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Some Remarks on Scheduling Nursing Personnel

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In an earlier issue of this journal, Warner published a mathematical programming approach to scheduling nursing personnel. Some inconsistencies in the formulation of his mathematical program are identified, and an alternative objective function for this problem is proposed.

IN [1], Warner does not clarify that E_k is meant to be the value of having *any number* of additional Registered Nurses on day/shift k , provided that it does not exceed F_k . Rather, E_k is defined as "the value of having an extra RN on day/shift k " [1, p. 853]. Also, F_k is not a real constraint on additional coverage, since the formulation of the model allows for additional nurses beyond F_k whose presence then, however, negatively influences the working conditions in the unit.

A mistake was made in the formulation of the two objective functions. In Warner's objective function of Phase 2, *additional* Registered Nurses are taken into consideration twice, because they are contained in $g(s_k)$ as well as in $g(t_k)$. Consequently, the objective function value is falsely increased, when more Registered Nurses than necessary are present and the minimum total coverage constraint is nevertheless exactly met. Therefore, $g(s_k)$ should be deleted from the objective function of Phase 2.

On the other hand, a *shortage* of a Registered Nurse may be more important than a shortage of a Licensed Practical Nurse. If it were therefore explicitly intended to weigh the shortage of a Registered Nurse twice—which is not mentioned in [1]—the objective function of Phase 1 of the algorithm would be correct. If this were not intended, $f(U_k)$ should be deleted from this objective function.

Finally, an alternative objective function is proposed, which seems more appropriate to this problem. If the aversion weights are provided with a negative sign [1, pp. 852–853], the maximization of C subject to the given constraints and to the additional constraints $\sum_{j=1}^J C_{ij} \cdot X_{ij} \geq C$ for all $i \in \{1, 2, \dots, L\}$ yields the result that the maximal individual aversion becomes as small as possible. At the same time this leads to a greater similarity of the quality of the individual nurses' schedules and in this way may contribute to a better working atmosphere in the unit.

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REFERENCE

1. D. M. WARNER, "Scheduling Nursing Personnel According to Nursing Preference: A Mathematical Programming Approach," *Opns. Res.* **24**, 842-856 (1976).

Equivalence of the 0-1 Integer Programming Problem to Discrete Generalized and Pure Networks

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We show how to formulate a 0-1 integer programming problem as a "mixed integer" generalized network and as a discrete "0-U" pure network problem. Special integer programming structures allow convenient simplifications. The usefulness of these formulations is in providing new relaxations for integer programming that can take advantage of recent advances in the development of efficient computer programs for network problems. We cite three practical applications in which these ideas have led to marked improvement in solution efficiency.

THE MIXED INTEGER generalized network problem and a 0-U (discrete) version of the pure network problem are capable of accommodating a variety of problems not ordinarily conceived of as related to networks, including the 0-1 integer programming problem. In this note, we will show more generally how to model the mixed problem

$$\text{Minimize } \sum_{j \in N} c_j x_j \quad (1)$$

subject to

$$d_i \leq \sum_{j \in N} a_{ij} x_j \leq b_i, \quad i \in M = \{1, \dots, m\} \quad (2)$$

$$u_j \geq x_j \geq 0 \quad \text{for } j \in N \quad (3)$$

$$x_j \in \{0, 1\} \quad \text{for } j \in N_1 \subset N \quad (4)$$