researcher observed that, It is tedious task for hospital authority to allocate nurses to appropriate jobs by considering the parameters like duty time (full time or part time), expertise or nurse's skill, willingness to work in multiple shifts and their mental health. So we try to allocate proper duties to available nurses using big graph and if any other proper solution is there
Keywords: - Assignment Problem, Bipartite Graph, Graph Theory, Nurse Shift Allocation, HRM

1. Introduction

Human Resource Management is study of managing employees in the organization. The responsibilities of human resource manager are staff allocation employee compensation and defining work [1]. As Edward L. Gubman observed in the *Journal of Business Strategy*, "the basic mission of human resources will always be to acquire, develop, and retain talent; align the workforce with the business; and be an excellent contributor to the business. Those three challenges will never change."

Resource allocation is process of allocating available resources to different jobs, services or individuals. This allocation is based on concept that maximize utilization of resources. These resources must be utilized in such as way that maximum output should be received. These resources are limited. To overcome this problem, concept of rationing emerged. Rationing refers to limiting the consumption of resources to meet the demand. [2]

There are various allocation strategies that can be used by organization to maximum utilization of resources. One of commonly used strategy is equal allocation of resources among duties or jobs. Another strategy is allocation of resources as per need. This strategy is used in health care, resources are allocated as per criticality of patient condition or as per requirement of respective department.

Rationing comes into picture when resources are limited and demand is high. Here, resources are allocated on First-Come, First-Serve mechanism. The department or job who demands the resources first will be allocated first. In health care industry, if there is scarcity of nurses, they are allotted double shifts or increase in working hours to achieve maximum utilization so that all departments will work fine.

When resources are limited, allocating resources as per requirement is best option. For instance, allocating nurses to department where there is scarcity is best option.[2]

An optimal resource allocation in health care is critical process as nurses' work in shifts, as per Employee Task Management Problem, allocating all nurses to duties in such as way that no nurse is unassigned and no duty is unallocated.

The **nurse scheduling problem** (**NSP**), also called the **nurse rostering problem** (**NRP**), is the operations research problem of finding an optimal way to assign nurses to shifts, typically with a set of hard constraints which all valid solutions must follow, and a set of soft constraints which define the relative quality of valid solutions. The nurse scheduling problem involves the assignment of shifts and holidays to nurses. Each nurse has their own wishes and restrictions, as does the hospital. The problem is described as finding a schedule that both respects the constraints of the nurses and fulfills the objectives of the hospital. Conventionally, a nurse can work 3 shifts because nursing is shift work: day shift, night shift, late night shift.

2. Factors affecting Nurse Scheduling

- **Qualification**: nurses are allocated to particular ward or department according to their qualification. Nurses are expected to upgrade themselves by opting next level qualification or specialization in particular area. Hospital management appoint educators to train fresher nurses also conduct their evaluation time to time and then allocate duties to them.
- **Experiences**: Nurses who will to work in critical area like NICU, ICU and OT (Operation Theater) required experience in relative ward.
- **Specialization**: some doctors prefer nurses who has specialized in particular area as neurologist or cardiologist prefer or demand nurses who have specialize in those areas.
- **Flexibility to work in shifts**: it is important factor to be considered while scheduling nurses duties as nurses duties are scheduled in shifts. Here, care should be taken that every nurse will be allocated to each shift, also check that nurse will not be allocated same shifts continuously. Fresher's are not allocated to night shifts or critical area duties. Here nurses willingness to work in all kind of all shifts is necessary.
- **Flexibility to work in wards/departments**: nurses should work in all departments in hospitals. It is observed that nurses are working in same departments for years. For example, nurses work in ICU, are normally work in ICU only. These nurses are not ready to work in other departments as in ICU they are handling single patient. It is difficult for ICU nurses to work in another departments

All these factors are considered while allocation of duties or scheduling duties of nurses in multispeciality hospitals. In multispeciality hospitals scheduling duties is tedious as there are number of departments. Therefore, while scheduling duties various factors are considered.

3. Research Gap

After reviewing literature, researcher observed that, allocation of nurses to duties in multispeciality hospitals can be possible with help of big graph as well as bipartite graph. Authors decided to use bipartite matching as there are two different sets with different functionalities and requirements as nurses available and different requirements of various departments in hospitals. At the same time big graph is required because number of nurses is not definite. There are 'n' number of nurses working in various wards in hospital, these wards varies from critical working area to general ward and OPD (outdoor patient department). Each ward / department requires different skill set, qualification, specialization and more importantly willingness to work in any ward. Another important thing need to be considered by hospital management is shifts. Hospital duties specially nurse duties are in shifts (morning, afternoon, night). After considering all these factors, it is being tedious to allocate duties to nurses in various shifts. Therefore authors decided to develop algorithm to this allocation with help of graph theoretic methods.

4. Weight Calculator

researcher has identified parameters based on which the nurse allocation is possible. The data related to available nurses, requirement of each ward is represented in big graph. Further the big graph is viewed as bipartite graph. The maximum matching technique is customized to applicable for nurses roastering problem. The researcher set the following algorithm.

Problem considered: Assign n nurses to r requirements across w wards, considering factors like:

- **Nurse Skills**
- **Ward Priorities**
- **Nurse Availability**
- **Shift Timing**

Representation of data into Big Graph

To solve this problem, researcher is looking for a Maximum Weight Matching in a multi-layered or multi bipartite graph structure. Based on graph, it appears three sets: Wards (W), Requirements (R), & Nurses (N), where nurses are being assigned to specific requirements within wards.

To ensure all nurses are allocated & all requirements are satisfied, researcher can model this as Minimum Cost Maximum Flow Problem or Constraint Satisfaction Problem.

4.1 Mathematical Formulation

To represent this algorithmically, researcher define the following variables:

$W = \{ w_1, w_2, \ldots, w_i \}$: set of wards

$R = \{ r_1, r_2, \ldots, r_j \}$: set of requirements

$N = \{n_1, n_2, \ldots, n_k\}$: set of nurses with weights V_k

E_{wr} : Edge exists if ward '*w'* has requirement '*r'*.

E_{rn} : Edge exists if nurse '*n'* can fulfill requirement '*r'*.

1. The Algorithm : Network Flow Approach

The most efficient way to ensure "all nurses allocated" & "all requirements met" is to use the '***Hopcraft – Karp algorithm***' (for flow)

Algorithm

1. Construct a super source (S) and Super-sink (T) :
   1.1 Connect S to every Nurse Node (nk). Set Capacity = 1
   1.2 Connect every requirement node (rj) to T. Set capacity = 1 (or the number of nurses needed for that specific requirement)
2. Define Intermediate Edges :
   2.1 Create directed edges from nk to rj, if the nurse is qualified / available for that requirement.
   2.2 Assign the weight of nurse to the edge nk -> rj
3. Run Max Flow Min Cost
   3.1 Use a successive shortest Path Algorithm (Using Bellman – Ford or SPFA for calculating weights)
   3.2 Find path from S to T that has highest total weight (or lowest cost if weights are involved)
   3.3 Augment the flow along this path
4. Verification
   4.1 If the Total Flow = f = | N | & f = Total Requirements, then a perfect assignment is found.

To calculate weights for Nurse Allocation, researcher set following algorithm

Weights calculator for the nurse skills

Step 3.1: To calculate weight for nurse, use following process

Step 3.1.1: Consider each factor

Step 3.1.2: Allocate 5 parameters to each factor

Step 3.1.3: Assign 1 to 5 rating to each parameter as 1 to lowest and 5 to highest.

Step 3.1.4: Add ratings to calculate weight as (1+2+3+4+5) = 15

Step 3.1.5: Consider total weight as 100

Step 3.1.6: To calculate weight of each parameter, 100 / 15 = 6.67 (approximately)

Step 3.1.7: Multiply each rating by 6.67

Step 3.1.8: Add all these multiplication to get weight for each factor.

Step 3.1.9: Repeat the process to calculate weight for all factors.

Sr. No.	Name of Factor	Parameters	Rating	Weight

1	**Experience**	0-3 years	1*6.67	6.67
		4-7 years	2*6.67	13.34
		8-10 years	3*6.67	20.01
		11-13 years	4*6.67	26.68
		Above 13 years	5*6.67	33.35
				100
2	**Skill**	Novice	1*6.67	6.67
		Advanced Beginner	2*6.67	13.34
		Complement	3*6.67	20.01
		Proficient	4*6.67	26.68
		Expert	5*6.67	33.35
				100
3	**Flexibility to work in shifts**	Unsatisfactory	1*6.67	6.67
		Need Improvement	2*6.67	13.34
		Meet Expectations	3*6.67	20.01
		Exceed Expectations	4*6.67	26.68
		Outstanding	5*6.67	33.35
				100
4	**Flexibility to work in wards**	Unsatisfactory	1*6.67	6.67
		Need Improvement	2*6.67	13.34
		Meets Expectations	3*6.67	20.01
		Exceeds Expectations	4*6.67	26.68
		Outstanding	5*6.67	33.35
				100
5	**Education**	Helper	1*6.67	6.67
		CNA	2*6.67	13.34
		LPN/LVN	3*6.67	20.01
		RN	4*6.67	26.68
		APRN	5*6.67	33.35
				100

Table 1: Parametrs

Education Levels :

Helper : Required basic training

CNA: Certified Nursing Assistant

LPN / LVN: Licensed Practical Nurse / Licensed Vocational Nurse

RN: Registered Nurse

APRN/MSN/DNP /PhD : Advanced **P**ractice **R**egistered **N**urse / **MSc** in **N**ursing / **D**octor **o**f **N**ursing **P**ractice

1. **Graphical Representation -Weighted Big Graph**

Based on weight calculated and algorithm for Graph Representation, researcher has drawn following big graph.

In below graph, set W, is considered to be wards in multispeciality hospital. Set R is set of requirements by each ward, where set N represent currently employed nurses. Graph represents relationship between these sets. In this graph, each ward is having number of requirements, which are priorities. The nurses are allocated as per priority of requirements.

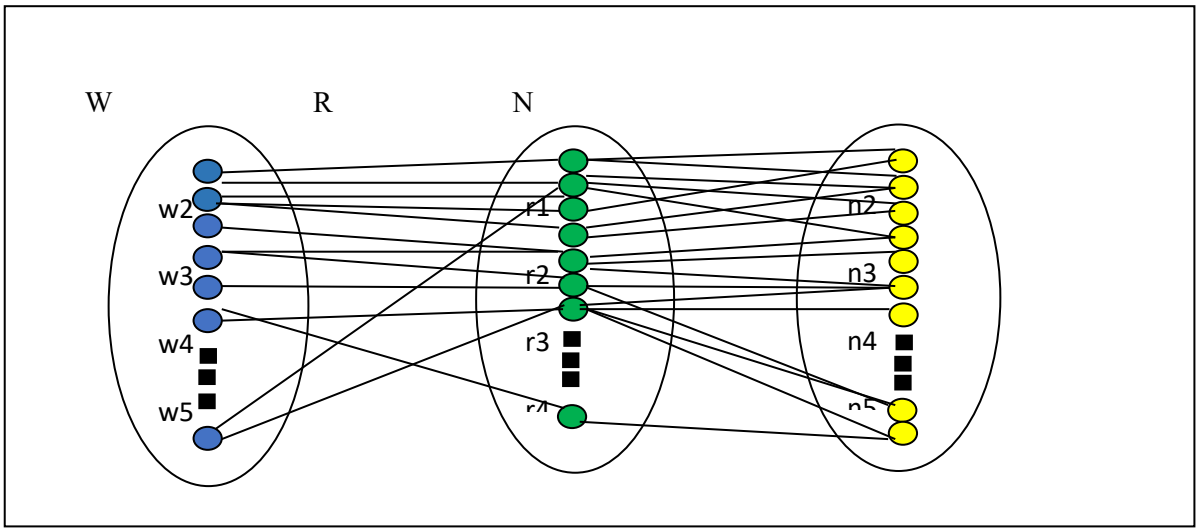

Fig: 1 Weighted Big Graph

5. Conclusion

In this research article, researcher has develop algorithm to accomplish the objectives of this research. Researcher has developed Weights calculator for the nurse skills algorithm for assigning values to concerned parameters based on which the nurse allocation is possible. Along with this researcher develop algorithm to calculate weights for nurses. The data related to available nurses, requirement of each ward is represented in big graph. Further the big graph is viewed as bipartite graph. The maximum matching technique is customized to be applicable for nurses' roastering problem.

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