Methods of Transposition of Nurses between Wards

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In this paper, a computer-implemented method for automating the transposition of a hospital’s nursing staff is proposed. The model is applied to the real case example ‘O’ hospital, which performs a transposition of its nursing staff once a year. Results are compared with real data obtained from this hospital’s current manual transposition system. The proposed method not only significantly reduces the time taken to construct the transposition, thereby significantly reducing management labor costs, but also is demonstrated to increase nurses’ levels of satisfaction with the process.

Key Words: Scheduling, Computer Aided Analysis, Staff Transposition, Nurses, Ward Assignment Method, Between Wards, Nurses’ Ward Preferences

1. Introduction

The modeling of a staff transposition problem requires many conditions to be taken into consideration, and various approaches have been previously proposed(1)–(3). However, there has been thus far only limited consideration of modeling the transposition of nurses between hospital wards. In the hospital-based problem, significant labor is required to perform the staff transposition of nurses between wards, and a variety of issues must be considered in performing this process. For example, nurses’ preferences must be included, which will depend on personal relationships with other nurses and with other wards, the nursing levels of the wards must be balanced, and the allocation of part-time-service personnel must also be considered. This study deals with the staff transposition of nurses in a hospital.

The purpose of this study is to propose a method, which may be computer-implemented, for automating the transposition of nursing staff. Such a method can then facilitate a reduction in the management labor cost of the transposition process in comparison to the present manual system. The model is applied to the real case example ‘O’ hospital, which performs a transposition of its nursing staff once a year. Results are compared with real data obtained from this hospital’s current manual transposition system.

2. Transposition Model

In this section we describe the aims and modeling assumptions of the present approach.

2.1 Aims

The aims of the present study are the automation of the staff transposition table by the introduction of a computer-implemented model, and to thereby reduce the management burden associated with the current manual transposition system. Furthermore, it is intended that the current algorithm should maximize the satisfaction levels of nurses in the transposition process.

2.2 Notation

- \( N \): The total number of nurses
- \( n \): Nurse number \( (n = 1, 2, \ldots, N) \)
- \( P \): The total number of wards
- \( p \): Ward number \( (p = 1, 2, \ldots, P) \)
- \( C_p \): The capacity of ward \( p \)
- \( H-C_p \): The capacity of ward \( p \) available for part-time-service personnel
- \( Cnt_p \): The number counters of nurses in ward \( p \)

- \( Ar_p \): The order of transposition in ward \( p \) \( (Ar_p = 1, 2, \ldots, P) \)
- \( S \): The number of different nurses’ seniority ranking levels
- \( s \): Rank number \( (s = 1, 2, \ldots, S) \)
- \( S_n \): Nurse \( n \)’s rank \( (S_n = 1, 2, \ldots, S) \)
- \( P_n \): The present ward of nurse \( n \) \( (P_n = 1, 2, \ldots, P) \)
- \( PA_n \): The ward of nurse \( n \) following transposition \( (PA_n = 1, 2, \ldots, P) \)
Table 1 The questionnaire survey conducted in O hospital

<table>
<thead>
<tr>
<th>Wards name Rank</th>
<th>Name</th>
<th>Date of birth</th>
<th>Age</th>
<th>Date of adoption</th>
<th>Year of last change</th>
<th>Last ward</th>
<th>Resign? Present ward</th>
<th>The 1st preference</th>
<th>The 2nd preference</th>
<th>The 3rd preference</th>
</tr>
</thead>
</table>

$Ad_n$: Entry year of nurse $n$ (A.D.)
$Ex_n$: Years of experience of nurse $n$ (years)
$L_n$: Last fiscal year in which nurse $n$ was transpositioned (A.D.)
$In_n$: Length of Interval in which nurse $n$ has been at present ward (years)
$Av_{wp}$: Average years of experience of ward $p$
$Av_{vt}$: Average years of experience of the nurse excluding those nurses who are resigning
$R_n$: Does nurse $n$ resign? 1 if YES. 0 if NO.
$C_n$: Does nurse $n$ desire a change? 1 if it is YES. 0 if it is NO.

2.3 Problem formulation

(1) $N$ nurses (excluding those nurses who are resigning) are assigned to $P$ wards.

(2) The capacity of each ward is a given, known quantity.

(3) The capacity of each ward to accommodate part-time-service personnel is a given, known quantity.

(4) Promotion of an executive etc. shall not be taken into consideration in the transposition process currently under consideration.

(5) There shall be no compulsory change of ward imposed on nurses who do not wish to be transposed.

(6) Input parameters:
Since this research is aimed at facilitating the staff transposition of nurses, input parameters are determined on the basis of a questionnaire (Table 1) conducted in O hospital.

- The number of nurses $N$
- Executive The nurse rank $S_n$ in the O hospital is expressed as follows.

The number $1= \text{director of nursing service department}, 2= \text{vice-director of nursing service department}, 3= \text{nurse chief}, 4= \text{vice-nurse chief}, 5= \text{nurses}, 6= \text{assistant nurses}, 7= \text{nurse aid}, 8= \text{part-time service personnel}, and 9= \text{part-time service personnel’s aid}

- Name
- Entry year $Ad_n$

Nurse $n$’s years of experience may then be calculated by $Ex_n = (\text{present fiscal year}) - Ad_n$.

- Fiscal year in which most recent transposition of nurse $n$ occurred $L_n$

Nurse $n$’s interval without a ward change is then given by $In_n = (\text{present fiscal year}) - L_n$.

(1) If a nurse has been transposed between wards within the last three years, she/he will not be moved to a new ward.

(2) The nurses’ ward preferences will be fulfilled as much as possible.

(3) The capacity of each ward to accommodate part-time service personnel must not be exceeded.

(4) The average years of experience of nurses on all the wards should be balanced.

3. Nurse Transposition Algorithm

The algorithm for performing automatic staff transposition is given by the following.

3.1 The overall algorithm

The overall algorithm for automatic staff transposition is performed by combining sections 3.2–3.5, as shown below.

[Step1] The “Distinction of Transposition Candidate” algorithm is performed.

[Step2] Given the results of the “Distinction of Transposition Candidate” algorithm, $Av_{wp}$ and $Av_{vt}$ are calculated.

[Step3] The “Investigation of Nurses’ Preferences” algorithm is performed.

[Step4] The “Transposition Taken Consideration of Candidate’s Conditions” algorithm is performed.

[Step5] The “Transposition Not Taken Consideration of Conditions” algorithm is performed.

[Step6] End
3.2 Distinction of transposition candidate

Transposition candidates (new entrants are included) are distinguished from those nurses not wishing to be moved, and these latter are not moved in the subsequent transposition process.

3.3 Investigation of Nurses’ Preferences

The transposition preferences of transposition candidates as identified by 3.2 are compiled, and the order of transposition is determined.

3.3.1 Procedure

[Step1] Nurses’ preferences are compiled and the order of transposition $A_{p}$ is determined.

[Step2] End

Numerical simulations of the transposition to wards were accomplished using the four patterns described below. Four different allocation techniques were used in order to assess how the results of the simulations depend on different techniques of accommodating the nurses’ stated preferences. As a first step, hospital wards are ordered in terms of their popularity, according to the nurses’ preferences as stated in the questionnaire, in two ways: In the first method all three expressed preferences of all the nurses are used, and wards are then ranked in terms of their popularity according to the total number of preferences received (A). In the second method, only the nurses’ first preferences are used, and the wards are ranked in terms of their popularity according to the total number of first-preference votes received (B). The four different simulation techniques may then be described:

1. **Numerical simulation 1**
   - Referring to the ranking of the hospital wards according to the aggregation of all the nurses’ expressed preferences (see (A) above), nurses are assigned to wards in order from the least popular to the most popular.

2. **Numerical simulation 2**
   - Referring to the ranking of the hospital wards according to the aggregation of all the nurses’ expressed preferences (see (A) above), nurses are assigned to wards in order from the most popular to the least popular.

3. **Numerical simulation 3**
   - Referring to the ranking of the hospital wards according to the aggregation of only the first of the nurses’ expressed preferences (see (B) above), nurses are assigned to wards in order from the least popular to the most popular.

4. **Numerical simulation 4**
   - Referring to the ranking of the hospital wards according to the aggregation of all the nurses’ expressed preferences (see (B) above), nurses are assigned to wards in order from the most popular to the least popular.

3.3.2 Small example data of preferences

For small example of four nurses and four wards, data of preferences is shown by Table 2, all nurses’ expressed preferences of wards is shown by Table 3, and 1st preference of ward is shown by Table 4.
wards in order from the least popular to the most popular order of minimum total preference. That result order is Ward 4, Ward 3, Ward 2, (or Ward 2, Ward 3), and Ward 1.

Numerical simulation 2 is according to the aggregation of all the nurses’ expressed preferences (see (A) above), and nurses are assigned to wards in order from the most popular to the least popular. That result order is Ward 1, Ward 2, Ward 3, (or Ward 3, Ward 2), and Ward 1.

Numerical Simulation 3 is according to the aggregation of only the first of the nurses’ expressed preferences (see (B) above), nurses are assigned to wards in order from the least popular to the most popular. That result order is Ward 4, Ward 3, Ward 2, (or Ward 3, Ward 2), and Ward 1.

Numerical Simulation 4 is according to the aggregation of all the nurses’ expressed preferences (see (B) above), nurses are assigned to wards in order from the most popular to the least popular. That result order is Ward 1, Ward 2, Ward 3, (or Ward 3, Ward 2), and Ward 4.

3.4 Transposition taken consideration of candidate’s conditions

Transposition candidates, as distinguished by 3.2, are assigned taking consideration of the conditions described as follows.

3.4.1 Conditions of transposition

(1) The variation in the average years of experience between wards should be small for equality of medical treatment.

(2) The capacity of each ward to accommodate part-time service personnel should not be exceeded.

(3) The nurses’ ward preferences will be fulfilled as much as possible.

3.4.2 Procedure of transposition

Order nurses according to their 1st, 2nd and 3rd ward preferences. If two or more appropriate nurses exist, order nurses for transposition according to the scores of new-entry nurses, and order nurses, excluding new-entry nurses, by input order.

3.5 Transposition not taken consideration of conditions

If there exist nurses who have not been re-assigned by the “Transposition Taken Consideration of Candidate’s Conditions” algorithm of 3.4, assign in turn order of one by one condition shown in section 3.4.1(1), 3.4.1(2), and 3.4.1(3) is being relaxed.

4. Numerical Simulations

4.1 Numerical simulations and results

Numerical simulations were performed based on the relevant data gathered from O hospital, together with data compiled from the conducted questionnaire. The total number, N, of nurses is 558, and, although the total number P of wards is 22, in practice 5 wards were not involved in the experiment, so the number of wards P was set to 17.

As explained in further detail in section 3.3, numerical simulation 1 assigns nurses to wards in order from the least popular to the most popular ward, with ward popularity determined by a ranking system based on the aggregation of all three of all the nurses’ expressed preferences. Numerical simulation 2 assigns nurses to wards in order from the most popular to the least popular ward, with ward popularity determined by a ranking system based on the aggregation of all three of all the nurses’ expressed preferences. Numerical simulation 3 assigns nurses to wards in order from the least popular to the most popular ward, with ward popularity instead determined by a ranking system based on the aggregation of only the first of the three preferences. Numerical simulation 4 assigns nurses to wards in the order from the most popular to the least popular ward, with ward popularity again determined by a ranking system based on the aggregation of only the first of the three preferences.

Table 5 shows the number of nurses with satisfied or dissatisfied preferences, the rate of satisfied or dissatisfied preferences, and an accumulation rate of satisfied or dissatisfied preferences detailed by the order of preferences from the first to the third. Table 6 shows the number of preferences expressed by nurses in the three categories, the number of satisfied preferences, and the rate of satisfied preferences to number of preferences.

The percentage (%) figures of simulations 3 and 4 in Table 6 differ from those of Table 5 because different denominators are used to calculate the figures of Tables 5 and 6. The rate of satisfied or dissatisfied preferences (%) of Table 5 shows the number of nurses with satisfied or dissatisfied preferences expressed as a proportion of total preferences, figures for those with no stated preference, and those whose destination ward lies outside of their preferred choices (76). Table 6, however, shows the number of satisfied preferences shown as a proportion of the number of expressed preferences in the three preference categories.

For reference it may be noted that the computation time to execute one of the numerical simulations was about 1 second (by Intel Pentium Processor III 1 GHz).

4.2 Discussion

With reference to Tables 5 and 6, it is clear that all the numerical simulations produce transpositions which have decreased the number of dissatisfied nurses in comparison to the manually-created distribution.

In comparing results of the four simulations, it is clear that an advantage of the distribution according to simulations 1 and 3 is that the number of nurses whose allocated ward lies outside of their three preferences is reduced. It may also be seen that the condition of not exceeding the ward’s capacity to accommodate part-time-service personnel is satisfied. However, these simulations suffer from the disadvantage of recording a low rate of satisfaction of nurses’ first preference.
Table 5  Number of nurses’ satisfied or dissatisfied preferences, rate of satisfied or dissatisfied preferences, and accumulated rate of satisfied or dissatisfied preferences as a proportion of the number of preferences

<table>
<thead>
<tr>
<th>Manualy created method</th>
<th>Numerical simulation 1</th>
<th>Numerical simulation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nurses satisfied or dissatisfied preference (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of satisfied or dissatisfied preferences (%)</td>
<td>Rate of satisfied or dissatisfied preferences (%)</td>
<td>Rate of satisfied or dissatisfied preferences (%)</td>
</tr>
<tr>
<td>1st preference</td>
<td>32 42.1 12 31.6 33 43.4</td>
<td></td>
</tr>
<tr>
<td>2nd preference</td>
<td>13 17.1 22 28.9 10 13.2</td>
<td></td>
</tr>
<tr>
<td>3rd preference</td>
<td>4 5.3 12 15.9 8 10.5</td>
<td></td>
</tr>
<tr>
<td>No stated preference**</td>
<td>9 11.8 3 11.8 9 11.8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76 100.0 76 100.0</td>
<td></td>
</tr>
</tbody>
</table>

| Rate of satisfied or dissatisfied preferences (%) * shows the number of nurses’ satisfied preferences, no stated preference and those allocated to a ward not selected by them expressed as a percentage of total nurses wishing to be moved (Total 76). ** The no stated preference denotes nurses who expressed no preferences between wards.

Table 6  Number of nurses’ satisfied preferences and rate of satisfied preferences to number of preferences

<table>
<thead>
<tr>
<th>Manualy created method</th>
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</thead>
<tbody>
<tr>
<td>Number of nurses satisfied or dissatisfied preference (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of satisfied or dissatisfied preferences (%)</td>
<td>Rate of satisfied or dissatisfied preferences (%)</td>
<td></td>
</tr>
<tr>
<td>1st preference</td>
<td>29 38.2 3 46.1</td>
<td></td>
</tr>
<tr>
<td>2nd preference</td>
<td>22 28.9 15 65.8</td>
<td></td>
</tr>
<tr>
<td>3rd preference</td>
<td>10 13.2 4 71.1</td>
<td></td>
</tr>
<tr>
<td>No stated preference**</td>
<td>9 11.8 9 82.9</td>
<td></td>
</tr>
<tr>
<td>Allocated to unselected ward</td>
<td>6 7.9 9.2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>76 100.0 76 100.0</td>
<td></td>
</tr>
</tbody>
</table>

In contrast, for simulations 2 and 4, which allocated nurses sequentially from the most popular to the least popular ward (according to the two different popularity ranking systems described in section 3.3), it is clear that the rate of satisfaction of nurses’ first preferences is high. However, the number of nurses whose allocated ward lies outside of any of their expressed preferences is large, and the condition of not exceeding the ward’s capacity to accommodate part-time-service personnel may not be fulfilled, in contrast to numerical simulations 1 and 3.

Our results find that simulation 3 displays the best results in terms of satisfaction of nurses’ ward preferences.
With the execution of four simulations as described above, and the subsequent selection of the best of these to provide a nurse transposition plan, the overall time required for this transposition process has been reduced, thus reducing the management burden of his task in comparison with the manual approach.

4.3 Future work
The ideal of a staff transposition method which computes a maximum level of satisfaction of nurses’ ward preferences with no nurse dissatisfaction in the transposition process is proposed as future work.

5. Conclusions
(1) An automatic staff transposition method considering the wish of nurses, average years of experience of nurses on each ward and the capacity of the ward to accommodate part-time-service personnel was proposed.
(2) A program of automatic staff transposition is implemented using the C-language. The computation time to execute a numerical simulation is small.
(3) By use of the present automated method, the time taken to implement a transposition of nurses between wards has been significantly reduced, and the management burden required for this task has consequently also been reduced.

In addition, the content of this paper is subject to a patent (application number for patent 2003-57297).

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References