International Journal of Operations Research Vol. 4, No. 4, 230−237 (2007)

Multi-Criteria University Decision Support System: An Operations Research Prototype Case Study

Marijane E. Hancock[1,*] **and Marc J. Schniederjans**[2]

[1]Director of Institutional Research and Planning, University of Nebraska-Lincoln, Lincoln, NE 68583-0743

[2]College of Business Administration, University of Nebraska-Lincoln, Lincoln, NE 68588-0491

Received October 2005; *Revised March 2007*; *Accepted May 2007*

Abstract**—**A decision support system (DSS) using a multi-criteria methodology is developed to assist decision makers in the Teachers College of the University of Nebraska-Lincoln. The DSS is designed to examine potential outcomes of resource allocation/reallocation decisions. This case study reports the process of prototyping undertaken by an analyst creating the DSS. The results of the study reveal how the multi-criteria DSS could be used to support decision making of resource allocations during times of significant changes in departmental academic programs. This study also reveals a number of prototyping implementation strategies useful for operations research modeling applications of DSS prototyping.

Keywords**—**Goal programming, Decision support systems

1. INTRODUCTION

Department chairs in colleges and universities face a recurring set of resource allocation/reallocation decisions several times a year. These decisions involve faculty, budgetary resources, and the complexity of their interaction. While some university departments are too small to justify decision support systems (DSS), many larger schools, which have the same reoccurring set of decisions, present an ideal situation for use of DSS.

An assignment decision problem, like faculty allocation/reallocations, possesses multiple hierarchical goals with conflicting resource allocations. Turban et al. (2004) and Mallach (1994) suggest that models be used in the development of DSS to predict outcomes of decision choices. Some researchers suggest using linear programming (Xu (2006)) models for faculty assignment problems, while others demonstrate how heuristic methodologies (Liu et al. (2006)), Schniederjans and Carpenter (1996)) can be applied to scheduling decisions that are applicable to faculty assignment problems. One of the limitations of linear programming and heuristic methods in solving faculty assignment problems is their unitary goal consideration of constrained resources while seeking the best satisfying solution based upon the hierarchical goal structure of the decision maker. One modeling methodology that is ideally suited for this decision environment is goal programming (GP) (Charnes and Cooper (1961), Lee (1972), Ignizio (1982)).

Early applications of GP use in modeling university planning appeared in early 1970s (Lee and Clayton (1972)). The first book entirely devoted to university planning with GP was published in the early 1980s (Lee and Van Horn (1983)). Over twenty journal publications illustrating the use of GP in university planning prior to 1995 were reported by Schniederjans (1995). These prior studies were limited to theoretical possibilities and one-time applications. One early study that combined DSS development with GP was Franz et al. (1981), who demonstrated how DSS utilizing GP could be used to support academic planning decisions. This study did not focus on the prototyping phases in development of a DSS.

In our case study, we present the development of DSS based on goal programming modeling methodology to support the decision making of department chairs at the University of Nebraska-Lincoln (UNL). As a prototyping study for the development of a university-wide system, the application reported here is limited to three departments in the Teachers College at UNL. The DSS examines potential outcomes of resource allocation/reallocation decisions, and thus, allows for consideration of different faculty and budget decisions supporting differing programs offered by the UNL Teachers College.

2. METHODOLOGY

The goal programming (GP) model by Charnes and Cooper (1961) was selected because its preemptive ranking of goals in the model best matches the actual decision environment reported by the department chairs. Different academic goals often compete for shares of the same resources. A department chair may not have complete information about the value or cost of each goal, but can make a decision on its relative priority and can provide an ordinal ranking in terms of its contribution to the university-wide goals of the institution. GP is ideal

*Corresponding author's email: Mhancock@nebraska.edu

1813-713X

designed to help address this type of problem. The GP model can generally be stated as:

$$\text{Minimize: } Z = \sum P_i (d_i^+ + d_i^-) \quad i \in m \tag{1}$$

$$\text{Subject to: } \sum a_{ij} x_j - d_i^+ + d_i^- = b_i, \quad \forall i \in m; j \in n \tag{2}$$

$$d_i^+, d_i^-, x_j \geq 0, \ \forall i \in m; \forall j \in n \tag{3}$$

where the x_1, x_2, ..., x_n are nonnegative decision variables and the objective function in Eq. (1) is subject to a set of m constraints in Eq. (2). In the constraints, the a_{ij}, where i = 1, 2, ..., n and j = 1, 2, ..., m are technological coefficients representing the per unit usage by x_j of the right-hand-side coefficient of b_i. In this model the n decision variables are required to be nonnegative as stated in Eq. (3), where d_i^+ is a positive deviation variable and d_i^- is a negative deviation variable from select b_i. The value of Z is the summation of all deviations. The statement in Eq. (1), that i is an element of the m possible positive and negative deviation variables, implies that the department chairs have the option to choose the selection of deviation variables to be included in the objective function. The P_i in Eq. (1) are the preemptive priority factors that serve only as a ranking symbol to mean no substitutions across categories of goals will be permitted. It is assumed the ordering of deviation variables in an objective function will be minimized in order, where $P_i > P_{i+1} > P_{i+2}$ >>> and so on, for as many priorities that may exist in a model. The development of the GP model incorporated into the prototype model for the DSS in this study is presented in Appendix A.

For prototyping purposes, the analyst ran the GP models on a PC-based system using Lee (1996) software. Hardcopies were then distributed to department chairs for revision. It was observed this prototyping implementation strategy has two advantages: it is inexpensive, since no specialized programming is necessary, and it allows flexibility in the presentation of the solutions results for continuous reformatting revisions. This prototyping strategy is supported by Wu et al. (2004), which suggests that hardcopy DSS is appropriate in executive decision situations similar to those made by the department chairs.

3. PROTOTYPING APPLICATION

Since the goal is to eventually use DSS for university-wide planning, the selection of the Teachers College at UNL was judged ideal for capturing the informational transaction exchanges necessary for college planning. College goals were implemented at the departmental level in the institution. Selecting all three departments (i.e., Curriculum and Instruction, Educational Administration, and Educational Psychology) within the Teachers College captures a fairly accurate picture of the decisions in a variety of different interacting programs in which the departments share responsibility and resources.

Since participation in the prototyping study was voluntary, the two principle groups of stakeholders (i.e., department chairs and college administrators) needed to be persuaded to participate. Using the prototyping approach suggested by Marakas (1999) in developing a DSS, presentations of the potential decision support benefits were presented to both the department chairs and the college administrators. Providing detailed information on the types of information and how they support commonly experienced decision situations makes the potential value of the DSS evident to potential users. Emphasizing the developmental role participants play in shaping the resulting DSS is particularly helpful in gaining full support from all stakeholders.

The reporting of the application of this prototyping case study is presented in four basic phases of a typical prototyping process suggested by Laudon and Laudon (2006)

3.1 Phase 1: To identify the user's basic requirements

After some orientation for the departmental department chairs on the possible usefulness of the proposed DSS, the analyst chose to obtain information for the DSS by beginning with a small pilot study of just the Elementary Education Program within the Curriculum and Instruction Department. It was observed that department chairs allocated resources to programs within their departmental domains, and therefore, decisions were based on programs rather than broader areas of responsibility. The selection of this program was also based on the fact it was complementary to most issues, which might arise in later programs. It was believed dealing with a broader, more complex set of issues initially, might save time later when department chairs require substantial add-on efforts. This is particularly true when dealing with multiple variable problem situations where the interplay of constrained resources could require substantial programming modifications. The department chair was also eager to participate in the pilot study because numerous resource allocation questions impacting the program began surfacing at the time of the study (e.g., limiting program enrollment from 240 to 160 students). The chair's willingness, the need to explore the ramifications of program changes on resource needs, and the fact that the Elementary Education Program could be studied without having to include interactions (initially) with other programs in the department made the selection of the Elementary Education Program an excellent choice for a pilot study of the proposed DSS.

The types of information sought during interviews with the department chair are consistent with the steps suggested by Romero (1991) and Schniederjans (1995) in GP model formulation procedures. These steps involve determining first the decision variables, then the goal constraints, and finally the goal priorities. Basically, the analyst first seeks to define the decision variables necessary to support decision making. Due to department administrative limitations, it was determined that only instructional staffing and their budgets needed to be modeled. The department chairs wanted to determine how well they were meeting programmatic requirements for staffing versus the capacity to provide staff. As stated in Appendix A, there are six categories of instructional staffing in the proposed DSS model. The goals for the development of the goal constraints were identified in conversations with the department chair. The analyst found that by starting with lists of university and college goals, the department chair could more easily identify specific goals within the context of the broader institutional goals. Development of the goal constraints required collecting parameter data from the department chair and incorporating them into six types of goal constraints listed in Appendix A. The initial data collected for the pilot study was based upon the current state of the department for purposes of comparison of the model versus actual faculty allocations. The goal constraint formulations used are modified versions of those found in the literature (see Franz et al. (1981), Lee and Clayton (1972), Lee and Van Horn (1983), Schniederjans and Kim (1987)). Finally, the identified departmental goals were prioritized by the department chair.

3.2 Phase 2: To develop an initial prototype

With the information collected from the pilot study of the Elementary Education Program, a GP model was formulated to test the viability of the modeling process for this program. Once the chair and the analyst believed the GP model accurately simulated the current program, the chair was encouraged to come up with "what if" questions to look at the effects changes would have on resource allocations and requirements. Considerable time was spent by the analyst with the chair studying the department to be able to provide relevant examples from other areas in the university that might have parallel decision situations in departmental planning. This was done to encourage the chair to look at a range of alternatives. Necessary modifications were made to the model, and solutions were generated to match the chair's questions. It should be noted that the GP modeling effort did not take much time. Discussions of the results were held, and the process was repeated until the chair was satisfied that all questions of interest had been explored.

3.3 Phase 3: To use the prototype

This process was expanded to include the entire set of programs supported by all three departments. Again, efforts were initially made to ensure the GP model accurately described the typical allocation/reallocation situation currently found in the departments. Once satisfied that the model described results for the various programs making up other departments, a more in- depth incorporation of resources was undertaken by the analyst. Rounds of questions and solutions were provided to other department chairs until they believed their areas of interest and questions had been addressed. This resulted in one standardized prototype model, which provided the ecessary planning information for all three departments.

3.4 Phase 4: To revise and improve the prototype

The department chairs were asked to explore resource allocation problems over several weeks of experimentation with the prototype DSS. Several dozen runs of the models on various planning scenarios were undertaken. Typical resource planning problems in the Elementary Education Program and the prototype DSS solution information are presented in Tables 1 and 2. The "model new program" was a shift in the targeted goal of "teaching credit hours of undergraduate courses" from a previous total of 240 hours down to the Table 1 Target Goal Level of 168 hours. This is an example of a confounding issue that could occur. In this case, it involves accreditation requirements, which adds substantial complexity to department chair staffing plans, and represents a serious and pressing issue that the department chair was anxious to analyze and resolve. Other simultaneous changes defined in the problem statements in Tables 1 and 2 demonstrate decision complexity that department chairs face in resource allocation/reallocation problems and issues the prototype DSS is capable of addressing.

Aloysius et al. (2006) reported previous research indicated decision makers are often reluctant to use potentially beneficial multi-criteria decision support systems. Yet the literature has shown building highly flexible and user-friendly systems can overcome most user issues (Bana e Costa et al. (1999)). Dozens of minor changes in the formatting of the information, which the system generated, and additional decision situations were incorporated. The implementation of these changes, guided by the department chairs in an active participant role, resulted in even greater participation by the department chairs and an observable increase in the enthusiasm with which they aggressively became more interested in the prototyping project. Among the design considerations proposed and integrated into the prototype system were user customization features (e.g., differing types of statistical analyses) to permit department chairs to generate unique information in order to analyze individual department goal achievement.

4. SUMMARY OBSERVATIONS, LESSIONS LEARNED, AND LIMITATIONS

The analyst used a structured set of questions to learn what department chairs experienced in using the prototype DSS system and how the analyst might adapt it in the future to fit their needs. When the department chairs were asked if they would use the proposed DSS in their planning, each responded with a resounding yes. This was further supported by the fact that two of the department chairs used the experimental DSS model output to explain their programs and needs to other decision making bodies in the college. Some of the learned lessons from this prototyping experience, as reported by the department chairs, included an awareness of the categories of instructional staff (i.e., GF, GM, Instr, OIS, GTA), the

Table 1. Elementary education scenario 1

Problem: Model new program. Lower number of graduate students allowed in the program to 48 doctoral and 84 masters/specialist students. Add supervisor of field experiences; shift distribution of effort for instructors and GTAs to allow for teaching of field experiences; all field experiences to be supervised by instructors or GTAs.

Goal	Priority (P_i)	Target goal level (b_i)	Positive deviation (d_i^+)	Negative deviatio (d_i^-)
Teach credit hours of undergraduate courses	1	168	0	0
Field experience sections	1	78	0	0
Student teacher supervision	1	80	0	0
Teach credit hours of graduate courses	2	35	0	0
Advise doctoral students	2	48	6	0
Advise masters students	2	84	21	0
Employ number of Graduate Fellows	3	6.75	0	0
Employ number of Graduate Members	4	2	0	0
Employ number of instructors	5	1.50	3	0
Employ number of GTAs	5	4	0	0
Minimize cost	6	0	$546,231	0
Employ supervisors of field experiences		1	0	
Employ outside instructors		0	18	0
Employ outside student teacher supervisors		0	35	0
Solution (x_j)				
Graduate Fellows	6.75			
Graduate Members	2			
Instructors	4.50			
GTAs	4			
Outside instructors	18			
Outside student teacher supervisors	35			
Resulting resource allocation				
Field experience supervisors	1			
Cost	$546,231			

qualifications needed by faculty and staff responsible for carrying out departmental programs, and how critical the mix of faculty was in the planning process. The department chairs indicated increased awareness that a graduate department must have GFs, because of the limited role less research-accomplished GMs serve in a doctoral program. The DSS helped them recognize that GMs must be given appropriate time and support to allow them to gain GF status. In addition, the DSS helped with human resource replacement problems. The DSS was used to support the request for authorization to replace a faculty member who had recently resigned. Results of the DSS highlighted the need to recruit a new faculty member, who could come to the program with experience that ensured prompt achievement of GF status.

Some of the analyst observations can be viewed as implementation strategies for prototyping projects utilizing quantitative methodologies in a more general context. These include:

- **Starting from a small, but comprehensive component program will save time in the long-term:** A small part of a system is easier to model initially and provides a faster way to bring a project to an end, provided the smaller part is representative of most of the add-on issues to be incorporated as other parts of the system are brought together.
- **Use the opportunity of nearing deadlines to motivate participation in a prototyping project:** Selling a project idea as a means to solve an approaching planning deadline is not only good business, but the best way to show potential users an immediate use for the proposed system. This is particularly true for complex, multi-variable problem decision situations.
- **Using hardcopy output for DSS provides much need formatting flexibility and the perception of an inexpensive system:** The model required changes each time a department chair came up with a new type of question. The analyst was quickly able to add the necessary program changes and redo the hardcopy for the department chairs with little reprogramming, because no fixed formatting of output had been performed. This has the added feature of giving the department chairs the perception that the system is initially an inexpensive experiment (particularly the prototyping phases) and not something that could come out of budgets later on. This was viewed as a factor in obtaining quick acceptance by the department chairs and in reducing resistance to later DSS revision sessions.
- **Identifying similarities of decisions at the program level of decision making makes the transition to the department level an easy step:** It turns out that information identified for decision making for individual educational programs is similar to decision making information needed at the department level. This observation aids the rapid modeling of different department variations in the DSS, and eventually allows for one final system to cover all issues raised by a study.

Table 2. Elementary education scenario 2

Problem: Model new program. Lower number of graduate students allowed in the program to 48 doctoral and 84 masters/specialist students. Preserve tenure. Require minimum of 60% of UG classes taught by Fellows and Members. Require maximum of 10% of UG classes to be taught by outside instructors.

Goal	Priority (P_i)	Target goal level (b_i)	Positive deviation (d_i^+)	Negative deviation (d_i^-)
Teach credit hours of undergraduate courses	1	246	0	0
Minimum 60% taught by GF and GM	2	147.6	0	0
Maximum 10% taught by outside instructors	2	24.6	0	0
Student teacher supervision	1	80	0	0
Teach credit hours of graduate courses	3	35	21.6	0
Advise doctoral students	5	48	6	0
Advise masters students	5	84	85.8	0
Employ number of Graduate Fellows	3	6.75	0	0
Employ number of Graduate Members	4	2	5.4	0
Employ number of instructors	6	1.50	1.267	0
Employ number of GTAs	6	4	0	0
Minimize cost	6	0	$682,439	0
Employ outside instructors		0	24.6	0
Employ outside student teacher supervisors		0	17.2	0
Solution (x_j)				
Graduate Fellows	6.75			
Graduate Members	7.4			
Instructors	2.767			
GTAs	4			
Outside instructors	24.6			
Outside student teacher supervisors	17.2			
Resulting resource allocation				
Cost	$682,439			

This is a very important finding. The analyst observed the transition from the department level to the university-wide system (the next step in the DSS process) was similar for departments in other colleges.

The DSS generated information represents a substantial improvement that optimizes the available resources as opposed to the current paper-and-pencil approach to planning or a trial-and-error approach. The DSS allows the department chairs to explore alternative priority structures and resource allocations quickly. It was observed in this study that once oriented to the possible advantages, the department chairs were eager to work on the project. Specific advantages of the DSS commonly used as benchmark criteria in evaluations of DSS include those suggested by Haag et al. (2008):

- **Sensitivity analysis** to explore the impact of minor shifts in available resources or personnel as a quick method to adjust to last minute changes in budgets or personnel leaves of absence. As suggested in the Hu et al. (2006) study of DSS image research, the comparative addition of information to support a decision can be a critical factor for successful outcomes.
- **What-if analysis** to explore changes in faculty assignments where faculty would opt to cover classes on an overload basis (i.e., for extra pay) and how it would impact both the coverage of classes and an existing solution. As suggested by Hung et al. (2007), this DSS advantage provided department chairs in this study a means for avoiding alternative assignments that might prove less desirable.
- **Goal-seeking analysis** to explore opportunities in altering resources to more fully achieve (i.e., reduce eviation) a particular goal in the model. Fundamental to the use of GP models in faculty assignment problems (Schniederjans and Kim (1987)), altering goal levels permits unique possible solutions to fit challenging situations faced by department chairs.

The limitations of the system to be expanded into further areas of department decision making became apparent when the analyst inquired as to how the DSS might be further improved for purposes of expansion university-wide and for the Teachers College in particular. During the study, there were many discussions on how other workload activities (i.e., scholarly activity and service) could be incorporated into the model, but no consensus was reached. To explore this issue, a review of the literature revealed a survey by Astin et al. (1991) including over 35,000 faculty at 392 colleges and universities, which reported 62 percent of the professors surveyed spent twelve hours or less per week on teaching. If activities are to be included in the goal programming models, they must be quantified. Percentage of time or days of research seems inadequate to express the nature of faculty activities. The model also requires some measurement of output, but it is difficult to define output of scholarly activity in solely quantitative terms. The same applies to service. Days of in-services, number of contacts made, or number of committee assignments do not begin to describe the impact a faculty member can have on improving the classroom environment in schools. Whether these parameters can or should be incorporated into a goal programming DSS system is not the focus of this prototype study and is left to the next phase in the development of this system.

Development and use of DSS in this study has outcomes with unintended consequences and raises a number of questions on seemingly non-related topics. Working with the model provides a picture in time of what the program looked like and what the questions might have been on an issue (e.g., doctoral advising loads recommended by the college study on doctoral programs). The department chairs talked about the "quality of experience" offered to students, the use of graduate students in instructional programs, the difference between students in residence and students from off campus, and the new doctoral mentoring seminars that were being implemented. Work with the model did not specifically address these matters, but work with the model made department chairs aware of these issues. The assumption of instructional workloads drove the model, but the loads provided by the department chairs were admittedly estimates and fluctuate each semester depending on the mix of other faculty activities. This represents a substantial expansion of the role of the proposed DSS and a possible subject for future research.

Finally, prototyping of the DSS resulted in an awareness of its possibilities to optimize a larger portion of the quantifiable variables that department chairs face in routine decision making, thereby helping them identify less-quantifiable variables, which require more personal attention and judgment. As time goes on, some or all of the less-quantifiable variables may find their way into the development of a DSS as it supports future decision making needs. This we believe is exactly what quantitative-based, multi-criteria DSS can and should accomplish.

REFERENCES

1. Aloysius, J., Davis, F., Wilson, D., and Kottemann, J. (2006). User acceptance of multi-criteria decision support sytems: The impact of preference elicitation techniques. *European Journal of Operational Research*, 169(1): 271-285.
2. Astin, S.L., Korn, W.S., and Dey, E.L. (1991). The American College Teacher: National Norms for the 1989-1990 HERI Faculty Survey. University of California Higher Education Research Institute, Los Angeles, CA.
3. Bana e Costa, C., Ensslin, L., Correa, E., and Vansnick, J.C. (1999). Decision support systems in action: Integrated application in a multicriteria decision aid process. *European Journal of Operational Research*, 113(2): 315-335.
4. Charnes, A. and Cooper, W.W. (1961). *Management Models and Industrial Applications of Linear Programming, Vols. 1 & 2*, Wiley, New York, NY.
5. Franz, L.S., Lee, S.M., and Van Horn, J.C. (1981). An adaptive decision support system for academic resource planning. *Decision Sciences*, 12(3): 276-293.
6. Haag, S., Baltzan, P., and Phillips, A. (2008). *Business Driven Technology*, 7th ed., McGraw-Hill/Irwin, Boston, MA.
7. Hung, S.Y., Ku, Y.C., Liang, T.P., and Lee, C.J. (2007). Regret avoidance as a measure of DSS success: An exploratory study. *Decision Support Systems*, 42(4): 2093-2106.
8. Hu, P.J.H., Wei, C.P., and Liu Sheng, O.R. (2006). Evaluating a decision support system for patient image pre-fetching: An experimental study. *Decision Support Systems*, 42(3): 1730-1746.
9. Ignizio, J.P. (1982). *Linear Programming in Single & Multiple Objective Systems*, Prentice Hall, Englewood Cliffs, NJ.
10. Laudon, K.C. and Laudon, J.P. (2006). *Management Information Systems*, 9th ed., Pearson/Prentice Hall, Upper Saddle River, NJ.
11. Lee, S.M. (1996). *AB:QM Software System*, Allyn & Bacon, Boston, MA.
12. Lee, S.M. (1972). *Goal Programming for Decision Analysis*, Auerbach, Philadelphia, PA.
13. Lee, S.M. and Clayton, E.R. (1972). A goal programming model for academic resource allocation. *Management Science*, 14(8): B395-B408.
14. Lee, S.M. and Van Horn, J.C. (1983). *Academic Administration: Planning, Budgeting, and Decision Making with Multiple Objectives*, University of Nebraska Press, Lincoln, NE.
15. Liu, C.M., Chang, T.C., and Huang, L.F. (2006). Multi-objective heuristics for the vehicle routing problem. *International Journal of Operations Research*, 3(3): 173-181.
16. Mallach, E.G. (1994). *Understanding Decision Support Systems and Expert Systems*, Irwin, Boston, MA.
17. Marakas, G.M. (1999). *Decision Support Systems in the Twenty-First Century*, Prentice Hall, Upper Saddle River, NJ.
18. Romero, C. (1991). *Handbook of Critical Issues in Goal Programming*, Pergamon Press, Oxford.
19. Schniederjans, M.J. (1995). *Goal Programming Methodology and Applications*, Kluwer Academic, Boston, MA.
20. Schniederjans, M.J. and Carpenter, D.A. (1996). A heuristic job scheduling decision support system: A case study. *Decision Support Systems*, 18: 159-166.
21. Schniederjans, M.J. and Kim, G.Y. (1987). A goal programming model to optimize departmental preferences in course assignments. *Computers & Operations Research*, 14(2): 87-96.
22. Turban, E., Aronson, J.E., and Liang, T.P. (2004). *Decision Support Systems and Intelligent Systems*, 7th ed., Prentice Hall, Upper Saddle River, NJ.
23. Wu, J.H., Doong, H.S., Lee, C.C., Hsia, T.C., and Liang, T.P. (2004). A methodology for designing form-based decision support systems. *Decision Support Systems*, 36: 313-335.

24. Xu, Z. (2006). Minimizing deviations models for solving MADM problems with preference information on alternatives in uncertain linguistic setting. *International Journal of Operations Research*, 3(1): 30-35.

APPENDIX A: DSS GOAL PROGRAMMING MODEL DEVELOPMENT

The variables or basic output information for the department chairs used in the GP model:

x_1 = number of Graduate Faculty Fellows (GF) (Research qualified)
x_2 = number of Graduate Faculty Members (GM) (Not research qualified)
x_3 = number of Instructors (Instr)
x_4 = number of Graduate Teaching Assistants (GTA)
x_5 = number of outside instructional staff units (OIS)
x_6 = number of outside student teacher supervisors units (OTS)

This model assumes the allocation of personnel can be proportioned (i.e., real decision variable value solutions) to permit less-than full-time faculty assignments. These proportioned assignments were necessary to meet contractual requirements with faculty and satisfy budget limitations. In models where full-time assignments are necessary, an integer solution methodology could be employed in the DSS.

Constants or basic information input from the chair in the GP model:

a_1 = number of GFs budgeted
a_2 = number of GMs budgeted
a_3 = number of Instr budgeted
a_4 = number of GTAs budgeted
b_1 = number of GFs with tenure
b_2 = number of GMs with tenure
c_{11} to c_{1j} = estimated number of undergraduate sections taught of each type of undergraduate course where j is the number of distinct types of experiences (e.g., traditional courses, field experiences, student teacher internships)
c_{21} to c_{2j} = estimated number of graduate sections taught of each type of graduate course where j is the number of distinct types of experiences (e.g., traditional courses, supervised practica)
c_3 = number of student teachers to be supervised
c_4 = number of undergraduate students enrolled
c_5 = number of graduate students enrolled in masters programs
c_6 = number of graduate students enrolled in specialist programs
c_7 = number of graduate students enrolled in doctoral programs
c_8 = desired average class size for undergraduate classes
c_9 = desired average class size for graduate classes
e_1 = average salary for GF
e_2 = average salary for GM
e_3 = average salary for Instr
e_4 = average salary for GTA
e_5 = average cost/unit of outside instruction
e_6 = average cost/unit of outside student teacher supervision

Both instructional loads and courses are described in terms of maximum credit hours:

Faculty	Undergrad courses	Graduate courses	Field experience	Student teachers
Graduate fellow (GF)	s_{11}	s_{12}	s_{13}	s_{14}
Graduate member (GM)	s_{21}	s_{22}	s_{23}	s_{24}
Instructor (Instr)	s_{31}		s_{33}	s_{34}
Graduate teach assistant (GTA)	s_{41}		s_{43}	s_{44}
Outside instruction (OIS)	s_{51}		s_{53}	s_{54}
Outside student teacher supv. (OTS)				s_{64}

Examples of the goals described by the departmental department chairs (i.e., each chair would prioritize individually) for the UNL Teachers College program were grouped into six generalized constraint categories given below:

1. **Undergraduate instruction goal.** A primary goal of the department is to ensure that there is adequate instructional staff to teach the number of undergraduate courses needed for its programs. Constraints were developed to describe each type of undergraduate course offering: sections of lecture courses, field experiences, and student teacher supervision. The equations were based on the number of instructional staff in each category, the instructional workload for each type of course for each category of instructional staff, and the number of sections taught based on Schniederjans and Kim (1987). The generalized equation for each category of undergraduate instruction:

$$\sum s_{ij} x_i + d_j^- - d_j^+ = c_{ij} \quad \text{(A-1)}$$

for all *i*, *j* where *j* represents a type of undergraduate offering.

2. **Graduate instruction goal.** Similarly, the department required adequate staff to offer its graduate program for each category of graduate instruction based on Franz et al. (1981) and Lee and Clayton (1972):

$$\sum s_{ij}x_i + d_j^- - d_j^+ = c_{2j} \quad \text{(A-2)}$$

for all *i*, *j* where j represents a type of graduate offering.

3. **Preservation of tenure goal.** To ensure the model preserves tenure, select constraints utilized only GF or GM. The generalized equations for each category are based on Schniederjans and Kim (1987) and Lee and Van Horn (1983):

$$x_1 + d_j^- - d_j^+ = b_1 \quad \text{(A-3)}$$

$$x_2 + d_j^- - d_j^+ = b_2 \quad \text{(A-4)}$$

4. **Preservation of budgeted line goal.** To provide a comparison baseline for any changes under alternative programs to the total instructional cost, the model minimized the deviations from the number of budgeted lines, for each category of faculty budgeted based on Lee and Clayton (1972) and Schniederjans and Kim (1987):

$$x_1 + d_j^- - d_j^+ = a_1 \quad \text{(A-5)}$$

$$x_2 + d_j^- - d_j^+ = a_2 \quad \text{(A-6)}$$

$$x_3 + d_j^- - d_j^+ = a_3 \quad \text{(A-7)}$$

$$x_4 + d_j^- - d_j^+ = a_4 \quad \text{(A-8)}$$

5. **Temporary instructional staff goal.** Constraints were used to allow for the addition of outside instructors and student teacher supervisors to supplement existing lines. The program employed temporary instructional staff on a per-course or per-student teacher basis based in part on Schniederjans and Kim (1987).

$$x_5 + d_j^- - d_j^+ = 0 \quad \text{(A-9)}$$

$$x_6 + d_j^- - d_j^+ = 0 \quad \text{(A-10)}$$

6. **Instructional cost goal.** To minimize total instructional cost, a generalized equation was included for the total instructional budget, similar to those in Franz et al. (1981) and Lee and Clayton (1972)

$$\sum e_j x_i + d_j^- - d_j^+ = 0, \text{ for all } i. \quad \text{(A-11)}$$