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A Value Focused Thinking Approach to Academic Course Scheduling

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AFIT/GOR/ENS/98M-14

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THESIS

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A Value Focused Thinking Approach to Academic Course Scheduling

THESIS

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Shane A. Knighton

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ABSTRACT

In 1997, the School of Engineering of the United States Air Force Institute of Technology began exploring ways of automating the academic course scheduling process. The administration desired an expedient approach for course scheduling which supports the institute's mission of "providing scientific and technological education" to officers from all branches of military service, as well as international military forces. The scheduling approach needed to be flexible, efficient, and represent the institute's values and principles. Decision Analysis (DA) and specifically, Value Focused Thinking (VFT), is used to decompose the complex problem of academic course scheduling and determine the factors that are important in a schedule. An MS Excel based Decision Support System generates a Mixed Integer Program (MIP). The MIP formulation combines the institute's goals with facility constraints, faculty preferences, student preferences, and administration guidance to develop an academic course schedule representative of the institute's values.

CHAPTER 1

The research documented in this thesis is in response to the Office of Academic Operations of the School of Engineering of the Air Force Institute of Technology's request for support. The staff of the Office of Academic Operations is responsible for scheduling the courses offered by the School of Engineering on a quarterly basis. In an effort to reduce the amount of time required to produce a schedule, an efficient approach to academic course scheduling was sought. Decision Analysis and Value Focused Thinking (VFT) were used to decompose the course scheduling problem and determine the important issues inherent in a quality schedule.

Our goal is to provide the Office of Academic Operations with a tool that will efficiently solve the academic course scheduling problem for the School of Engineering and reduce the time and effort expended by the staff in the production of a schedule. We have done this through the development of an Educational Decision Support Scheduling System (EDSSS). EDSSS combines an MS Excel based spreadsheet and suite of Visual Basic Modules, with the IBM Mixed Integer Solver named Optimization Subroutine Library (OSL).

The remainder of this thesis explains the theoretical background and methodology used in the development of EDSSS. Textual copies of the Visual Basic Modules and a user manual are included. This thesis is organized so that Chapter 2 is a stand-alone article on our research, suitable for submission to an academic journal. Chapter 3 outlines some obvious extensions to this work.

Appendix A contains the completed schedule for the 1998 Spring Quarter for the School of Engineering of AFIT. Appendix B provides the Visual Basic source code for

the electronic questionnaire used in EDSSS, while Appendix C gives the Visual Basic source code for the modules used by the mixed integer problem generator portion of EDSSS. Appendices D through G show the results for each of the four scheduling variations obtained from IBM's mixed integer solver, Optimization Subroutine Library (OSL). Appendix H provides a user manual for EDSSS. Finally, Appendix I and J contain the Preference Table and Ed Plan Query used by EDSSS in the development of the Spring Quarter 98 schedule.

CHAPTER 2

INTRODUCTION

The School of Engineering (EN) of the United States Air Force Institute of Technology (AFIT), located on Wright-Patterson Air Force Base, Ohio, provides ABET accredited post-graduate education to officers in the U.S. Air Force, along with officers from other branches of service and international military forces. The school of engineering has an enrollment of approximately 350 students, and is comparable in size to a small civilian college or secondary school. AFIT's School of Engineering is divided into six departments, each under the direction of a Department Head. The six departments include Aeronautics and Astronautics (ENY), Electrical and Computer Engineering (ENG), Engineering and Environmental Management (ENV), Mathematics and Statistics (ENC), Operational Sciences (ENS), and Engineering Physics (ENP).

Academic course scheduling at the School of Engineering of the United States Air Force Institute of Technology is largely a manual process. The institute's six departments propose days and times for the courses to be offered by that department in the upcoming academic quarter. Students create Education Plans specifying enrollment in courses for the upcoming quarter. The office of Academic Operations gathers the departmental proposals and is challenged with combining the offered times and student education plans into a working course schedule. A working schedule assigns courses to days, times, and rooms. The schedule must comply with all administrative policy as well as facility constraints. The staff of the office of Academic Operations performs this task by hand, with a working schedule often requiring multiple revisions and over 65 person-hours.

This paper documents a new approach to academic course scheduling for the School of Engineering of AFIT. The objectives of the research are: (1) to quantify the factors and issues important to EN in a course schedule, (2) to find metrics that can measure how well a schedule addresses the important factors, (3) to create a Decision Support System that will aid the offices of Academic Operations in scheduling future quarters, and (4) to develop a efficient means of solving the academic course scheduling problem for the School of Engineering.

The remainder of this paper is organized in the following manner. The survey of academic course scheduling literature is presented followed by the theoretical background for the Value Focused Thinking (VFT) approach used to decompose and quantify the complex issues. A Mixed Integer Programming (MIP) is developed whose objective maximizes the institute's values and whose implementation efficiently solves the academic course scheduling problem at AFIT. Finally, the results of this research are presented.

SURVEY OF LITERATURE

Academic course scheduling is generally broken into two main tracts in the literature: (1) faculty to course assignments and (2) the assignment of courses to days, times, and rooms, herein referred to as course timetabling. This research deals only with the latter area, as each course at the School of Engineering for AFIT has been assigned to a faculty member, by departmental process, prior to scheduling.

Mixed Integer Programming Approach

Many examinations of the course timetabling problem in the literature present a Mixed Integer Problem (MIP) formulation. Mulvey (1982) presents the following MIP using binary variables, denoted as problem P1.

Problem P1: Mulvey's MIP Formulation

Maximize $$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \qquad (1)$$

Subject To $$\sum_{j=1}^{n} x_{ij} = 1 \qquad \text{all } i, \qquad (2)$$

$$\sum_{i=1}^{m} k_i x_{ij} \le f_j \qquad \text{all } j, \qquad (3)$$

$$\sum_{i \in I_p}\sum_{j \in S_t} x_{ij} \le 1 \qquad \text{all } p,t, \qquad (4)$$

$$\sum_{i \in I_r}\sum_{j \in S_t} x_{ij} \le 1 \qquad \text{all } r,t, \qquad (5)$$

$$x_{ij} = \{0,1\} \qquad (6)$$

where i is defined as a course, and j as a classroom/day/time combination. The binary variable x_{ij} is 1 if course i is taught during the classroom/day/time combination j and 0 otherwise. I_p is an indexed set defining which classes are taught by faculty member p, while I_r defines which classes are assigned to student r. Finally, S_t is the set of classroom/day/time combinations that occur simultaneously and c_{ij} is a cost coefficient realized when course i is assigned to classroom/day/time combination j. The first constraint, equation (2), ensures that each class is assigned to only one classroom/day/time combination. Equation (3) requires adequate capacity of the

classrooms, while (4) and (5) preclude instructors and students from being assigned to two activities at one time (Mulvey: 1989).

Mulvey classifies this MIP formulation as a "well-defined model", meaning the solution can theoretically be found using a standard MIP solution technique, such as branch and bound. However, the large number of binary variables required to implement the MIP formulation led Mulvey (1989) to state that "a realistic size [academic course scheduling] problem cannot be solved within a reasonable length of processing time." For example, consider a timetabling problem in which there are 100 courses to schedule in 10 classrooms. We will restrict the problem further by requiring each course to be started on the hour between 0800 and 1700, thus allowing only 45 time slots per week. This relatively small timetabling problem's formulation would require, 100*10*45 or 45,000 binary variables, rendering the problem computationally intractable by most existing MIP solvers.

Sampson, Weiss, and Freeland (1995) propose a similar MIP formulation to solve the course timetabling problem. As with the Mulvey formulation, the MIP was abandoned "because of the combinatoric nature of the problem" (Sampson, Freeland and Weise: 1995). Mulvey (1989) eventually proposed a relaxation of the MIP and a "man-machine interaction" approach to finding a solution. Man-machine interaction requires user input as the solver executes. Sampson and Weiss (1995), Ferland and Fleurent (1994), and Bloomfield and McSharry (1979) propose heuristic techniques as well as man-machine interaction to solve the course timetabling problem and develop a working schedule for academic courses.

Alvarez-Valdez, Martin, and Tamarit (1996) developed a tabu search heuristic to solve a timetabling problem for Spanish secondary schools. Costa (1994) also proposes a tabu search approach to course scheduling. In both implementations, a traditional MIP formulation of the academic course scheduling problem is solved to near optimality. Great improvements in CPU time are realized by a tabu search over a Mixed Integer Solver.

Cost Coefficients

Although the overriding theme of the academic course scheduling literature proposes heuristic or iterative approaches, the definition of the c_{ij}, (cost coefficients) differ. Mulvey proposes a metric, such as the number of occupied seats, be used to determine a cost associated with scheduling course *i* in classroom/day/time combination *j* (1982).

Bloomfield and McSherry determine the cost coefficients using instructor preferences (1979). Each instructor is given a choice of either a Monday, Wednesday, and Friday schedule or a Tuesday and Thursday schedule. Additionally, instructors can pick either AM or PM time of day and a type of classroom. As with most of the models, classrooms are grouped by type, e.g. those classrooms having similar capacities, equipment, and so forth. Each instructor provides a preferred choice for a day, time, and room and a ranking of the choices. The heuristic, proposed by Bloomfield and McSherry (1979), tries to satisfy as many preferences as possible. The heuristic initially schedules a day to each instructor who ranked "day" the highest, a time to each instructor who chose "time" as the highest and a location to each instructor who preferred "room type". The heuristic continues to iterate until a working schedule is found.

Sampson, Freeland and Weiss (1995) also use faculty preferences to determine the cost coefficients. Additionally, they incorporated the students' request to enroll in specific classes. Their model uses a "modified-local search heuristic" to develop a timetable. Furthermore, an enrollment-construction heuristic was used to maximize the number of students who are able to attend the courses they desired. This iterative approach is used to find a schedule that works within faculty preferences and constraints, while attempting to maximize the number of courses available to interested students (Sampson, Freeland and Weiss, 1995).

Graves, Schrage and Sankaran (1993) implement an auction method to incorporate student preferences. Students are allowed to pick from an already establish timetable. Each student is given a place in a queue. The number of preferences satisfied during the previous quarter's schedule primarily determines this placement. For subsequent class registration an inverse order of scheduling permitted students a priority advantage based upon the number of previously scheduled preferences. In other words, positioning in the queue is relative to the extent to which preferences were accommodated by previous schedules.

VFT THEORETICAL MODEL

Although the formulation of the MIP is straight forward, the number of binary variables associated with a course timetabling problem require a computationally intractable amount of time for solution. The goal to produce a course schedule is a difficult, complex problem. Decision analysis, a branch of operations research, "provides

structure and guidance for thinking systematically about hard decisions" (Clemens, 1996).

Decision analysis requires the involvement of a decision maker, presumably the Dean of the institution, for the academic course scheduling problem. The decision maker's values are the key elements in the process. According to Clemens, the decision analysis process can be broken down into key elements or steps. As these steps are followed, a clearer understanding and solution to the problem may be available. This process decomposes the problem to make it simpler. Clemens points out that "decomposition is the key to decision analysis" (Clemens, 1996). The following flow chart from Clemens illustrates the decision analysis process.

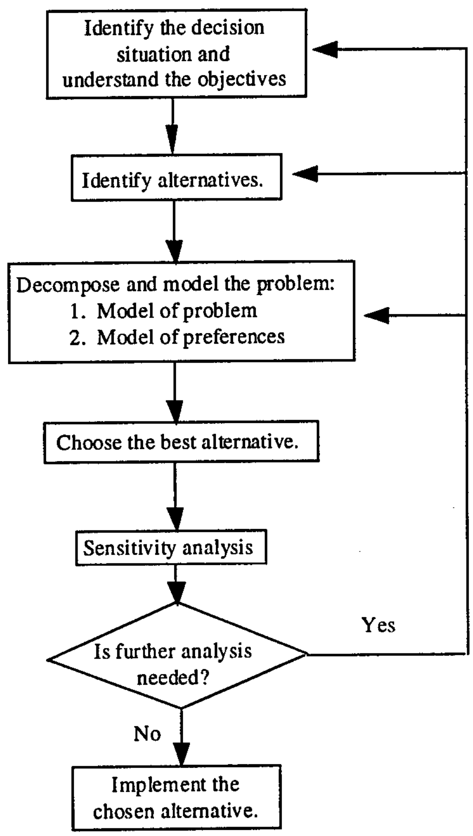


Figure 1: Decision Analysis Process Flowchart (Clemens, 1996)

Note the process is iterative. The desired result may always be improved, through continual refinement of the decision situation, the addition of new alternatives, or refined insight and further decomposition.

To ascertain a precise understanding, the decision situation must be well defined and the objectives clearly outlined, prior to decomposing the problem. There are two prevailing thoughts with regard to this effort. Keeney (1992) identifies the first approach as "alternative-focused thinking". This approach concentrates on developing potential solutions to the problem, known as alternatives, and using the differences in the alternatives for evaluation. A comparison of two or more working schedules created manually by staff of the office of Academic Operation would be an example of this approach. Keeney (1992) does not favor this approach, claiming it is backwards; "it puts the cart of identifying alternatives before the horse of articulating values".

Value Focused Thinking

Conversely, Keeney (1992) concentrates on an approach he calls "value-focused thinking". Contrary to "alternative-focused thinking", this approach concentrates on soliciting from the decision maker and others who are knowledgeable about the problem, a set of values or goals, which address what is important in the decision situation. Having identified these goals, they are structured into general and specific objectives, that if achieved will realize the established goals. These objectives are then organized into a value hierarchy. A value hierarchy structures these objectives such that the upper level values are more general and have a greater impact on the overall value of the hierarchy, while lower level values further describe the upper levels. The most specific values are then given evaluation measures or metrics that show how well an alternative has met that

value. Furthermore, each level of the value hierarchy can be weighted based on the decision maker's preference for obtaining that value over other values at the level. Below is an example of a value hierarchy with weights.

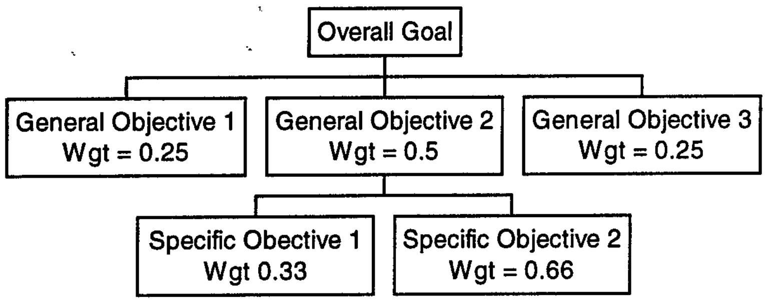


Figure 2: Value Hierarchy Example

The value hierarchy can be used to inspire the creation of new alternatives that had not been previously considered. According to Kirkwood (1997), "When you know what you are trying to accomplish, then you can attempt to identify alternatives that address these objectives". Furthermore, the value hierarchy provides a means for evaluating various alternatives. The use of the evaluation measures, associated with the most specific values, provide "formal methods... [using] a mathematical function to combine evaluation measures from the hierarchy" that can be used to rank alternatives and determine the best solution to a difficult problem (Kirkwood, 43:1997).

Multiple Objective Value Analysis

Once a value hierarchy has been established, evaluation measures or metrics are used to capture an alternative's worth with regards to a specific objective. Evaluation measures are attributes that provide an objective evaluation of performance. Single

dimensional value functions translate the metric performance into a unitless quantity known as value. Single dimensional value functions are either monotonically increasing or decreasing (Kirkwood, 1997).

Weights are determined for each evaluation measure. The weights are used to show "different degrees of importance attached" to the performance of an alternative with regards to a specific evaluation measure. That is, if evaluation measure (1) is weighted more heavily than evaluation measure (2), "variations over the range for [evaluation measure (1)] are more important than variations over the range for [evaluation measure (2)] when using this set of weights" (Kirkwood, 1997).

Once the weights and single dimensional value functions are established, the final value or overall value of each level of the value hierarchy becomes

$$v(X_1, X_2, \ldots, X_n) = w_1 v_1(X_1) + w_2 v_2(X_2) + \ldots + w_n v_n(X_n) \tag{7}$$

where $v_i(X_i)$ is the value determined using the single dimensional value functions associated with evaluation measure or attribute X_i and w_i is the weight given to that evaluation measure (Kirkwood, 1997). This assessment of value is called an additive value function.

Kirkwood (1997) states that the attributes, X_i, of an additive value function must have mutual preferential independence. Mutual preferential independence exists if Y is preferentially independent of Z, where Y and Z are a partition of $\{X_1, X_2, \ldots, X_n\}$. Kirkwood (1997) shows that "Y is preferentially independent of Z if the rank ordering of alternatives that have common levels for all attributes in Z does not depend on these common levels." These assumptions will later be shown to hold for this research.

METHODOLOGY

Academic Course Scheduling can be decomposed into a series of separate decisions. A decision is made whether to schedule course *i* on day/time *j* and in room *r* or not. A schedule is created once a decision is made for each course *i*. Obviously, there exist myriad different combinations of decisions that all create a schedule. Therefore, an additional decision chooses the "best" schedule from the set of possible schedules. The methodology herein uses this view of the academic course scheduling problem. The decision maker, for this research was the Dean of the School of Engineering; his decision was supported by his staff, and the Department Heads.

Influence Diagram

The effort began with the creation of an influence diagram. An influence diagram is a visualization tool that allows a decision maker to annotate the decision to be made and the important factors that influence the value of the result of the decision. The influence diagram for the course scheduling problem at AFIT is shown in Figure 3. Directives from the Dean of the School of Engineering, as well as department, faculty and student preferences are factors that influence the value of the decision to schedule course *i* on day/time *j* in room *r*. The outcome of the individual course scheduling decisions as well as room capacities, room availability, instructor conflicts and student conflicts effect the value of the overall schedule. The influence diagram as a whole defines the decision situation.

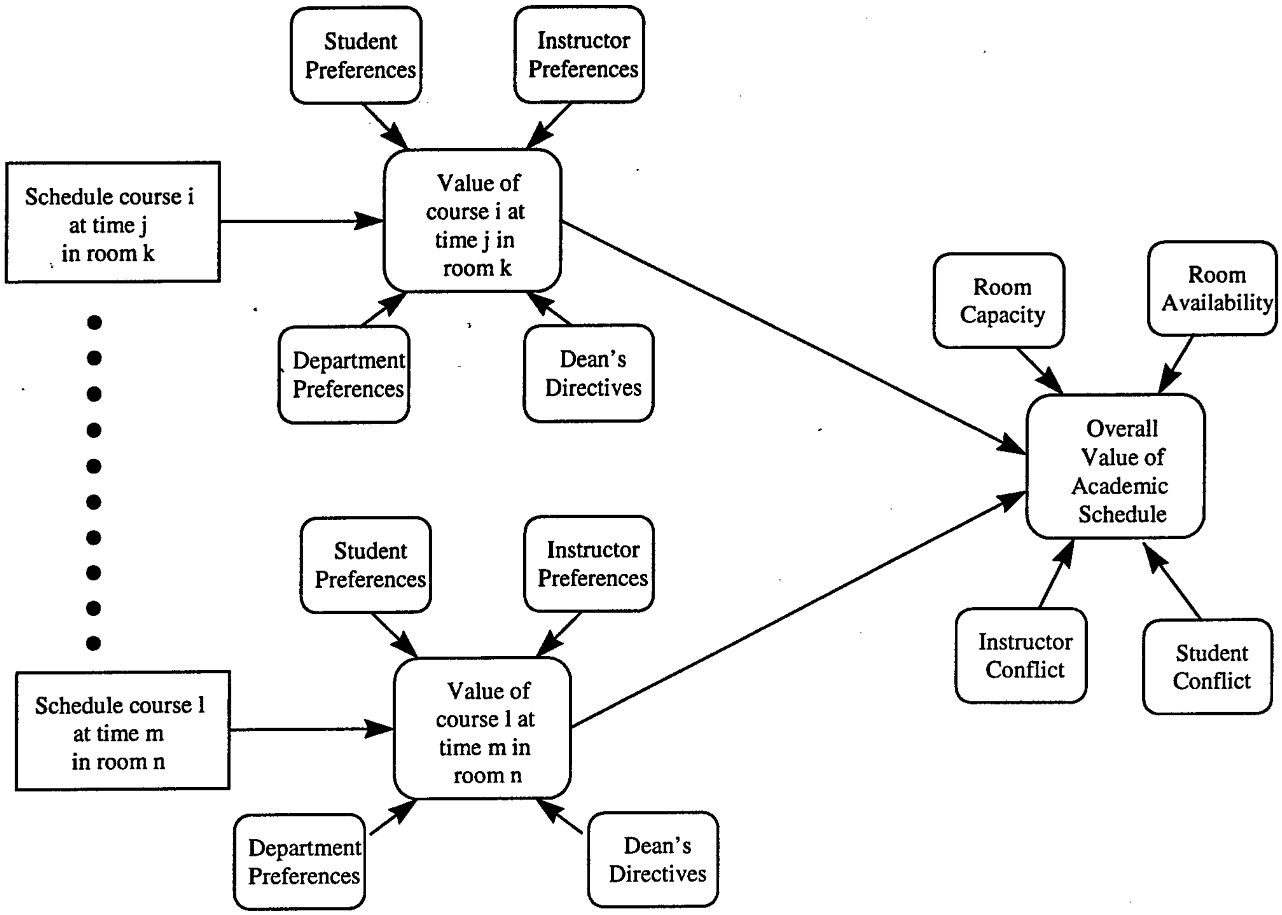


Figure 3: Influence Diagram

Rectangles represent decisions, while rounded boxes represent values. The arrows show a direct influence imparted by a decision or value.

Value Hierarchy

The influence diagram aids in the creation of the value hierarchy. A value hierarchy is developed by working closely with the decision maker to decompose his decision into the factors that influence the decision situation. These are placed within the levels of the hierarchy. The value hierarchy must be mutually exclusive and collectively

exhaustive. Figure 4 shows the value hierarchy for the decision situation illustrated by the influence diagram in Figure 3.

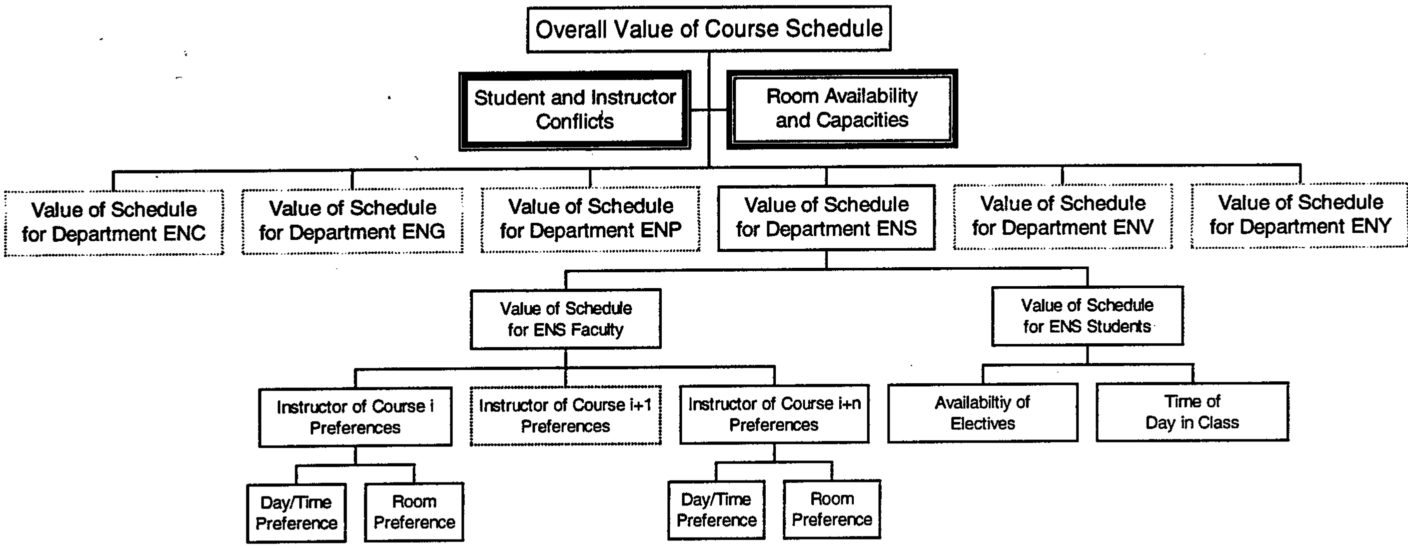


Figure 4: Value Hierarchy

The value hierarchy has five distinct levels and two go/no-go criteria. The go/no-go criteria are shown in bold outline and are defined later. The value of the schedule for each department has the most influence on the overall value of the schedule. The decision maker, through weighing of the values at this level, determines the contribution of each department's value towards the overall value. In a similar fashion, the contribution of the values from lower levels on upper levels is dictated by weighting. The weights of any level of the hierarchy must be a convex combination. Therefore, the following equations govern the weights used in the calculation of value.

$$\sum_{D=1}^{6} w_D = 1 \tag{8}$$

$$w_{f_D} + w_{s_D} = 1 \quad \text{for all } D \tag{9}$$

$$\sum_{i_D} w_{i_D} = 1 \quad \text{for all } D \tag{10}$$

$$w_{j_{i_D}} + w_{r_{i_D}} = 1 \quad \text{for all } i_D \tag{11}$$

where w_D is the weight of each department, w_{fD} is the weight of the faculty preferences in department D and w_{sD} is the weight of the students in department D. w_{iD} is defined as the weight of each course in department D, w_{jiD} is the weight of day/time preference j for course i_D and, w_{riD} is the weight of room preference r for course i_D. The Dean assigns the departmental weighting, while the respective Department Heads assign the faculty and course weightings. Instructors assign day/time scenario and room group weights.

For the purposes of this research for AFIT, the weight of the student's values, w_{sD}, for each department was set to zero, making w_{fD} equal to1. This was done for two reasons: (1) the value of the availability of electives is covered by the go/no-go criteria of a deconflicted schedule, and (2) as active duty military officers attending course is considered a student's primary duty and additional duties that may make a day/time scenario unattractive are kept to a minimum. Of course, student weighting can be utilized in a different operational setting.

The following value function describes the contribution of day/time preference j of course i on the overall value of the schedule.

$$V_{i_D j} = w_D \cdot w_{f_D} \cdot w_{i_D} \cdot w_{j_{i_D}} \cdot v_{j_{i_D}} \tag{12}$$

where V_{iDj} is the contribution to the overall value and v_{jiD} is the value of scheduling course i in day/time j. In a similar manner, equation (13) describes the contribution of room preference r of course i.

$$V_{i_D r} = w_D \cdot w_{f_D} \cdot w_{i_D} \cdot w_{r_{i_D}} \cdot v_{r_{i_D}} \quad (13)$$

where V_{iDr} is the contribution to the overall value and v_{riD} is the value of scheduling course i in room r.

The value of v_{jiD} and v_{riD} is determined using a single dimensional value function. The single dimensional value function is a monotonically decreasing step function that transforms preference numbers into a unitless property known as value. Figure 5 shows the value function used to determine the value of both the instructors' day/time and room preferences. This value function is used for all courses scheduled. The department heads unanimously agreed to the slope and shape of the function.

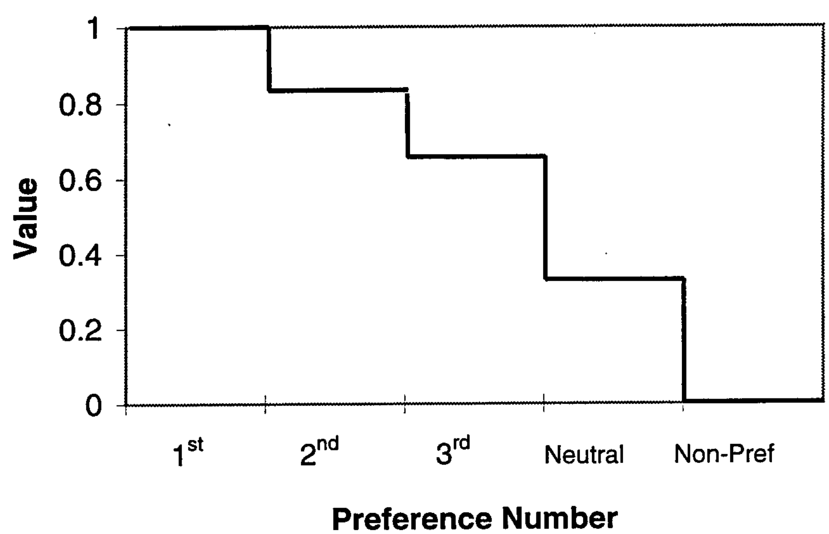


Figure 5: Single Dimensional Value Function

Therefore, course i's total contribution on the overall value, V_{iD}, is found by combining equations (12) and (13).

$$V_{i_D} = V_{i_D j} + V_{i_D r} = w_D \cdot w_{f_D} \cdot w_{i_D} \left(w_{j_{i_D}} \cdot v_{j_{i_D}} + w_{r_{i_D}} \cdot v_{r_{i_D}} \right) \tag{14}$$

Finally, summing the value of all courses and multiplying the quantity by the binary go/no-go variables, C_s and R_s, determines the overall value, V_s, of schedule s. The binary variable C_s is 1 if no student or instructor is assigned to attend any two courses at simultaneous days and times and 0 otherwise. The individual's education plan specifies the courses for which the student is enrolled. This go/no-go criteria is essential to a academic course schedule because of the 18 month window in which all students assigned to AFIT must take *all* required courses for graduation and *all* electives that directly support their research. The binary variable R_s is 1 if: (1) all courses assigned to a room group do not have an enrollment that exceed the capacity of the rooms in that group and, (2) the number of courses scheduled at any time does not exceed the number of rooms available. R_s is equal to 0 if either of the above condition is not met.

$$V_s = C_s \cdot R_s \left(\sum_{i_D} V_{i_D} \right) \tag{15}$$

Clearly the most valuable schedule can be found by comparing the overall value, V_s, of every possible schedule. A Mixed Integer Program is used to make these comparisons and determine the most valuable schedule.

Mixed Integer Program

The formulation of the Mixed Integer Program (MIP) requires the definition of a binary variable x_{ijk}, where i is a three-digit course index number, j is a three-digit day/time scenario index and k is a room group index number. A course index number is assigned to each course to be scheduled. A day/time scenario consists of a set of days per week on which a course is taught combined with a time on each day, herein referenced as scenarios.

The scenarios used in this research require identical time periods be used on each day of the week. Additionally, the time periods are of equivalent length equal to 1 hour. These requirements are not essential for the formulation, but reduce the number of possible scenarios and are representative of standard academic course schedule. In general, a course that meets from 0800 – 0900 on Monday will meet during the same hours on subsequent days of the week. Table 1 shows the scenarios, by number of hours per week a course meets and an index number assigned to each scenario. When a time range is given, the scenarios are numbered in increasing order as the start hour increases throughout the days of the week.

Table 1: Day/Time Scenarios

	Days of the Week	Start Times (on the hour)	Scenario ID #
1 Hour Class	M	0800 -1600	001 - 009
	T	0800 -1600	010 - 018
	W	0800 -1600	019 - 027
	R	0800 -1600	028 - 036
	F	0800 -1600	037 - 045
2 Hour Class	M	0800 -1500	046 - 053
	T	0800 -1500	054 - 061
	W	0800 -1500	062 - 069
	R	0800 -1500	070 - 077
	F	0800 -1500	078 - 085
3 or 4 Hour Class	MW	0800 -1500	086 - 093
	TR	0800 -1500	094 - 101
	MR	0800 -1500	102 - 109
	MF	0800 -1500	110 -117
	TF	0800 -1500	118 - 125
3 Hour Class	MWF	0800 -1600	126 - 134
	MTR	0800 -1600	135 - 143
	MTF	0800 -1600	144 - 152
	MWR	0800 -1600	153 - 161
	MRF	0800 -1600	162 - 170
	TWF	0800 -1600	171 - 179
	TRF	0800 -1600	180 - 188
4 Hour Class	MTWR	0800 -1600	189 - 197
	MTWF	0800 -1600	198 - 206
	MTRF	0800 -1600	207 - 215
	MWRF	0800 -1600	216 - 224
	TWRF	0800 -1600	225 - 233
6 Hour Lab	MW	0900	234
	MW	1300	235
	TR	0900	236
	TR	1300	237
3 Hour Lab	M	0900	238
	M	1300	239
	T	0900	240
	T	1300	241
	W	0900	242
	W	1300	243
	R	0900	244
	R	1300	245

Rooms in the School of Engineering were grouped into categories based on similar capacities, equipment, and their location within the school building. Table 2 shows the room group index number and the actual room numbers that correspond to the grouping.

Table 2: Room Groups

Room Group	Classroom Numbers	Capacity
1	60,62	35
2	160-163	30
3	260-263	28
4	172, 176B	35&24
5	64A,164A,176A	10
6	Labs 241,265,121	25
7	Lecture Hall 121	54
8	Lecture Hall 230	54
9	Computer Lab 165	16

Solicitation of Preferences

An electronic questionnaire, which took the instructor through a step by step process, was provided to the instructor of each course, lab and lecture to be scheduled. The questionnaire elicits a first, second and third choice for day/time preferences. The instructors chose a set of days of the week and a time range on those days for the start of their course or courses for each of the three preferences. The time ranges corresponded to five periods within the day. Table 4 shows the ranges and the corresponding start times with that range. In every case, with the exception of MORN, the range contains two start times. These preferences were transformed into scenario index numbers defined in Table 2. For example, if an instructor chose MWF MIDM as a preference, scenarios

127 and 128 are used as indicators of this preference. In effect, each instructor could chose up to six scenarios via the three preferences.

Table 3: Time Ranges

Course Start Time	Time Range
0800	MORN
0900,1000	MIDM
1100,1200	NOON
1300,1400	EAFT
1500,1600	LAFT

In a similar fashion, the questionnaire provided three room group preferences. Additionally, instructors could provide days of the week and time ranges when teaching was of no value. These scenarios are known as non-preferences. This will be discussed further later. Finally, the instructors indicated what contribution the day/time scenario preference and room preference would have on the value of course index number by providing weights, w_{jiD} and w_{riD}.

Each completed questionnaire provided 18 binary variables to the MIP, a combination of 6 scenarios and 3 room group preferences. For example, the variable x0011283 would describe a preference for course 001 of day/time scenario 128 and room group 3. The value of this variable would be determined using equation (14) and the single dimensional value function shown in Figure 5. This value becomes the cost coefficient of the objective function of the MIP.

MIP Formulation

Obviously, a maximization of an objective function made up of the variables produced from the questionnaires would produce a schedule with the greatest overall value. An objective function of this type is of the form of equation (14), which is an additive value function. The use of an additive value function as the objective function does not violate the assumptions of an MIP formulation.

Winston (1994: 53) states that a viable objective function must meet two criteria. First, "the contribution to the objective function from each decision variable must be proportional to the decision variable." The fact that the value function is additive and linear satisfies this criteria. Secondly, according to Winston (1994: 53), "the contribution to the objective function for any variable is independent of the values of the other decision variables." As stated in the VFT theoretical presentation, additive value functions require mutual preferential independence of the attributes on which value is evaluated.

Mutual preferential independence is shown for the each attribute x_{ijk} in the following manner. The value of any day/time scenario j and room group k of course i remains constant to the decision maker regardless of the preferences placed on other day/time scenarios and room groups by the remaining instructors. In other words the partition of day/time scenarios and room groups for course i is preferentially independent of the remaining day/time scenarios and room groups for other courses.

However, a schedule that simply maximized the additive value function would most certainly violate one of the go/no-go criteria and therefore be reduced, via equation (15), to an overall value of zero. Therefore, the following MIP formulation restricts the

feasible region to schedules that do not violate the go/no-go criteria. This is done through the use of three distinct types of constraints.

The first set of constraints require that each course is scheduled against one and only one scenario and room combination. The number of these constraints is equal to the total number of courses being scheduled. This set of constraints may possibly produce an MIP that has no feasible solution. If every combination of preference variables violate the other go/no-go criteria then a feasible solution does not exist. To remedy this possibility, a dummy variable, whose contribution to the objective function is zero, is included in this constraint. The dummy variable will, by definition, not violate any of the other constraints. The constraints become:

$$\sum_{j}\sum_{k} x_{ijk} + x_{id} = 1 \qquad \text{for all i} \qquad (16)$$

A second set of constraints insure that no student or instructor conflicts exist through the use of zoning constraints. Patterson and Albright (1975) used similar constraints in assembly line balancing problems. Zoning constraints preclude two sets of variables from using the same resource. Here zoning constraints prevent courses with common students or instructors from being scheduled, either in part or in whole, at simultaneous times on the same day(s). Variables whose course ID shares common students with course *i* and whose scenario takes place across the same hour and day as any hour and day in scenario *j* are included in the set $DECON_{ij}$. The zoning constraints then become:

$$M \cdot \sum_{k} x_{ijk} + \sum_{x_{ijk} \in DECON_{ij}} x_{ijk} \leq M \qquad \text{for all i and j} \qquad (17)$$

where M is a constant greater than the cardinality of $DECON_{ij}$. There are i times j number of constraints of this type.

The third set of constraints insure that the number of courses scheduled during any hour of the week in a room group does not exceed the number of rooms in that group. Variables whose room group includes r and whose scenario occurs during time t are included in the set $ROOM_{rt}$. $RMNUM_{rt}$ is a constant defined by the number of rooms in room group r at time t. The constraints then become:

$$\sum_{x_{ijk} \in ROOM_{rt}} x_{ijk} \leq RMNUM_{rt} \qquad \text{for all } r \text{ and } t \qquad (18)$$

There are r times t constraints of this type.

The final MIP formulation maximizes the objective function subject to equations (16), (17), (18) and a restriction of the variables as binary. The full MIP formulation is shown below as problem P2.

Problem P2: MIP Formulation

Maximize $\sum_i \sum_j \sum_k c_{ijk} \cdot x_{ijk}$

Subject To

$$\sum_j \sum_k x_{ijk} + x_{id} = 1 \qquad \text{for all i}$$

$$M \cdot \sum_k x_{ijk} + \sum_{x_{ijk} \in DECON_{ij}} x_{ijk} \leq M \qquad \text{for all i and j}$$

$$\sum_{x_{ijk} \in ROOM_{rt}} x_{ijk} \leq RMNUM_{rt} \qquad \text{for all r and t}$$

$$x_{ijk} = \{0,1\} \qquad \text{for all i, j, and k}$$

If an instructor fails to provide three preferences for either day/time or room, the scheduler may assign neutral scenario and room preferences to generate variables associated with the course. The neutral scenarios and neutral rooms have a lower value than any of the three preferences (Refer to Figure 5). Moreover, neutral variables are assigned to any course whose dummy variable is chosen in the solution to P2. The scheduler chooses neutral scenarios from the set of possible scenarios minus preferred scenarios and non-preferred scenarios. Problem P2 can be solved in an iterative fashion until no dummy variables are selected, given a feasible schedule exists. A solution to P2 will provide the schedule with the best overall value for the preferences provided and the neutral variables chosen.

Decision Support System

In conjunction with a main goal of this research, a Decision Support System (DSS) makes implementation of Problem P2 virtually seamless. The Educational Decision Support and Scheduling System (EDSSS) is comprised of three parts: (1) an electronic questionnaire, (2) a problem generator, and (3) the Optimization Subroutine Library (OSL), an IBM MIP solver.

The electronic questionnaire is a menu driven Visual Basic Module run in MS Excel, that can be delivered via E-mail. The module displays a Windows dialogue box through which instructors indicate preferences and non-preferences for days and times as well as preferences for room groups. The questionnaire also solicits the respective

weighting for day/times and room groups. Dropdown menus, containing available days, times and room groups, provide a user-friendly environment for preference selection.

The problem generator is an MS Excel spreadsheet, and uses a suite of modules programmed in Visual Basic. Preferences, obtained via the electronic questionnaire, are arranged into a value table within the problem generator. A course listing, containing the SSN of all students enrolled in each course, is automatically transformed into a course confliction matrix. The course confliction matrix is a square matrix whose rows and columns are made up of the course listing. Element [i,j] equals 1 if course i and course j possess a common student, and 0 otherwise. Similarly, a scenario confliction matrix is a square matrix whose rows and columns are made up of the scenario list. Element [i,j] of the scenario confliction matrix is 1 if scenario i and scenario j share any common hour on any matching day, and 0 otherwise.

The problem generator automatically generates the $DECON_{ij}$ and $ROOM_{rt}$ sets. Problem P2 is then generated in Mathematical Programming System (MPS) format. The MPS formulation is transferred to OSL and solved as a maximization MIP. OSL returns the x_{ijk} variables whose value is 1 and a schedule is created. If any dummy variables are returned then new neutral variables are entered into the generator value table and the process is rerun.

RESULTS

The results presented are for the spring quarter at the School of Engineering for AFIT. The spring quarter contains 83 different courses, labs, and group lectures. The school building is divided into the 9 room groups shown in Table 2. The instructors for

each course, lab or lecture were given the opportunity to provide preferences for day/times and rooms. If an instructor is assigned to teach more than one course, lab or lecture, then multiple questionnaires were filled out and preferences were captured for each course. If an instructor did not wish to provide any preferences or did not completely fill out the questionnaire, then neutral preferences were assigned to the instructor by the scheduler. Implementation of Problem P2 for the spring quarter utilizes 1398 binary variables and 953 constraints.

Four different schedules were created. The schedules differed by the weighting assigned to each department, w_D. Therefore, only the cost coefficients of the objective function change. The variation in schedules provides the decision maker with a sensitivity of the departmental weighting on the overall value of the schedule, the number of 1st day/time preferences accommodated, and the number of neutral preferences assigned. These measures are considered to provide the most insight into the quality of a schedule. The number of 1st day/time preferences is used, in lieu of room preferences, because the overwhelming majority of instructors gave day/time preferences more weight.

The initial schedule uses an equal weighting for each department. The second schedule's departmental weighting is the percent of courses taught by that department of the total 83 offered by the school. This weighting potentially gives each course equal impact on the overall value. However, if department heads wish to weight a subset of their courses higher than the remaining courses in the department to reward the instructors with a greater opportunity of achieving first preferences, the remaining courses impact are less than the impact of courses whose department weighted all courses

equally. The third schedule uses weighting commensurate with the number of students the courses within that department instruct. The final variation combines the weighting used in the second schedule, however, all group lectures are given their first day/time preference. Table 4 shows the weights used for each scheduling variation.

Table 4: Departmental Weightings

Schedule Weighting	Departments					
	ENC	ENG	ENP	ENS	ENV	ENY
Equal	0.167	0.167	0.167	0.167	0.167	0.167
Number of Courses	0.145	0.349	0.205	0.108	0.06	0.133
Number of Students	0.128	0.391	0.203	0.149	0.047	0.082
Number of Courses with Lectures Given	0.145	0.349	0.205	0.108	0.06	0.133

Table 5 summarizes the problem generator time, OSL solver time and number of course not scheduled, i.e. assigned a dummy variable. The problem generator and OSL were run on a 200 MHz PC platform using WindowsNT.

Table 5: Summary of Processing Times

Schedule Weighting	Problem Generator CPU Time (sec)	OSL Solver CPU Time (sec)	Number of Courses Not Scheduled
Equal	580	1121	4
Number of Courses	619	1197	4
Number of Students	575	1073	3
Number of Courses with Lectures Given	620	798	4

Table 5 clearly shows that each schedule took less than 30 minutes to generate on a personal computer. The relatively short processing time will allow the scheduler to make new runs if enrollment data changes or instructors are reassigned to different courses. Additionally, any subsequent sensitivity analysis important to the decision maker can be readily provided.

The percentage of courses not scheduled, based on the preference variables, is less than 5% for any of the four schedules. The scheduler can assign new neutral preferences to these courses and rerun the process or, manually schedule the relatively small number of courses that remain unscheduled.

Figure 6 compares the overall value, whose range is 0 to 1, of the four scheduling variations. Clearly, the overall value is very insensitive to the departmental weighting.

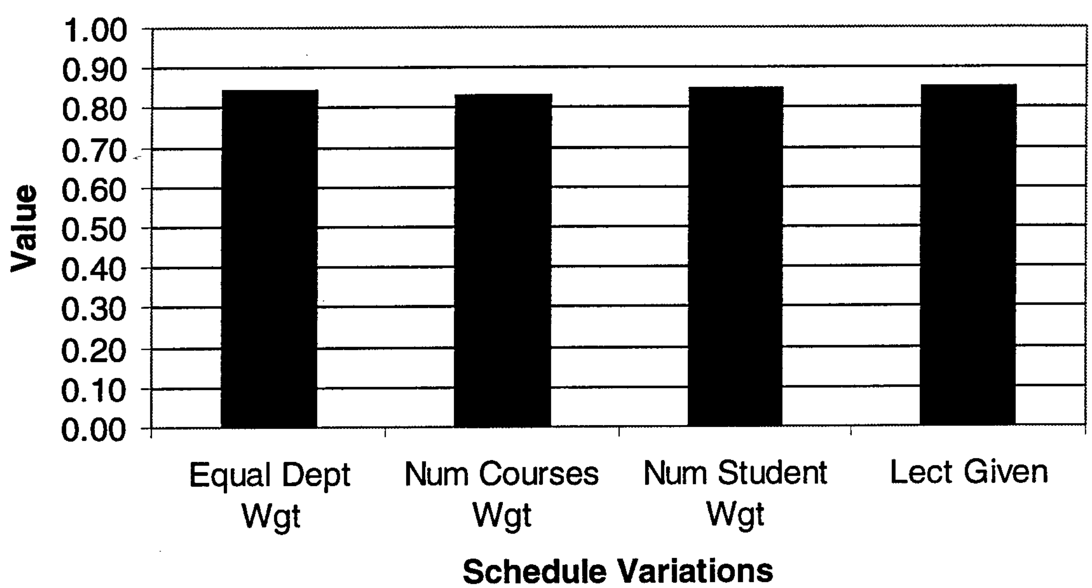


Figure 6: Overall Value of Schedules

Figure 7 shows the value of each department for the four different departmental weightings.

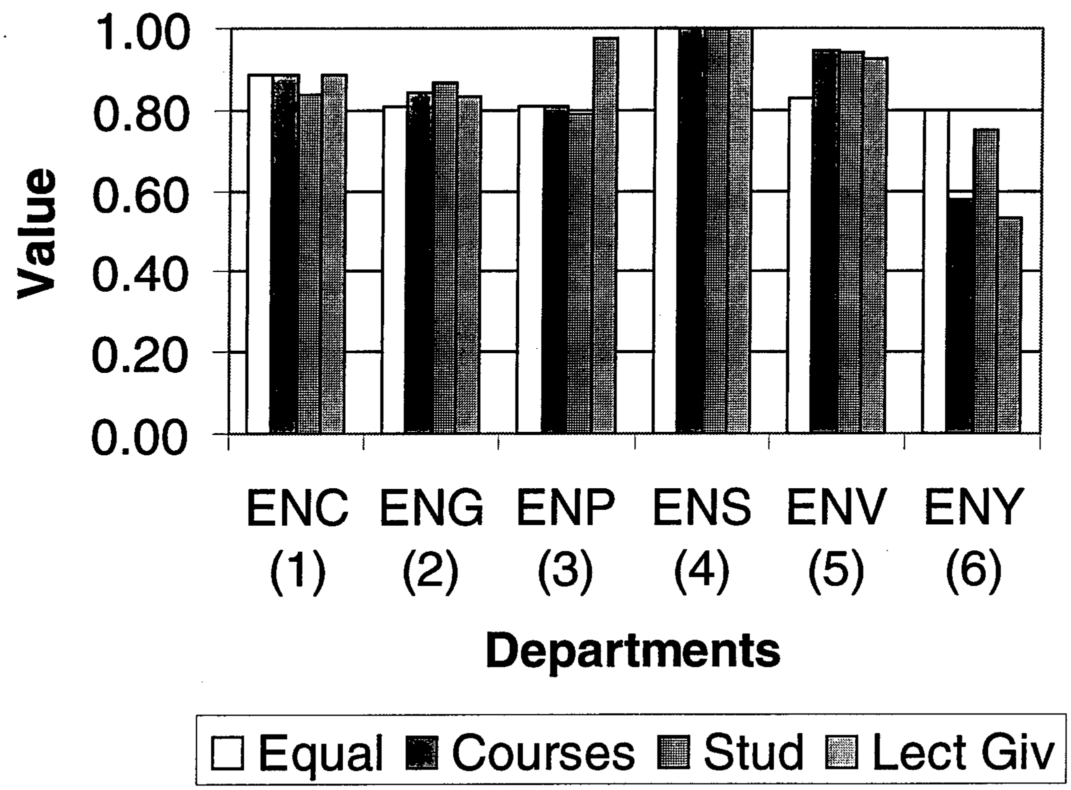


Figure 7: Departmental Value of Schedules

The value of ENY shows the most sensitivity to departmental weighting. However, the change in value is still relatively small, amounting to only 0.23 difference from highest value achieved with the equal weighting schedule and the lowest value when the departmental weighting is based upon number of courses. Other departments indicate even less sensitivity to departmental weighting.

Another measure important to the decision maker is the amount of courses whose 1st day/time preference is accommodated. Figure 8 reveals the extent to which 1st day/time preferences were achieve for each department.

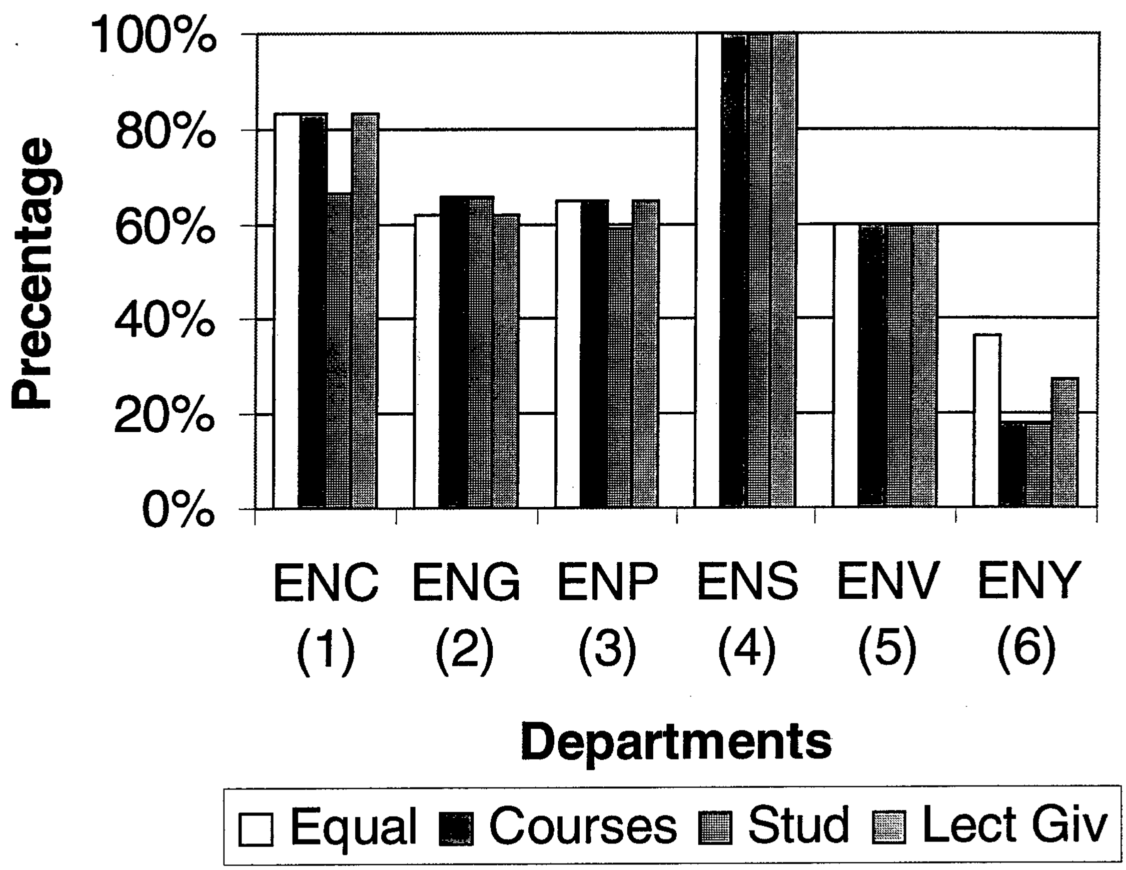


Figure 8: Percentage of 1st Day/Time Preferences Accommodated

In most cases, the number of 1st preferences given is from 60% - 100%. The exception is ENY. Again, little sensitivity is shown to the departmental weighting used to create the schedule. Figure 9 gives some insight to why departments such as ENS have a higher value and number of 1st preferences accommodated than other departments, such as ENY.

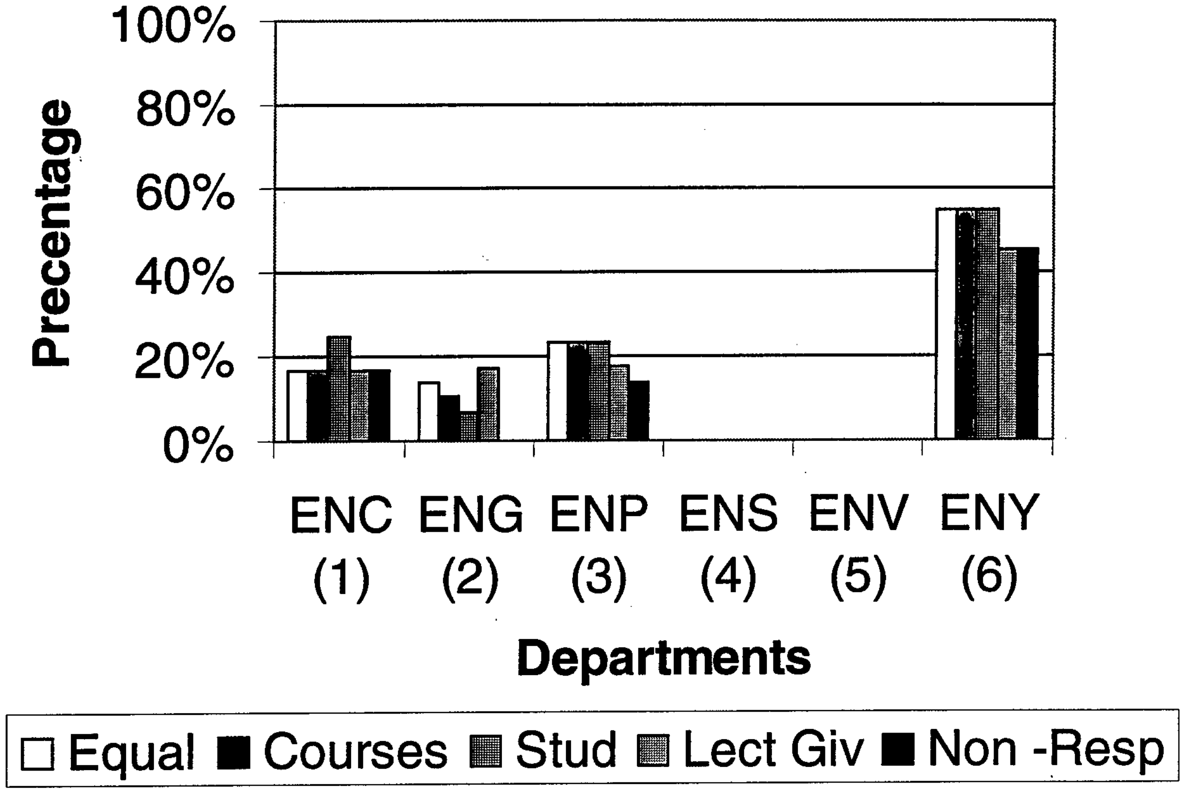


Figure 9: Comparison of Neutral Day/Time Assignments to Non-Respondents

Figure 9 shows a clear trend. The number of neutral day/time scenarios scheduled is proportionate to the number of instructors who did not provide any preferences. Neutral day/times are of significantly less value than any of the three preferred day/times and therefore contribute to a lower departmental value. Additionally, if no preferences are provided, 1st preferences cannot be accommodated.

Iterative Approach to a Complete Schedule

In each case, the schedules developed did not achieve a complete working schedule. The scheduling variation based upon departmental weighting proportionate to the number of course taught was chosen for completion. This variation was chosen because is provides the opportunity for equal weighting of all courses throughout the school.

The initial schedule did not schedule 4 courses, because the preferences associated with these course violated one of the go/no-go criteria. Therefore, preferences of these four instructors were changed to neutral preferences by the scheduler. Two additional iterations were required before a completed schedule was achieved. The overall value of this schedule was equal to .84, slightly higher than the original overall value. The completed schedule can be used to show room utilization throughout the school building. Figure 10, shows the utilization of classrooms, room groups 1-5.

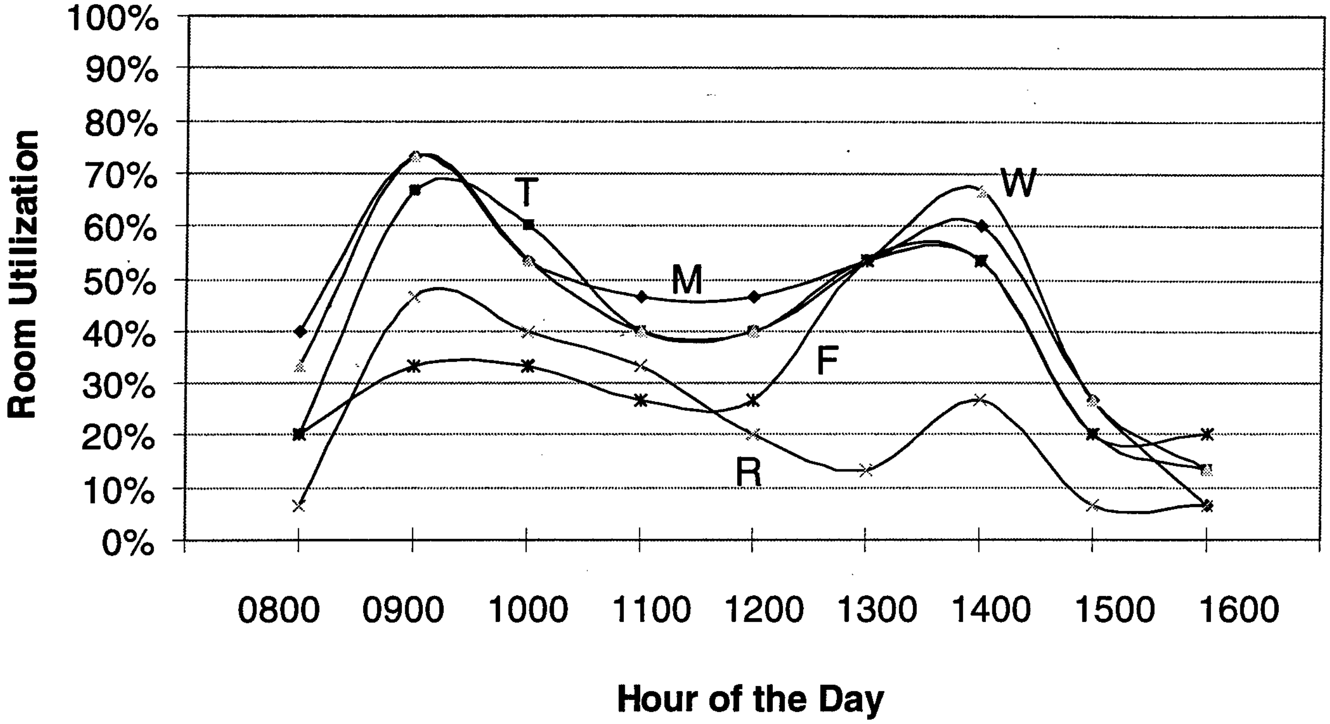


Figure 10: Classroom Utilization for Completed Schedule

Room utilization peaks at the most popular times of day, midmorning and early afternoon. However, room utilization levels during these popular times do not approach 100%. Therefore, any difficulty in scheduling 1st preferences must result from student or instructor conflicts.

CONCLUSIONS

The research presented in this paper addresses four significant goals for academic course scheduling at the School of Engineering for AFIT. The important factors or values effecting the quality of an academic course schedule for the School of Engineering are identified. Metrics are established that measure how well a schedule addresses these

values. A Decision Support System enables the Office of Academic Operations to implement the research and solicit individual preference efficiently. Finally, the research provides an expedient means of solving the academic course scheduling problem for the School of Engineering. The MIP formulation utilizes only a relatively small number of binary variables, allowing an initial solution in less than 30 minutes and a complete working schedule was achieved in less than 2 hours.

Moreover, the benefits of this research are not lost on larger institutions, for which Problem P2 becomes computationally inefficient to solve optimally. Heuristic solutions, using tabu or other search criteria, readily solve MIPs such as Problem P2, achieving working schedules representative of the institution's goals and principles.

Value Focused Thinking enabled the decision maker to decompose a difficult, complex problem into a simple set of values. These values are used to create alternatives and solve the difficult problem. The academic course scheduling problem at the School of Engineering for AFIT is solved in a manner that maximizes the contribution the schedule makes to the institutes values and principles. Clearly, the ability of Decision Analysis and VFT as a viable technique to tackle the academic course scheduling problem and find a solution is validated.

CHAPTER 3

Now that the EDSSS has been used to develop a schedule for the School of Engineering, an obvious extension to this research would create a working schedule for the entire Air Force Institute of Technology. This would require the solicitation of preferences for both the School of Engineering and the School of Logistics. The larger problem would give insight into the upper bound of courses that can be solved using a Mixed Integer Solver.

Additionally, other military institutions such as the Air Force Academy in Colorado Springs or the Military or Naval academies may provide an excellent source for application of this approach. However, this approach is equally applicable to civilian institutions that wish to efficiently create an academic course schedule representative of the values of the varying stakeholders in the academic community.

A second area for extension would be to create a heuristic algorithm that can be incorporated in the existing EDSSS framework. A quick heuristic solver incorporated into EDSSS would alleviate the requirement for an external Mixed Integer Solver. A self-contained scheduling system would allow the simultaneous creation of multiple schedules on different PCs.

The final recommendation would determine the effect student day/time preferences have on the creation of a schedule. Many civilian institutions may be less concerned with obtaining a completely deconflicted schedule, but rather wish to accommodate the majority of students' time/day preferences. Intercollegiate athletic practice, part-time or full-time jobs, and so forth, may make certain day/time scenarios more or less attractive.

APPENDIX A: COMPLETE 1998 SPRING QUARTER SCHEDULE

Below is the completed schedule, assigning all courses to days, times and room group. Individual rooms within each group may be assigned arbitrarily or by departmental policy.

Course			Instructor	Days	Times	Room Groups
MATH	508	01	BAKER	MTWR	0900-1000	2
MATH	521	01	WOOD	MTWF	0800-0900	5
MATH	633	01	LAIR	MTWF	1300-1400	2
MATH	674	01	CHILTON	MTWR	0900-1000	2
MATH	705	01	OXLEY	MWRF	0900-1000	5
STAT	528	01	REYNOLDS	MWF	1600-1700	3
STAT	528	01	REYNOLDS	T	0800-1000	9
STAT	583	91	CROWN	MTWF	0900-1000	5
STAT	696	01	CROWN	TWF	1300-1400	2
STAT	696	91	CROWN	T	1400-1600	9
STAT	696	02	REID	MWF	1300-1400	2
STAT	696	92	REID	T	1000-1200	9
CSCE	532	01	POTOCZNY	MW	1200-1400	2
CSCE	544	01	POTOCZNY	TF	1000-1200	4
CSCE	595	01	GRAHAM	TF	1400-1600	2
CSCE	595	91	GRAHAM	R	1300-1600	6
CSCE	623	01	BANKS	MW	1400-1600	3
CSCE	646	01	TALBERT	TF	1200-1400	3
CSCE	654	01	RAINES	MW	1400-1600	2
CSCE	656	01	LAMONT	TF	1200-1400	3
CSCE	682	01	STYTZ	TWRF	1600-1700	5
CSCE	683	01	SHOMPER	TF	1400-1600	5
CSCE	686	01	LAMONT	MTRF	0800-0900	4
CSCE	698	01	RAINES	R	1000-1100	7
CSCE	793	01	HARTRUM	MW	1000-1200	4
CSCE	793	91	HARTRUM	R	1100-1200	8
EENG	533	01	MILLER	MW	1000-1200	3
EENG	533	91	MILLER	R	1300-1500	6
EENG	621	01	GUFESTAFSEN	MW	1200-1400	5
EENG	625	01	TERZUOLI	MTWF	1600-1700	6
EENG	629	01	PYATI	MTWF	0900-1000	5
EENG	630	01	COLLINS	MTWF	1400-1500	4
EENG	635	01	LEWANTOWICZ	TR	1000-1200	
EENG	640	01	PATCHER	TF	1100-1300	3
EENG	670	01	TEMPLE	TF	1200-1400	3
EENG	695	01	GELOSH	TF	1300-1500	3
EENG	695	91	GELOSH	R	1300-1600	6
EENG	698	01	TEMPLE	R	1000-1100	8
EENG	700	01	TERZUOLI	R	1200-1300	6
EENG	708	01	PATCHER	MW	1200-1400	3
EENG	766	01	MAYBECK	TF	0900-1100	5

CHEM	585	01	BURGGRAF	MTRF	1000-1100	4
CHEM	675	01	WOLF	MTWF	1400-1500	5
EVSC	560	01	BURGGRAF	MTRF	1100-1200	1
EVSC	670	01	MATHEWS	TWRF	1400-1500	5
METG	630	01	ASKUE	M	1300-1500	3
METG	630	91	ASKUE	TR	1300-1600	9
METG	642	01	DUNGEY	MTWR	1200-1300	2
METG	798	01	DUNGEY	W	1500-1600	7
NENG	560	01	SUSALLA	MW	1000-1200	5
NENG	631	01	SUSALLA	TR	0900-1100	5
OENG	620	01	ROH	MTWF	0900-1000	2
OENG	650	01	HENGEHOLD	TWRF	1100-1200	1
PHYS	519	01	GOLDIZEN	MTWF	1000-1100	2
PHYS	542	01	ROH	MWF	1400-1500	2
PHYS	542	91	ROH	R	1300-1600	2
PHYS	650	01	BAILEY	MTWR	1000-1100	2
PHYS	798	01	LARGENT	M	1300-1400	8
OPER	403	01	MILLER	R	1300-1500	7
OPER	561	01	BAUER	TR	1100-1300	4
OPER	561	02	BAILEY	MW	1000-1200	4
OPER	561	03	MILLER	MW	0900-1100	1
OPER	601	01	DECKRO	R	0900-1000	5
OPER	610	01	CHAN	TWRF	1000-1100	5
OPER	610	02	CHRISSIS	MW	1400-1600	4
OPER	610	03	MOORE	MW	1400-1600	4
OPER	645	01	KLOBER	MW	0800-1000	4
EMGT	571	01	GILL	MW	1200-1400	1
ENVR	503	01	LOFGREN	T	0900-1000	2
ENVR	535	01	NIXON	TR	1300-1500	3
ENVR	621	01	SHELLEY	TR	0900-1100	3
ENVR	623	01	BLECKMAN	MW	0800-1000	3
MECH	533	01	AGNES	MWF	1400-1500	3
MECH	605	01	PALAZOTTO	TR	1100-1300	5
MECH	620	01	POHL	MW	0800-1000	5
MECH	628	01	LIEBST	TF	1500-1700	4
MECH	636	01	WIESEL	MW	1100-1300	1
MECH	642	01	TURCOTTE	MTWF	1000-1100	3
MECH	723	01	SPENNY	MTWF	0800-0900	2
MENG	531	01	LITTLE	MTWF	1300-1400	3
MENG	732	01	KING	TWRF	1400-1500	3
SENG	535	01	KRAMER	R	0900-1200	6
SENG	665	01	HEISE	MTWR	0900-1000	3

APPENDIX B: ELECTRONIC QUESTIONNAIRE SOURCE CODE

This appendix contains the visual basic modules used to generate the electronic questionnaire used by EDSSS to capture faculty day/time preferences and nonpreferences, as well as room group preferences. The modules were written in MS Excel 97.

```
'This subroutine hides specific worksheets when file is opened

Sub Auto_Open()
  Worksheets("Data").Visible = False
  DialogSheets("dlgFacultyInput").Visible = False
  DialogSheets("dlgPref1").Visible = False
  DialogSheets("dlgPref2").Visible = False
  DialogSheets("dlgPref3").Visible = False
  DialogSheets("dlgPref4").Visible = False
  DialogSheets("dlgInstr1").Visible = False
  DialogSheets("dlgInstr2").Visible = False
  DialogSheets("dlgInstr3").Visible = False
  DialogSheets("dlgInstr4").Visible = False
  DialogSheets("dlgThanks").Visible = False
  Modules("modQuest").Visible = False
End Sub

'This subroutine displays hidden worksheeets

Sub UnHide()
  Worksheets("Data").Visible = True
  DialogSheets("dlgFacultyInput").Visible = True
  DialogSheets("dlgPref1").Visible = True
  DialogSheets("dlgPref2").Visible = True
  DialogSheets("dlgPref3").Visible = True
  DialogSheets("dlgPref4").Visible = True
  DialogSheets("dlgInstr1").Visible = True
  DialogSheets("dlgInstr2").Visible = True
  DialogSheets("dlgInstr3").Visible = True
  DialogSheets("dlgInstr4").Visible = True
  DialogSheets("dlgThanks").Visible = True
  Modules("modQuest").Visible = True
End Sub

'This subroutine shows the instructions dialogue box

Sub ShowInstructions()
  If DialogSheets("dlgInstr1").Show = True Then
    If DialogSheets("dlgInstr2").Show = True Then
```

```
      If DialogSheets("dlgInstr3").Show = True Then
        DialogSheets("dlgInstr4").Show
      End If
    End If
  End If
End Sub
```

This subroutine shows the preferences dialogue box and captures the inputs by the user

```
Sub ShowDialog()

  With DialogSheets("dlgFacultyInput")
    If .Show = True Then
      Instructor = .EditBoxes("txtInstructor").Text
      Course = .EditBoxes("txtCourse").Text
      Dept = .DropDowns("drpDepartment").Value
      If .OptionButtons("optHour1").Value = 1 Then
          With DialogSheets("dlgPref1")
                If .Show = True Then
                      hrPerWeek = 1
                      daysP1 = .DropDowns("drpDaysP1").Value
                      daysP2 = .DropDowns("drpDaysP2").Value
                      daysP3 = .DropDowns("drpDaysP3").Value
                      daysNP1 = .DropDowns("drpDaysNP1").Value
                      daysNP2 = .DropDowns("drpDaysNP2").Value
                      daysNP3 = .DropDowns("drpDaysNP3").Value
                      timeP1 = .DropDowns("drpTimesP1").Value
                      timeP2 = .DropDowns("drpTimesP2").Value
                      timeP3 = .DropDowns("drpTimesP3").Value
                      timeNP1 = .DropDowns("drpTimesNP1").Value
                      timeNP2 = .DropDowns("drpTimesNP2").Value
                      timeNP3 = .DropDowns("drpTimesNP3").Value
                      roomP1 = .DropDowns("drpRoomsP1").Value
                      roomP2 = .DropDowns("drpRoomsP2").Value
                      roomP3 = .DropDowns("drpRoomsP3").Value
                      dayWgt = .EditBoxes("txtDayWgt").Text
                      feedbck = .EditBoxes("txtComments").Text
                      DialogSheets("dlgThanks").Show
                Else
                      Worksheets("INTERFACE").Activate
                End If
          End With
      End If
      If .OptionButtons("optHour2").Value = 1 Then
          With DialogSheets("dlgPref2")
                If .Show = True Then
                      hrPerWeek = 2
                      daysP1 = .DropDowns("drpDaysP1").Value
                      daysP2 = .DropDowns("drpDaysP2").Value
                      daysP3 = .DropDowns("drpDaysP3").Value
                      daysNP1 = .DropDowns("drpDaysNP1").Value
                      daysNP2 = .DropDowns("drpDaysNP2").Value
                      daysNP3 = .DropDowns("drpDaysNP3").Value
                      timeP1 = .DropDowns("drpTimesP1").Value
                      timeP2 = .DropDowns("drpTimesP2").Value
                      timeP3 = .DropDowns("drpTimesP3").Value
```

```
                timeNP1 = .DropDowns("drpTimesNP1").Value
                timeNP2 = .DropDowns("drpTimesNP2").Value
                timeNP3 = .DropDowns("drpTimesNP3").Value
                roomP1 = .DropDowns("drpRoomsP1").Value
                roomP2 = .DropDowns("drpRoomsP2").Value
                roomP3 = .DropDowns("drpRoomsP3").Value
                dayWgt = .EditBoxes("txtDayWgt").Text
                feedbck = .EditBoxes("txtComments").Text
                DialogSheets("dlgThanks").Show
            Else
                Worksheets("INTERFACE").Activate
            End If
        End With
    End If
    If .OptionButtons("optHour3").Value = 1 Then
        With DialogSheets("dlgPref3")
            If .Show = True Then
                hrPerWeek = 3
                daysP1 = .DropDowns("drpDaysP1").Value
                daysP2 = .DropDowns("drpDaysP2").Value
                daysP3 = .DropDowns("drpDaysP3").Value
                daysNP1 = .DropDowns("drpDaysNP1").Value
                daysNP2 = .DropDowns("drpDaysNP2").Value
                daysNP3 = .DropDowns("drpDaysNP3").Value
                timeP1 = .DropDowns("drpTimesP1").Value
                timeP2 = .DropDowns("drpTimesP2").Value
                timeP3 = .DropDowns("drpTimesP3").Value
                timeNP1 = .DropDowns("drpTimesNP1").Value
                timeNP2 = .DropDowns("drpTimesNP2").Value
                timeNP3 = .DropDowns("drpTimesNP3").Value
                roomP1 = .DropDowns("drpRoomsP1").Value
                roomP2 = .DropDowns("drpRoomsP2").Value
                roomP3 = .DropDowns("drpRoomsP3").Value
                dayWgt = .EditBoxes("txtDayWgt").Text
                feedbck = .EditBoxes("txtComments").Text
                DialogSheets("dlgThanks").Show
            Else
                Worksheets("INTERFACE").Activate
            End If
        End With
    End If
    If .OptionButtons("optHour4").Value = 1 Then
        With DialogSheets("dlgPref4")
            If .Show = True Then
                hrPerWeek = 4
                daysP1 = .DropDowns("drpDaysP1").Value
                daysP2 = .DropDowns("drpDaysP2").Value
                daysP3 = .DropDowns("drpDaysP3").Value
                daysNP1 = .DropDowns("drpDaysNP1").Value
                daysNP2 = .DropDowns("drpDaysNP2").Value
                daysNP3 = .DropDowns("drpDaysNP3").Value
                timeP1 = .DropDowns("drpTimesP1").Value
                timeP2 = .DropDowns("drpTimesP2").Value
                timeP3 = .DropDowns("drpTimesP3").Value
                timeNP1 = .DropDowns("drpTimesNP1").Value
                timeNP2 = .DropDowns("drpTimesNP2").Value
```

```
                timeNP3 = .DropDowns("drpTimesNP3").Value
                roomP1 = .DropDowns("drpRoomsP1").Value
                roomP2 = .DropDowns("drpRoomsP2").Value
                roomP3 = .DropDowns("drpRoomsP3").Value
                dayWgt = .EditBoxes("txtDayWgt").Text
                feedbck = .EditBoxes("txtComments").Text
                DialogSheets("dlgThanks").Show
            Else
                Worksheets("INTERFACE").Activate
            End If
        End With
    End If

    Worksheets("DATA").Cells(3, 1).Value = Instructor
    Worksheets("DATA").Cells(3, 2).Value = Course
    Worksheets("DATA").Cells(3, 3).Value = Dept
    Worksheets("DATA").Cells(3, 4).Value = hrPerWeek
    Worksheets("DATA").Cells(3, 5).Value = dayWgt
    Worksheets("DATA").Cells(3, 6).Value = 1 - Val(dayWgt)
    Worksheets("DATA").Cells(3, 7).Value = daysP1
    Worksheets("DATA").Cells(3, 8).Value = timeP1
    Worksheets("DATA").Cells(3, 9).Value = roomP1
    Worksheets("DATA").Cells(3, 10).Value = daysP2
    Worksheets("DATA").Cells(3, 11).Value = timeP2
    Worksheets("DATA").Cells(3, 12).Value = roomP2
    Worksheets("DATA").Cells(3, 13).Value = daysP3
    Worksheets("DATA").Cells(3, 14).Value = timeP3
    Worksheets("DATA").Cells(3, 15).Value = roomP3
    Worksheets("DATA").Cells(3, 16).Value = daysNP1
    Worksheets("DATA").Cells(3, 17).Value = timeNP1
    Worksheets("DATA").Cells(3, 18).Value = daysNP2
    Worksheets("DATA").Cells(3, 19).Value = timeNP2
    Worksheets("DATA").Cells(3, 20).Value = daysNP3
    Worksheets("DATA").Cells(3, 21).Value = timeNP3
    Worksheets("DATA").Cells(3, 22).Value = feedbck
  End If
 End With
End Sub
```

APPENDIX C: PROBLEM GENERATOR SOURCE CODE

This appendix contains the visual basic modules used in the problem generator portion of EDSSS to write the Mixed Integer Program shown by Problem P2 in Mathematical Programming System (MPS) format. The modules were written in MS Excel 97.

```
'This subroutine hides specific spreadsheets when the document is opened

Sub AutoOpen()
  ThisWorkbook.Activate
  With ActiveWorkbook
    Worksheets(2).Visible = False
    Worksheets(3).Visible = False
    Worksheets(4).Visible = False
    Worksheets(5).Visible = False
    Worksheets(6).Visible = False
    Worksheets(7).Visible = False
  End With
End Sub

'This subroutine unhides the spreadsheets hidden upon opening

Sub UnHide()
  ThisWorkbook.Activate
  With ActiveWorkbook
    Worksheets(2).Visible = True
    Worksheets(3).Visible = True
    Worksheets(4).Visible = True
    Worksheets(5).Visible = True
    Worksheets(6).Visible = True
    Worksheets(7).Visible = True
  End With
End Sub

'This subroutine is the main routine and calls the other main routines in the
'correct order

Sub Schedule()
  MsgBox (Now())
  Call EdPlans
  Call Variables
  Call WriteMps
  MsgBox (Now())
End Sub
'This subroutine puts the Value table into the correct format for
```

```
'processing.

Sub FormatTable()
   Worksheets("Vbl Def").Select
   With ActiveSheet
      Set eeRange = Range("M1:R83")
      For Each C In eeRange
         If C.Value <> "" Then
            If Len(LTrim(Str(C.Value))) = 1 Then C.Value = "'00" & LTrim(Str(C.Value))
            If Len(LTrim(Str(C.Value))) = 2 Then C.Value = "'0" & LTrim(Str(C.Value))
            If Len(LTrim(Str(C.Value))) = 3 Then C.Value = "'" & LTrim(Str(C.Value))
         End If
         Next C
   End With
End Sub

'This subroutine writes all the variables in the variable list

Sub WriteVbls()
   Worksheets("Vbl Def").Select
   With ActiveSheet
      Set clearRange = Range("A1:G10000")
      clearRange.ClearContents
      clearRange.Font.Bold = False

      i = 1
      Do Until Cells(i, 10) = ""
         C = 1 + (i - 1) * 18
         Cells(C, 1).Value = Cells(i, 10).Value
         j = 1
         Do Until Cells(i, 12 + j) = "" Or j > 6
            d = C + (j - 1) * 3
            Cells(d, 2).Value = Cells(i, 12 + j).Value
            If Cells(i, 12 + j).Font.Bold = True Then
               Cells(d, 2).Font.Bold = True
            End If
            k = 1
            Do Until Cells(i, 18 + k) = "" Or k > 3
               e = d + k - 1
               Cells(e, 4).Value = Cells(i, 18 + k).Value
               If Cells(i, 18 + k).Font.Bold = True Then
                  Cells(e, 4).Font.Bold = True
               End If
               Cells(e, 6).Value = "x" & Cells(i, 10) & Cells(i, 12 + j) & Cells(i, 18 + k)
               k = k + 1
            Loop
            j = j + 1
         Loop
         i = i + 1
      Loop
   End With
End Sub

'Writes objective value for each variable

Sub PutValues()
```

```
  Worksheets("Vbl Def").Select
  With ActiveSheet
    i = 1
    j = 1
    Do While i < 10000 And j < 10000
      If Cells(i, 2) <> "" Then
        If Cells(i, 2).Font.Bold = True Then
          ScenValue = 0.333
        Else
          ScenValue = GetScenValue(i)
        End If
        Cells(i, 3).Value = ScenValue
        Cells(i + 1, 3).Value = ScenValue
        Cells(i + 2, 3).Value = ScenValue
        i = i + 3
      Else
        i = i + 3
      End If
      If Cells(j, 4) <> "" Then
        If Cells(j, 4).Font.Bold = True Then
          RoomValue = 0.333
        Else
          RoomValue = GetRoomValue(j)
        End If
        Cells(j, 5).Value = RoomValue
        j = j + 1
      Else
        j = j + 1
      End If
    Loop

    k = 1
    m = 1
    Do While k < 10000
      If Cells(k, 6) <> "" Then
        impact = (Cells(m, 11).Value * Cells(k, 3) + Cells(m, 12).Value * Cells(k, 5)) *
Cells(m, 22) * 100000
        Cells(k, 7).Value = Int(impact)
        k = k + 1
      Else
        k = k + 1
      End If
      If k Mod 18 = 1 Then m = m + 1
    Loop
  End With
End Sub

Function GetScenValue(vrow)
  p = vrow Mod 18
  If p = 1 Then GetScenValue = 1
  If p = 4 Then GetScenValue = 1
  If p = 7 Then GetScenValue = 0.833
  If p = 10 Then GetScenValue = 0.833
  If p = 13 Then GetScenValue = 0.667
  If p = 16 Then GetScenValue = 0.667
End Function
```

```
Function GetRoomValue(vrow)
   p = vrow Mod 18
   If p = 1 Then GetRoomValue = 1
   If p = 2 Then GetRoomValue = 0.833
   If p = 3 Then GetRoomValue = 0.667
   If p = 4 Then GetRoomValue = 1
   If p = 5 Then GetRoomValue = 0.833
   If p = 6 Then GetRoomValue = 0.667
   If p = 7 Then GetRoomValue = 1
   If p = 8 Then GetRoomValue = 0.833
   If p = 9 Then GetRoomValue = 0.667
   If p = 10 Then GetRoomValue = 1
   If p = 11 Then GetRoomValue = 0.833
   If p = 12 Then GetRoomValue = 0.667
   If p = 13 Then GetRoomValue = 1
   If p = 14 Then GetRoomValue = 0.833
   If p = 15 Then GetRoomValue = 0.667
   If p = 16 Then GetRoomValue = 1
   If p = 17 Then GetRoomValue = 0.833
   If p = 0 Then GetRoomValue = 0.667
End Function

'This subroutine puts the value list in the correct format

Sub FormatList()
   Worksheets("Vbl Def").Select
   With ActiveSheet
      Set ddRange = Range("A1:B10000")
      For Each C In ddRange
         If C.Value <> "" Then
            If Len(LTrim(Str(C.Value))) = 1 Then C.Value = "'00" & LTrim(Str(C.Value))
            If Len(LTrim(Str(C.Value))) = 2 Then C.Value = "'0" & LTrim(Str(C.Value))
            If Len(LTrim(Str(C.Value))) = 3 Then C.Value = "'" & LTrim(Str(C.Value))
         End If
         Next C
   End With
End Sub

'Subroutine called by Schedule

Public Sub Variables()
   Call FormatTable
   Call WriteVbls
   Call PutValues
   Call FormatList
End Sub

Dim mpsrow As Integer
 Dim conCourCol As Integer
 Dim conScenCol As Integer
 Dim mpsPath As String
 Dim mpsFileName As String

 Dim numvbls As Integer
 Dim numcourses As Integer
```

```
Dim numscenarios As Integer
Dim scenRange As Range
Dim courRange As Range
Dim vblCourRange As Range
Dim vblScenRange As Range
Dim vblRoomRange As Range
Dim vblVblRange As Range

'Sets certain constants provided by the user on the "Code Data"
'spreadsheet

Sub GetConstants()
  numcourses = Sheets("Code Data").Cells(2, 3)
  numscenarios = Sheets("Code Data").Cells(3, 3)
  numvbls = Sheets("Code Data").Cells(5, 3)
  mpsPath = Worksheets("Code Data").Cells(6, 3)
  mpsFileName = Worksheets("Code Data").Cells(7, 3)
  Set scenRange = Worksheets("Scenario Confl").Range("A1:IV1")
  Set courRange = Worksheets("Course Confl").Range("A1:IV1")
  Set vblCourRange = Worksheets("Vbl Def").Range("A1:A1530")
  Set vblScenRange = Worksheets("Vbl Def").Range("B1:B1530")
  Set vblRoomRange = Worksheets("Vbl Def").Range("D1:D1530")
  Set vblVblRange = Worksheets("Vbl Def").Range("F1:F1520")
End Sub

'This subroutine opens the output file named schedmps.mps where
'the mps data will be written.

Sub OpenOutFile()
  mpsFile = mpsPath & mpsFileName
  Open mpsFile For Output As #9
  '       1234567890123456789012345
  Print #9, "NAME          SchedMps  FREE"
  Print #9, "ROWS"
  Print #9, " N    obj"
End Sub

'This subroutine writes to schedmps the ROWS portion of the .mps file.
'Where:
'axpppij are the one assignment per course "ppp" constraints
'dxpppqqqi are the deconfliction constraints associated with course
'       "ppp" and time scenario "qqq"
'rhhg are the room resourse constraints associated with time slot
'       "hh" and room group "g"

Sub WriteRows()

  Worksheets("Vbl Def").Select
  With ActiveSheet

    'Writes the single assignments rows
    i = 1
    Do Until i > numvbls
      If Cells(i, 6).Value = "" Then
        i = i + 18
      Else
```

```
      Print #9, " E    " & "a" & Left(Cells(i, 6), 4) & "ij"
      i = i + 18
    End If
  Loop

  'Writes the deconfliction rows
  j = 1
  Do Until j > numvbls
    If Cells(j, 6).Value = "" Then
      j = j + 3
    Else
      Print #9, " L    " & "d" & Left(Cells(j, 6), 7) & "i"
      j = j + 3
    End If
  Loop

  'Writes the room resourse rows, 45 time slots per week &
  '9 different room groups
  k = 1
  Do Until k > 45
    l = 1
    Do Until l > 9
      If Len(LTrim(Str(k))) = 1 Then
        timeslot = "0" & LTrim(Str(k))
      Else
        timeslot = LTrim(Str(k))
      End If
      Print #9, " L    " & "r" & timeslot & l
      l = l + 1
    Loop
    k = k + 1
  Loop

 End With
End Sub

'Retrieves the three digit scenario number "sss" from the variable
'of the type xccc,sss,r

Function IsolateScenario(variable)
  IsolateScenario = Mid(variable, 5, 3)
End Function

'Retrieves the three digit course number "ccc" from the variable
'of the type xccc,sss,r

Function IsolateCourse(variable)
  IsolateCourse = Mid(variable, 2, 3)
End Function

'Matches the current scenario with the same scenario on the
'"Scenario Confl" spreadsheet

Function ScenarioCol(scenario)
  If TypeName(scenRange.Find(scenario)) = "Range" Then
    ScenarioCol = scenRange.Find(scenario).column
```

```
  Else
    ScenarioCol = 9999
  End If
End Function

'Matches the current course with the same course on the
'"Course Confl" spreadsheet

Function CourseCol(courseNumber)
  If TypeName(courRange.Find(courseNumber)) = "Range" Then
    CourseCol = courRange.Find(courseNumber).column
  Else
    CourseCol = 9999
  End If
End Function

'Isolates a single Day from a string of Days

Function EachDay(days, x)
  EachDay = Mid(days, x, 1)
End Function

'Writes the Initial Columns for the .mps file

Sub InitialColumnEntry(ByVal variable, ByVal impact)
  Print #9, "    " & variable & "    obj" & "    " & impact
  Print #9, "    " & variable & "    a" & Left(variable, 4) & "ij" & "    1.0"
  Print #9, "    " & variable & "    d" & Left(variable, 7) & "i" & "    100.0"
End Sub

'Writes the deconfliction columns, i.e. any course and time to which
'the current variable is conflicted a 1.0 is placed in that column

Sub DeconColumnEntry(ByVal variable)
  Dim scenConflicts(1 To 100) As String
  Dim courConflicts(1 To 100) As String

  'Gets the scenario and course number for the variable
  courseNum = IsolateCourse(variable)
  scenario = IsolateScenario(variable)

  'Reads into an array all of the scenarios that conflict with
  'the current variable's scenario
  i = 3
  scencol = ScenarioCol(scenario)
  Do Until Worksheets("Scenario Confl").Cells(i, scencol).Value = ""
      scenConflicts(i) = Worksheets("Scenario Confl").Cells(i, scencol)
      i = i + 1
  Loop

  'Reads into an array all of the courses that conflict with the
  'current variable's course
  j = 3
  courCol = CourseCol(courseNum)
  Do Until Worksheets("Course Confl").Cells(j, courCol).Value = ""
      courConflicts(j) = Worksheets("Course Confl").Cells(j, courCol)
```

```
    j = j + 1
  Loop

  'Checks for both course confliction and scenario confliction
  'and writes the coulumn variable for the conflicted row if
  'both course and scenario are indeed conflicted

  Worksheets("Vbl Def").Select
  With ActiveSheet
  k = 1
  Do While k <= j - 1
    If TypeName(vblCourRange.Find(courConflicts(k))) = "Range" Then
      conCourrow = vblCourRange.Find(courConflicts(k)).row
      l = 1
      Do While l <= i
        endrow = conCourrow + 17
        z = conCourrow
        Do While z <= endrow And scenConflicts(l) <> ""
          inside = i
          If Cells(z, 2) = scenConflicts(l) Then
            Print #9, "      " & variable & "      " & "d" & Left(Sheets("Vbl Def").Cells(z,
6).Value, 7) & "i" & "    1.0"
            z = conCourrow + 20
          Else
          z = z + 3
          End If
        Loop
        l = l + 1
      Loop
    End If
    k = k + 1
  Loop
  End With
End Sub

'Writes the room resource columns in the .mps file

Sub RoomColumnEntry(variable)
  roomgrp = Right(variable, 1)
  scenario = IsolateScenario(variable)
  scencol = ScenarioCol(scenario)

  'Gets the days involved in the current scenario

  i = 1
  scendays = Sheets("Scenario Confl").Cells(2, scencol)

  'Determines what hour/day slots the scenario will use

  Do While i <= Len(scendays)
    d = EachDay(scendays, i)
    If d = "M" Then dayindex = 1
    If d = "T" Then dayindex = 10
    If d = "W" Then dayindex = 18
    If d = "R" Then dayindex = 26
    If d = "F" Then dayindex = 34
```

```
      hour1 = Sheets("Scenario Confl").Cells(3, scencol)
      hour2 = Sheets("Scenario Confl").Cells(4, scencol)
      hour3 = Sheets("Scenario Confl").Cells(5, scencol)

      'Gives time slot index, from 1 to 45 corresponding to
      'whole hours from M at 0800 (Index 1) to F 1600 (Index 45)

      timeslot1 = LTrim(Str((dayindex + (hour1 - 8))))
      If Len(timeslot1) = 1 Then timeslot1 = "0" + timeslot1

      RoomCon1 = "r" + timeslot1 + roomgrp
      Print #9, "    " & variable & "    " & RoomCon1 & "    1.0"

      If hour2 <> "0" Then
         timeslot2 = LTrim(Str((dayindex + (hour2 - 8))))
         If Len(timeslot2) = 1 Then timeslot2 = "0" + timeslot2
         RoomCon2 = "r" + timeslot2 + roomgrp
         Print #9, "    " & variable & "    " & RoomCon2 & "    1.0"
      End If

      If hour3 <> "0" Then
         timeslot3 = LTrim(Str((dayindex + (hour3 - 8))))
         If Len(timeslot3) = 1 Then timeslot3 = "0" + timeslot3
         RoomCon3 = "r" + timeslot3 + roomgrp
         Print #9, "    " & variable & "    " & RoomCon3 & "    1.0"
      End If
      i = i + 1
   Loop
End Sub

'Writes the COLUMNS portion of the .mps File

Sub WriteColumns()

   Print #9, "COLUMNS"

   'Tells solver, all the variable will be integer

   Print #9, "    MARK000    'MARKER'    'INTORG'"

   'Counter for number of variables
   i = 1

   Do While i <= numvbls
      variable = Sheets("Vbl Def").Cells(i, 6).Value
      If variable = "" Then
         i = i + 1
      Else
         impact = Sheets("Vbl Def").Cells(i, 7).Value

         Call InitialColumnEntry(variable, impact)

         Call DeconColumnEntry(variable)

         Call RoomColumnEntry(variable)
```

```
        i = i + 1

      End If
    Loop

    'Writes the neurtal variables

    j = 1
    Do While j <= numvbls
      If Sheets("Vbl Def").Cells(j, 6).Value <> "" Then
        variable = Sheets("Vbl Def").Cells(j, 6).Value
        Print #9, "    " & Left(variable, 4) & "000n" & "    " & "a" & Left(variable, 4) & "ij" & "
1.0"
        j = j + 18
      End If
    Loop

    Print #9, "    MARK001    'MARKER'    'INTEND'"

End Sub

'Determines the number of rooms in the room group "grp"

Function GetRoomcap(grp)
    If grp = 1 Then GetRoomcap = 2
    If grp = 2 Then GetRoomcap = 4
    If grp = 3 Then GetRoomcap = 4
    If grp = 4 Then GetRoomcap = 2
    If grp = 5 Then GetRoomcap = 3
    If grp = 6 Then GetRoomcap = 3
    If grp = 7 Then GetRoomcap = 1
    If grp = 8 Then GetRoomcap = 1
    If grp = 9 Then GetRoomcap = 1
End Function

'Writes the RHS portion of the .mps file

Sub WriteRHS()

    Worksheets("Vbl Def").Select
    With ActiveSheet
      Print #9, "RHS"

      'Writes the single assignments rhs
      i = 1
      Do Until i > numvbls
        If Cells(i, 6).Value = "" Then
          i = i + 18
        Else
          Print #9, "    rhs    " & "a" & Left(Cells(i, 6), 4) & "ij" & "    1.0"
          i = i + 18
        End If
      Loop

      'Writes the deconfliction rhs
```

```
    j = 1
    Do Until j > numvbls
      If Cells(j, 6).Value = "" Then
        j = j + 3
      Else
        Print #9, "    rhs     " & "d" & Left(Cells(j, 6), 7) & "i" & "     100.0"
        j = j + 3
      End If
    Loop

    'Writes the room resourse rhs, 45 time slots per week &
    '9 different room groups
    k = 1
    Do Until k > 45
      l = 1
      Do Until l > 9
        If Len(LTrim(Str(k))) = 1 Then
          timeslot = "0" & LTrim(Str(k))
        Else
          timeslot = LTrim(Str(k))
        End If
        roomcap = GetRoomcap(l)
        Print #9, "    rhs     " & "r" & timeslot & l & "     " & roomcap
        l = l + 1
      Loop
      k = k + 1
    Loop

  End With

End Sub

'Closes the output file mpsfile

Sub CloseOutFile()
  Print #9, "ENDATA"
  Close #9
End Sub

Public Sub WriteMps()
  Call GetConstants
  Call OpenOutFile
  Call WriteRows
  Call WriteColumns
  Call WriteRHS
  Call CloseOutFile
End Sub
'Variables used by two or more subroutines in this module

Dim maxstudents As Integer
Dim numcours As Integer

'This subroutine combines the course name and number and section

Sub CombineDeptNumber()
  i = 1
```

```
  Worksheets("Ed Plans").Select
  With ActiveSheet
    Do While Cells(i, 2).Value <> ""
      Cells(i, 8).Value = Cells(i, 2).Value & " " & Cells(i, 3).Value & Cells(i, 4).Value
      i = i + 1
    Loop
  End With
End Sub
```

This subroutine develops the course deconfliction matrix rows

```
Sub DevelopCourseConflicts()
  i = 1
  r = 1
  maxstudents = 0
  Set clearRange = Worksheets("Course SSNs").Range("A1:IV3000")
  clearRange.Clear
  Worksheets("Ed Plans").Select
  With ActiveSheet
    Do While Cells(i, 8).Value <> ""
      course = Cells(i, 8).Value
      j = 0
      m = i
      Do While Cells(m, 8).Value = course
        j = j + 1
        m = m + 1
      Loop
      If j > maxstudents Then maxstudents = j
      Worksheets("Course SSNs").Cells(r, 1).Value = Cells(i, 8).Value
      Worksheets("Course SSNs").Cells(r, 2).Value = Cells(i, 1).Value
      l = i
      k = 3
      Do While l < i + j
        Worksheets("Course SSNs").Cells(r, k).Value = Cells(l, 5).Value
        l = l + 1
        k = k + 1
      Loop
      i = i + j
      r = r + 1
    Loop
  End With
End Sub
```

This subroutine formats the matrix area

```
Sub InsertRows()
  endrange = maxstudents + 2
  Worksheets("Course SSNs").Select
  With ActiveSheet
    Set xRange = Range(Cells(1, endrange), Cells(endrange, endrange))
    xRange.Select
    Selection.EntireRow.Insert
  End With
End Sub
```

This subroutine lists the columns portion of the matrix

```
Sub Transpose()
  endrange = maxstudents + 2
  Worksheets("Course SSNs").Select
  With ActiveSheet
    blanks = 0
    i = 1
    Do Until Cells(i, 1) <> ""
      blanks = blanks + 1
      i = i + 1
    Loop
    Do Until Cells(i, 1) = ""
      courses = courses + 1
      i = i + 1
    Loop
    numcours = courses
    Set zRange = Range(Cells(blanks + 1, 1), Cells(blanks + courses, endrange))
    zRange.copy
    Cells(1, (endrange + 2)).Select
    Selection.PasteSpecial Paste:=xlAll, Operation:=xlNone, SkipBlanks:=False _
    , Transpose:=True
  End With
End Sub

'This subroutine fills in the course deconfliction matrix

Sub WriteMatrix()
  i = maxstudents + 3
  Worksheets("Course SSNs").Select
  With ActiveSheet
    Do Until Cells(i, 1) = ""
      j = 3
      Do Until Cells(i, j) = ""
        k = maxstudents + 4
        Do Until Cells(1, k).Value = ""
          l = 3
          Do While l <= maxstudents + 2
            If Cells(i, j).Value = Cells(l, k).Value Then
              Cells(i, k) = 1
            End If
            l = l + 1
          Loop
          k = k + 1
        Loop
        j = j + 1
      Loop
      i = i + 1
    Loop
  End With
End Sub

'This subroutine writes the confliction lists for each course

Sub WriteCourConflicts()
  maxstudents = 36
  numcours = 83
```

```
    Worksheets("Course SSNs").Select
    With ActiveSheet
      k = 0
      Set courseIDRange = Range(Cells(2, (maxstudents + 4)), Cells(2, 247))
      courseIDRange.copy
      Worksheets("Course Confl").Select
      With ActiveSheet
        Cells(1, 1).Select
        ActiveSheet.Paste
      End With
      Worksheets("Course SSNs").Select
      Set matrixRange2 = Range(Cells(maxstudents + 3, maxstudents + 4), Cells(maxstudents +
  numcours + 3, maxstudents + numcours + 4))
      matrixRange2.Select
      For Each C In matrixRange2
        If C.Value = 1 Then
          i = C.row
          j = C.column
          If Cells(i, 2) <> Cells(2, j) Then
            listColumn = j - (maxstudents + 3)
            Worksheets("Course Confl").Select
            With ActiveSheet
              Range(Cells(3, listColumn), Cells(103, listColumn)).copy
              Cells(4, listColumn).Select
              ActiveSheet.Paste
            End With
            Worksheets("Course Confl").Cells(3, listColumn).Value = Worksheets("Course
SSNs").Cells(i, 2).Value
            Worksheets("Course SSNs").Select
          End If
        End If
        Next C
  End With
End Sub

'This subroutine calls the other subroutines in this model to develop
'the course deconfliction matrix and lists

Public Sub EdPalns()
  MsgBox Now()
  Call CombineDeptNumber
  Call DevelopCourseConflicts
  Call InsertRows
  Call Transpose
  Call WriteMatrix
  Call WriteCourConflicts
  MsgBox Now()
End Sub
```

APPENDIX D: OSL OUTPUT FOR "EQUAL WEIGHTING" SCHEDULING VARIATION

Run # 1 - Scheduling Variation with Departments Weighted Equally

```
 EKK0008I Description of Problem SchedMps
 EKK0016I         Matrix has 953 rows, 1398 columns and 13830 entries
 EKK0009I Problem Status
 EKK0001I Iteration Number:     49775; Objective Value:
84590.00--Optimal
1EKK0011I    Columns Section                                         Page 9
 EKK0063I                ..Name..  Stat   ......Activity......
 EKK0064I          1    x1011905   BS             1.00000000
 EKK0064I         23    x1022012   BS             1.00000000
 EKK0064I         38    x1032031   FX             1.00000000
 EKK0064I         55    x1041902   BS             1.00000000
 EKK0064I         73    x1052175   FX             1.00000000
 EKK0064I         94    x1061343   FX             1.00000000
 EKK0064I        109    x1070549   BS             1.00000000
 EKK0064I        115    x1081995   BS             1.00000000
 EKK0064I        133    x1091762   BS             1.00000000
 EKK0064I        152    x1100609   BS             1.00000000
 EKK0064I        157    x1111273   BS             1.00000000
 EKK0064I        176    x1120569   BS             1.00000000
 EKK0064I        184    x2010902   FX             1.00000000
 EKK0064I        202    x2021204   BS             1.00000000
 EKK0064I        220    x2031242   FX             1.00000000
 EKK0064I        235    x2042456   BS             1.00000000
 EKK0064I        253    x2050913   FX             1.00000000
 EKK0064I        280    x2061223   BS             1.00000000
 EKK0064I        299    x2070924   FX             1.00000000
 EKK0064I        316    x2081223   FX             1.00000000
 EKK0064I        348    x2101243   FX             1.00000000
 EKK0064I        379    x2120307   BS             1.00000000
 EKK0064I        384    x2130884   FX             1.00000000
 EKK0064I        414    x2140314   BS             1.00000000
 EKK0064I        432    x2160756   BS             1.00000000
 EKK0064I        449    x2170892   FX             1.00000000
 EKK0064I        465    x2182066   BS             1.00000000
 EKK0064I        475    x2191993   BS             1.00000000
 EKK0064I        492    x2202044   BS             1.00000000
 EKK0064I        510    x2221213   BS             1.00000000
 EKK0064I        534    x2231223   FX             1.00000000
 EKK0064I        543    x2241233   BS             1.00000000
 EKK0064I        561    x2252456   FX             1.00000000
 EKK0064I        567    x2260308   BS             1.00000000
 EKK0064I        569    x2270326   BS             1.00000000
 EKK0064I        587    x2280893   BS             1.00000000
 EKK0064I        606    x2291191   BS             1.00000000
 EKK0064I        630    x3012095   FX             1.00000000
 EKK0064I        650    x3022045   FX             1.00000000
 EKK0064I        669    x3032105   FX             1.00000000
 EKK0064I        678    x3042311   BS             1.00000000
 EKK0064I        700    x3050522   BS             1.00000000
```

EKK0064I	711	x3062379	BS	1.00000000
EKK0064I	723	x3071932	FX	1.00000000
EKK0064I	734	x3080267	BS	1.00000000
EKK0064I	739	x3090885	FX	1.00000000
EKK0064I	754	x3100955	BS	1.00000000
EKK0064I	772	x3111992	FX	1.00000000
EKK0064I	796	x3122283	FX	1.00000000
EKK0064I	811	x3132002	FX	1.00000000
EKK0064I	829	x3141322	FX	1.00000000
EKK0064I	847	x3152452	FX	1.00000000
EKK0064I	861	x3161911	FX	1.00000000
EKK0064I	871	x3170017	FX	1.00000000
EKK0064I	885	x4010767	FX	1.00000000
EKK0064I	887	x4020974	FX	1.00000000
EKK0064I	908	x4030884	FX	1.00000000
EKK0064I	926	x4040881	FX	1.00000000
EKK0064I	944	x4050305	FX	1.00000000
EKK0064I	962	x4062275	FX	1.00000000
EKK0064I	977	x4070924	FX	1.00000000
EKK0064I	992	x4080914	FX	1.00000000
EKK0064I	1010	x4090944	FX	1.00000000
EKK0064I	1037	x5010901	FX	1.00000000
EKK0064I	1046	x5020202	FX	1.00000000
EKK0064I	1070	x5030993	FX	1.00000000
EKK0064I	1085	x5040963	FX	1.00000000
EKK0064I	1103	x5051263	FX	1.00000000
EKK0064I	1121	x6011323	FX	1.00000000
EKK0064I	1145	x6020975	FX	1.00000000
EKK0064I	1154	x6030865	FX	1.00000000
EKK0064I	1172	x6040945	FX	1.00000000
EKK0064I	1192	x6050861	FX	1.00000000
EKK0064I	1223	x6060893	FX	1.00000000
EKK0064I	1235	x6072013	FX	1.00000000
EKK0064I	1247	x6082003	FX	1.00000000
EKK0064I	1265	x6091003	FX	1.00000000
EKK0064I	1287	x6102417	FX	1.00000000
EKK0064I	1301	x6111913	FX	1.00000000
EKK0064I	1336	x209000n	FX	1.00000000
EKK0064I	1338	x211000n	FX	1.00000000
EKK0064I	1342	x215000n	FX	1.00000000
EKK0064I	1348	x221000n	FX	1.00000000

*** An optimal integer solution has been found ***

*** Application terminated ***

APPENDIX E: OSL OUTPUT FOR "NUMBER OF COURSES WEIGHTING" SCHEDULING VARIATION

```
 Run # 2 - Scheduling Variation where Department Weights based upon
Number of Courses
         being taught.

 EKK0008I Description of Problem SchedMps
 EKK0016I         Matrix has 953 rows, 1398 columns and 13830 entries
 EKK0009I Problem Status
 EKK0006I Optimization Subroutine Library Version 1.3 (76162)
Page 62
 EKK0001I Iteration Number:     65817; Objective Value:
83163.00--Optimal
 EKK0011I    Columns Section                                    Page 63
 EKK0063I            ..Name..  Stat  ......Activity......
 EKK0064I        2  x1011902   BS            1.00000000
 EKK0064I       22  x1022015   BS            1.00000000
 EKK0064I       38  x1032031   FX            1.00000000
 EKK0064I       55  x1041902   FX            1.00000000
 EKK0064I       73  x1052175   FX            1.00000000
 EKK0064I       92  x1061331   BS            1.00000000
 EKK0064I      109  x1070549   BS            1.00000000
 EKK0064I      115  x1081995   FX            1.00000000
 EKK0064I      133  x1091762   BS            1.00000000
 EKK0064I      152  x1100609   FX            1.00000000
 EKK0064I      157  x1111273   FX            1.00000000
 EKK0064I      176  x1120569   BS            1.00000000
 EKK0064I      184  x2010902   FX            1.00000000
 EKK0064I      202  x2021204   BS            1.00000000
 EKK0064I      220  x2031242   BS            1.00000000
 EKK0064I      235  x2042456   BS            1.00000000
 EKK0064I      256  x2050923   FX            1.00000000
 EKK0064I      280  x2061223   FX            1.00000000
 EKK0064I      299  x2070924   BS            1.00000000
 EKK0064I      316  x2081223   FX            1.00000000
 EKK0064I      347  x2101241   BS            1.00000000
 EKK0064I      379  x2120307   BS            1.00000000
 EKK0064I      384  x2130884   BS            1.00000000
 EKK0064I      416  x2140318   FX            1.00000000
 EKK0064I      417  x2150873   FX            1.00000000
 EKK0064I      432  x2160756   BS            1.00000000
 EKK0064I      448  x2170893   BS            1.00000000
 EKK0064I      465  x2182066   FX            1.00000000
 EKK0064I      474  x2191995   FX            1.00000000
 EKK0064I      492  x2202044   BS            1.00000000
 EKK0064I      510  x2221213   BS            1.00000000
 EKK0064I      534  x2231223   FX            1.00000000
 EKK0064I      543  x2241233   FX            1.00000000
 EKK0064I      561  x2252456   BS            1.00000000
 EKK0064I      567  x2260308   BS            1.00000000
 EKK0064I      569  x2270326   FX            1.00000000
 EKK0064I      587  x2280893   FX            1.00000000
 EKK0064I      605  x2291195   FX            1.00000000
```

EKK0064I	629	x3012091	BS	1.00000000
EKK0064I	650	x3022045	FX	1.00000000
EKK0064I	668	x3032101	FX	1.00000000
EKK0064I	677	x3042315	BS	1.00000000
EKK0064I	696	x3050511	FX	1.00000000
EKK0064I	711	x3062379	BS	1.00000000
EKK0064I	723	x3071932	FX	1.00000000
EKK0064I	732	x3080277	BS	1.00000000
EKK0064I	739	x3090885	BS	1.00000000
EKK0064I	754	x3100955	BS	1.00000000
EKK0064I	772	x3111992	FX	1.00000000
EKK0064I	796	x3122283	FX	1.00000000
EKK0064I	813	x3132004	FX	1.00000000
EKK0064I	829	x3141322	FX	1.00000000
EKK0064I	847	x3152452	FX	1.00000000
EKK0064I	859	x3161912	BS	1.00000000
EKK0064I	881	x3170067	BS	1.00000000
EKK0064I	883	x4010757	BS	1.00000000
EKK0064I	887	x4020974	BS	1.00000000
EKK0064I	908	x4030884	BS	1.00000000
EKK0064I	926	x4040881	BS	1.00000000
EKK0064I	941	x4050295	FX	1.00000000
EKK0064I	962	x4062275	FX	1.00000000
EKK0064I	977	x4070924	FX	1.00000000
EKK0064I	995	x4080924	FX	1.00000000
EKK0064I	1010	x4090944	FX	1.00000000
EKK0064I	1039	x5010905	FX	1.00000000
EKK0064I	1046	x5020202	FX	1.00000000
EKK0064I	1073	x5031003	FX	1.00000000
EKK0064I	1082	x5040953	FX	1.00000000
EKK0064I	1103	x5051263	FX	1.00000000
EKK0064I	1121	x6011323	FX	1.00000000
EKK0064I	1142	x6020965	FX	1.00000000
EKK0064I	1154	x6030865	FX	1.00000000
EKK0064I	1172	x6040945	FX	1.00000000
EKK0064I	1190	x6050865	FX	1.00000000
EKK0064I	1217	x6060883	FX	1.00000000
EKK0064I	1236	x6072012	FX	1.00000000
EKK0064I	1250	x6082033	FX	1.00000000
EKK0064I	1265	x6091003	FX	1.00000000
EKK0064I	1307	x6111933	FX	1.00000000
EKK0064I	1336	x209000n	FX	1.00000000
EKK0064I	1338	x211000n	FX	1.00000000
EKK0064I	1348	x221000n	FX	1.00000000
EKK0064I	1397	x610000n	FX	1.00000000

*** An optimal integer solution has been found ***

*** Application terminated ***

APPENDIX F: OSL OUTPUT FOR "NUMBER OF STUDENTS WEIGHTING" SCHEDULING VARIATION

```
 Run # 4 - Department Weights based upon number of Students being
taught
 EKK0008I Description of Problem SchedMps
 EKK0016I        .  Matrix has 953 rows, 1398 columns and 13830 entries
 EKK0009I Problem Status
 EKK3000W Iteration Number:     37223; Objective Value:
84868.00--Infeasible
 EKK0003I The sum of the primal infeasibilities is 4.337215D-07, and
the number of primal infeasibilities is 1
1EKK0011I     Columns Section                                  Page 11
 EKK0063I              ..Name..  Stat  ......Activity......
 EKK0064I          1  x1011905   BS            1.00000000
 EKK0064I         22  x1022015   FX            1.00000000
 EKK0064I         40  x1032042   FX            1.00000000
 EKK0064I         67  x1041892   BS            1.00000000
 EKK0064I         74  x1052172   FX            1.00000000
 EKK0064I         94  x1061343   BS            1.00000000
 EKK0064I        110  x1070629   FX            1.00000000
 EKK0064I        115  x1081995   FX            1.00000000
 EKK0064I        133  x1091762   BS            1.00000000
 EKK0064I        152  x1100609   FX            1.00000000
 EKK0064I        157  x1111273   FX            1.00000000
 EKK0064I        176  x1120569   BS            1.00000000
 EKK0064I        184  x2010902   FX            1.00000000
 EKK0064I        202  x2021204   FX            1.00000000
 EKK0064I        220  x2031242   BS            1.00000000
 EKK0064I        235  x2042456   BS            1.00000000
 EKK0064I        256  x2050923   BS            1.00000000
 EKK0064I        280  x2061223   FX            1.00000000
 EKK0064I        298  x2070923   FX            1.00000000
 EKK0064I        316  x2081223   FX            1.00000000
 EKK0064I        325  x2091005   FX            1.00000000
 EKK0064I        352  x2100935   FX            1.00000000
 EKK0064I        379  x2120307   BS            1.00000000
 EKK0064I        384  x2130884   BS            1.00000000
 EKK0064I        409  x2140297   FX            1.00000000
 EKK0064I        417  x2150873   BS            1.00000000
 EKK0064I        432  x2160756   BS            1.00000000
 EKK0064I        447  x2170895   BS            1.00000000
 EKK0064I        465  x2182066   FX            1.00000000
 EKK0064I        475  x2191993   BS            1.00000000
 EKK0064I        492  x2202044   FX            1.00000000
 EKK0064I        510  x2221213   FX            1.00000000
 EKK0064I        534  x2231223   BS            1.00000000
 EKK0064I        546  x2241243   BS            1.00000000
 EKK0064I        561  x2252456   FX            1.00000000
 EKK0064I        567  x2260308   BS            1.00000000
 EKK0064I        569  x2270326   BS            1.00000000
 EKK0064I        590  x2280903   BS            1.00000000
 EKK0064I        605  x2291195   BS            1.00000000
 EKK0064I        632  x3012101   BS            1.00000000
```

```
EKK0064I     650  x3022045   FX              1.00000000
EKK0064I     666  x3032095   BS              1.00000000
EKK0064I     677  x3042315   BS              1.00000000
EKK0064I     698  x3050523   FX              1.00000000
EKK0064I     710  x3062369   BS              1.00000000
EKK0064I     723  x3071932   FX              1.00000000
EKK0064I     734  x3080267   FX              1.00000000
EKK0064I     739  x3090885   BS              1.00000000
EKK0064I     754  x3100955   FX              1.00000000
EKK0064I     772  x3111992   BS              1.00000000
EKK0064I     796  x3122283   FX              1.00000000
EKK0064I     822  x3132034   FX              1.00000000
EKK0064I     829  x3141322   FX              1.00000000
1EKK0011I   Columns Section                                  Page 12
EKK0063I          ..Name..  Stat  ......Activity......
EKK0064I     847  x3152452   FX              1.00000000
EKK0064I     861  x3161911   FX              1.00000000
EKK0064I     882  x3170068   FX              1.00000000
EKK0064I     883  x4010757   FX              1.00000000
EKK0064I     887  x4020974   FX              1.00000000
EKK0064I     908  x4030884   FX              1.00000000
EKK0064I     926  x4040881   FX              1.00000000
EKK0064I     944  x4050305   FX              1.00000000
EKK0064I     962  x4062275   FX              1.00000000
EKK0064I     977  x4070924   FX              1.00000000
EKK0064I     995  x4080924   FX              1.00000000
EKK0064I    1010  x4090944   FX              1.00000000
EKK0064I    1038  x5010902   FX              1.00000000
EKK0064I    1046  x5020202   FX              1.00000000
EKK0064I    1073  x5031003   FX              1.00000000
EKK0064I    1082  x5040953   FX              1.00000000
EKK0064I    1103  x5051263   FX              1.00000000
EKK0064I    1121  x6011323   FX              1.00000000
EKK0064I    1142  x6020965   FX              0.99999993
EKK0064I    1143  x6020964   FX     0.655040660602D-07
EKK0064I    1154  x6030865   FX              1.00000000
EKK0064I    1172  x6040945   FX              1.00000000
EKK0064I    1191  x6050863   FX              1.00000000
EKK0064I    1217  x6060883   FX              1.00000000
EKK0064I    1235  x6072013   FX              1.00000000
EKK0064I    1250  x6082033   FX              1.00000000
EKK0064I    1265  x6091003   FX              1.00000000
EKK0064I    1307  x6111933   FX              1.00000000
EKK0064I    1338  x211000n   FX              1.00000000
EKK0064I    1348  x221000n   FX              1.00000000
EKK0064I    1397  x610000n   FX              1.00000000

*** An optimal integer solution has been found ***


*** Application terminated ***
```

APPENDIX G: OSL OUTPUT FOR "NUMBER OF COURSE WITH LECTURES GIVEN WEIGHTING" SCHEDULING VARIATION

```
 Run # 3 - Department Weights based upon Number of Courses being taught
with each
           department's siminars weighted highly to insure scheduling
at first preference

 EKK0008I Description of Problem SchedMps
 EKK0016I        Matrix has 953 rows, 1398 columns and 13830 entries
 EKK0009I Problem Status
 EKK0001I Iteration Number:    39012; Objective Value:
155038.0--Optimal
1EKK0011I     Columns Section                                     Page 12
 EKK0063I            ..Name..  Stat  ......Activity......
 EKK0064I        3  x1011903   BS              1.00000000
 EKK0064I       25  x1022055   FX              1.00000000
 EKK0064I       37  x1032032   FX              1.00000000
 EKK0064I       55  x1041902   FX              1.00000000
 EKK0064I       73  x1052175   FX              1.00000000
 EKK0064I       91  x1061333   BS              1.00000000
 EKK0064I      109  x1070549   FX              1.00000000
 EKK0064I      115  x1081995   BS              1.00000000
 EKK0064I      133  x1091762   FX              1.00000000
 EKK0064I      152  x1100609   BS              1.00000000
 EKK0064I      157  x1111273   FX              1.00000000
 EKK0064I      176  x1120569   FX              1.00000000
 EKK0064I      184  x2010902   FX              1.00000000
 EKK0064I      202  x2021204   FX              1.00000000
 EKK0064I      220  x2031242   BS              1.00000000
 EKK0064I      235  x2042456   BS              1.00000000
 EKK0064I      256  x2050923   FX              1.00000000
 EKK0064I      280  x2061223   BS              1.00000000
 EKK0064I      299  x2070924   FX              1.00000000
 EKK0064I      316  x2081223   BS              1.00000000
 EKK0064I      348  x2101243   BS              1.00000000
 EKK0064I      379  x2120307   BS              1.00000000
 EKK0064I      384  x2130884   BS              1.00000000
 EKK0064I      415  x2140317   FX              1.00000000
 EKK0064I      420  x2150883   FX              1.00000000
 EKK0064I      433  x2160766   FX              1.00000000
 EKK0064I      451  x2170903   FX              1.00000000
 EKK0064I      465  x2182066   FX              1.00000000
 EKK0064I      474  x2191995   FX              1.00000000
 EKK0064I      492  x2202044   FX              1.00000000
 EKK0064I      510  x2221213   BS              1.00000000
 EKK0064I      534  x2231223   FX              1.00000000
 EKK0064I      546  x2241243   BS              1.00000000
 EKK0064I      561  x2252456   BS              1.00000000
 EKK0064I      567  x2260308   BS              1.00000000
 EKK0064I      569  x2270326   BS              1.00000000
 EKK0064I      590  x2280903   BS              1.00000000
 EKK0064I      605  x2291195   FX              1.00000000
 EKK0064I      629  x3012091   FX              1.00000000
```

```
 EKK0064I        650  x3022045   FX          1.00000000
 EKK0064I        668  x3032101   FX          1.00000000
 EKK0064I        678  x3042311   FX          1.00000000
 EKK0064I        695  x3050513   BS          1.00000000
 EKK0064I        711  x3062379   FX          1.00000000
 EKK0064I        723  x3071932   BS          1.00000000
 EKK0064I        732  x3080277   FX          1.00000000
 EKK0064I        739  x3090885   BS          1.00000000
 EKK0064I        754  x3100955   FX          1.00000000
 EKK0064I        772  x3111992   BS          1.00000000
 EKK0064I        796  x3122283   FX          1.00000000
 EKK0064I        812  x3132003   FX          1.00000000
 EKK0064I        829  x3141322   FX          1.00000000
 EKK0064I        847  x3152452   FX          1.00000000
1EKK0011I     Columns Section                                 Page 13
 EKK0063I             ..Name..  Stat  ......Activity......
 EKK0064I        861  x3161911   FX          1.00000000
 EKK0064I        881  x3170067   FX          1.00000000
 EKK0064I        883  x4010757   FX          1.00000000
 EKK0064I        887  x4020974   FX          1.00000000
 EKK0064I        908  x4030884   FX          1.00000000
 EKK0064I        926  x4040881   FX          1.00000000
 EKK0064I        941  x4050295   FX          1.00000000
 EKK0064I        962  x4062275   FX          1.00000000
 EKK0064I        977  x4070924   FX          1.00000000
 EKK0064I        992  x4080914   FX          1.00000000
 EKK0064I       1010  x4090944   FX          1.00000000
 EKK0064I       1037  x5010901   FX          1.00000000
 EKK0064I       1046  x5020202   FX          1.00000000
 EKK0064I       1073  x5031003   FX          1.00000000
 EKK0064I       1082  x5040953   FX          1.00000000
 EKK0064I       1103  x5051263   FX          1.00000000
 EKK0064I       1124  x6011273   FX          1.00000000
 EKK0064I       1145  x6020975   FX          1.00000000
 EKK0064I       1154  x6030865   FX          1.00000000
 EKK0064I       1174  x6040942   FX          1.00000000
 EKK0064I       1199  x6050895   FX          1.00000000
 EKK0064I       1211  x6062003   FX          1.00000000
 EKK0064I       1232  x6072003   FX          1.00000000
 EKK0064I       1262  x6090993   FX          1.00000000
 EKK0064I       1283  x6102396   FX          1.00000000
 EKK0064I       1310  x6111943   FX          1.00000000
 EKK0064I       1336  x209000n   FX          1.00000000
 EKK0064I       1338  x211000n   FX          1.00000000
 EKK0064I       1348  x221000n   FX          1.00000000
 EKK0064I       1395  x608000n   FX          1.00000000

*** An optimal integer solution has been found ***


*** Application terminated ***
```

APPENDIX H: EDSSS USER MANUAL

Preface

This user manual is written in support of the Educational Decision Support and Scheduling System (EDSSS), developed 1Lt Shane Knighton, as part of the thesis research entitled "A Value Focused Approach to Academic Course Scheduling." This manual assumes the user has a working knowledge of MicroSoft Excel 97 and DOS. The programs use code written in Visual Basic within MS Excel. The user operating EDSSS is assumed to be the academic course scheduler and is herein referred to as the scheduler. Notes and Cautions are provided in *italics* throughout the manual. A Note is used to provide the user with information that will help EDSSS run smoothly, a Caution provides information that may cause the program to execute incorrectly.

Introduction

The Educational Decision Support and Scheduling System (EDSSS) assigns academic courses for the School of Engineering (EN) of AFIT to days, times, and rooms. The system will not allow student or instructor conflicts and will not utilize more rooms than are available within the EN building. If more in-depth information is required about the methodology used by EDSSS, the user is referred to the thesis by 1Lt Shane Knighton entitled "A Value Focused Thinking Approach to Academic Course Scheduling."

EDSSS is comprised of three different programs:

1) Electronic Questionnaire
2) Mixed Integer Program Problem Generator

3) Optimization Subroutine Library

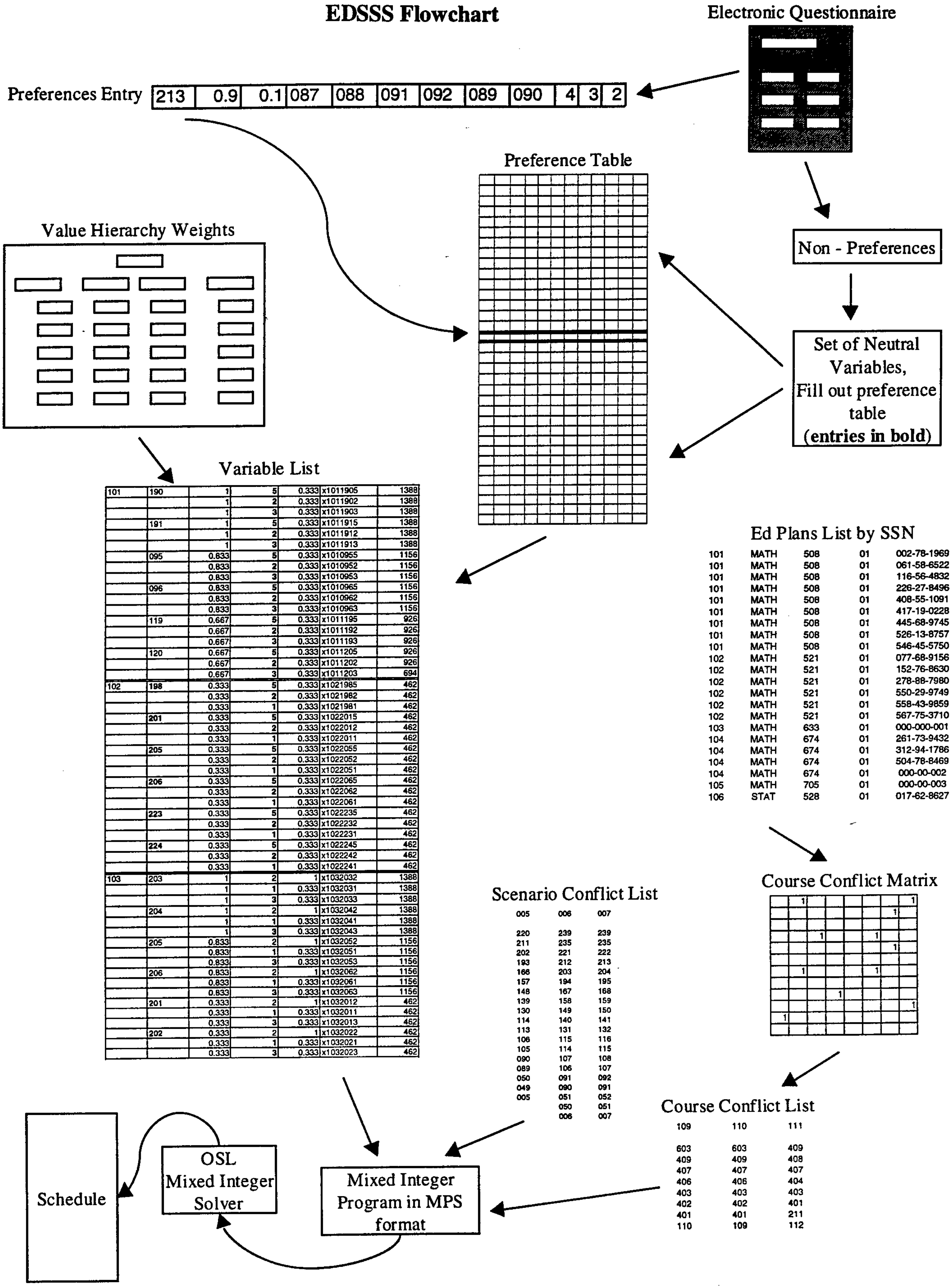
The flowchart on the following page gives the user an overview of how each of these programs interact. A more detailed description of each program is provided.

Prior to using EDSSS to produce an academic schedule, a finalized course listing from each department is required. The course listing must contain the name of the instructor for each course listed. The scheduler must then assign a three-digit course ID number to each of the courses.

NOTE: It is suggested that the ID numbers be assigned in the following manner. The first digit of a course offered by ENC is 1; the final two digits are assigned as the order listed on the proposed course listing. In a similar fashion, the first digit of courses offered by ENG, ENP, ENS, ENV, and ENY will be 2, 3, 4, 5, and 6 respectively.

Additionally, a query from the Education Plans database is needed prior to scheduling. The query must list the department, course number, section/lab number, and the SSN of all students enrolled in that course. The course ID number is added to the first column of the list. The ID number must be repeated for every SSN in the same course. The query must be in the form shown by Figure 1 of this manual.

EDSSS Flowchart



Caution: The list must be sorted by ID number. All identical ID numbers must be grouped together in the list. The program assumes that if a new ID number is encountered, all SSN for the previous ID number have been counted.

Caution: The Ed Plan List must contain information for every course given an ID. If the list is not complete, the scheduler must include the missing courses in the list prior to scheduling. The scheduler must enter the missing courses in the same format as the rest of the list, however no SSN should be given.

101	MATH	508	01	002-78-1969
101	MATH	508	01	061-58-6522
101	MATH	508	01	116-56-4832
101	MATH	508	01	226-27-8496
101	MATH	508	01	408-55-1091
101	MATH	508	01	417-19-0228
101	MATH	508	01	445-68-9745
101	MATH	508	01	526-13-8757
101	MATH	508	01	546-45-5750
102	MATH	521	01	077-68-9156
102	MATH	521	01	152-76-8630
102	MATH	521	01	278-88-7980
102	MATH	521	01	550-29-9749
102	MATH	521	01	558-43-9859
102	MATH	521	01	567-75-3710
103	MATH	633	01	000-000-001
104	MATH	674	01	261-73-9432
104	MATH	674	01	312-94-1786
104	MATH	674	01	504-78-8469
104	MATH	674	01	000-00-002
105	MATH	705	01	000-00-003
106	STAT	528	01	017-62-8627
106	STAT	528	01	023-52-7817
106	STAT	528	01	263-63-8302
106	STAT	528	01	399-68-3166
106	STAT	528	01	414-49-4391
106	STAT	528	01	459-79-1577
106	STAT	528	01	460-33-1803
106	STAT	528	01	480-60-4053
107	STAT	528	91	017-62-8627
107	STAT	528	91	023-52-7817
107	STAT	528	91	263-63-8302
107	STAT	528	91	399-68-3166
107	STAT	528	91	414-49-4391
107	STAT	528	91	459-79-1577
107	STAT	528	91	460-33-1803
107	STAT	528	91	480-60-4053

Figure 1: Example of Ed Plan Query

Electronic Questionnaire

The electronic questionnaire is a set of Windows dialogue boxes which run in MS Excel. The purpose of the questionnaire is to capture the day/time preferences, day/time non-preferences, and room preferences of the instructor for each course to be scheduled. This questionnaire can be delivered to each instructor via E-mail or place in a central location accessible to everyone being scheduled.

Note: Instructors teaching more that one course must fill out a different questionnaire for each course to be scheduled.

The initial screen offers the user two options. Single clicking on the INSTRUCTIONS option button provides instructions on filling out the questionnaire. Single clicking on the FACULTY PREFERENCES option button displays the following dialogue box.

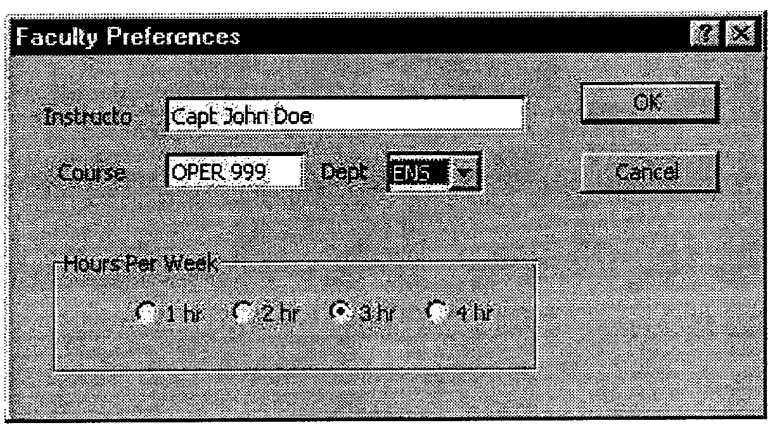


Figure 2: Faculty Preferences Dialogue Box # 1

The instructors must fill in their name, course, department, and course ID. The ID number should be assigned to each instructor prior to delivering the questionnaire. Additionally, the instructor must indicate the number of hours their course meets per week.

Caution: The number of hours the course meets per week must be indicated correctly. The choices for day combinations differ according to the number of hours indicated.

Once the information has been entered, single click the OK button, this will automatically display the dialogue box containing the available day/time scenarios. The instructor can fill out the preferences and non-preferences by selecting an entry from the appropriate dropdown list. The day/time weight must be placed in the appropriate box and be within the range of 0 to 1. An example of the preferences dialogue box is shown in Figure 3 of this manual.

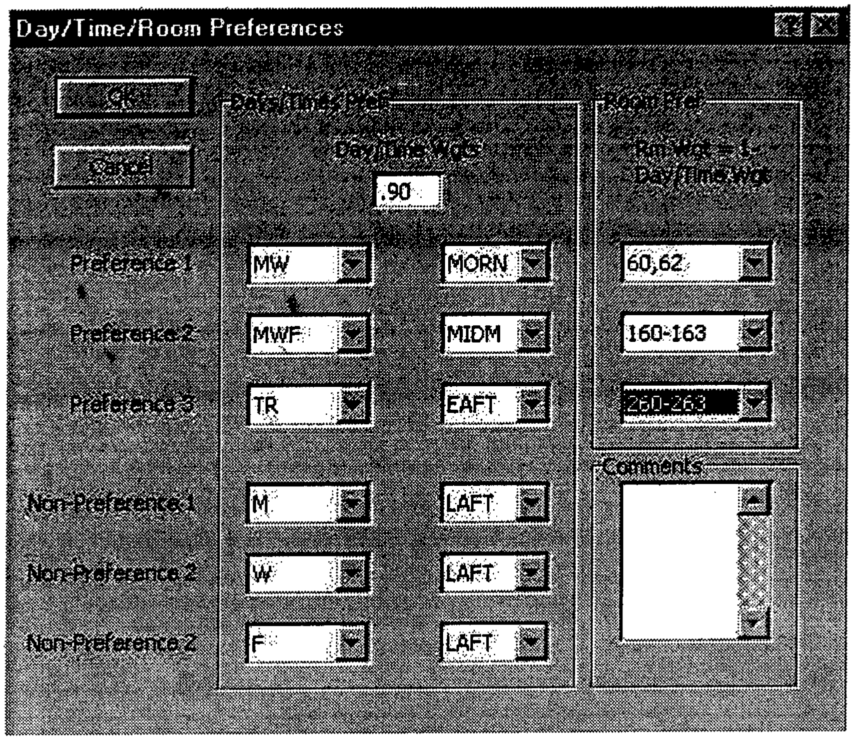


Figure 3: Faculty Preferences Dialogue Box #2

Note: If no day/time weight is indicated the weighting is selected by the scheduler.

Once the instructor completes the questionnaire, the preferences are put into Range B1:B12 on the PREFERENCES sheet of the electronic questionnaire. This Range is the entry for the course in the Preference Table of the Mixed Integer Problem Generator. The instructor's non-preferences for day/time scenarios are shown in Range E1:E6.

Mixed Integer Problem Generator

The Mixed Integer Problem Generator is an MS Excel spreadsheet using a suite of Visual Basic Modules. The purpose of the problem generator is to construct the Mixed Integer Academic Scheduling Problem in Mathematical Programming System (MPS) format. This file is read by OSL, the Mixed Integer Solver. Open the problem generator in MS Excel 97.

The scheduler is required to update four Ranges before running the problem generator. Initially, the scheduler should enter the weights for each department and the courses to be scheduled on the VALUE HIERARCHY sheet.

Note: The weights for each Department should come from the Dean or his staff, while the weights for each course are given by the respective Department Heads.

Caution: An entry in the Value Hierarchy, i.e. course ID and weight, is required for every course in the Preference Table.

The three remaining Ranges to be updated are located on the CODE DATA sheet. The Ed Plan query, in the format shown by Figure 1 of this manual, should be placed in Range A12:D12. The Preference Table is built by combining the entries from all the instructors' individual preference entries. These entries were obtained via the Electronic Questionnaire, refer to that portion of this manual for further information. The entries are placed on consecutive rows, with the first entry being placed in Range I12:T12.

If the instructor did not completely fill out the questionnaire, the scheduler using neutral preferences can complete the entry. Neutral preferences are defined as the day/time scenarios not given as non-preferences by the instructor via the electronic questionnaire. Neutral preferences for day/time scenarios and room groups must be indicated as such by using **bold font** for the neutral scenario and room group numbers in the preferences entry for that course.

The final range is located in cells, C2:C7. The number of courses to be scheduled is entered into cell C2. Cells C3:C5 are used by the program and should not be changed. The path and filename of the file created that contains the Mixed Integer Program in MPS is entered in Cells C6:C7. Once all of the above tasks have been completed, single clicking the WRITE MPS FILE button on the CODE DATA sheet creates the MPS file named in cell C7. The following figure shows an updated CODE DATA sheet.

Educational Decision Support & Scheduling System
AFIT School of Engineering
Developed In Support of Thesis Research Conducted by: 1Lt Shane Knighton /GOF
Advisors: LtC Jack Jackson
Dr Dick Deckro

Education Plan Query

101	MATH	508	01	002-78-1969
101	MATH	508	01	061-58-6522
101	MATH	508	01	116-56-4832
101	MATH	508	01	226-27-8496
101	MATH	508	01	408-55-1091
101	MATH	508	01	417-19-0228
101	MATH	508	01	445-68-9745
101	MATH	508	01	526-13-8757
101	MATH	508	01	546-45-5750
102	MATH	521	01	077-68-9156
102	MATH	521	01	152-76-8630
102	MATH	521	01	278-88-7980
102	MATH	521	01	550-29-9749
102	MATH	521	01	558-43-9859
102	MATH	521	01	567-75-3710
103	MATH	633	01	000-000-001
104	MATH	674	01	261-73-9432
104	MATH	674	01	312-94-1786
104	MATH	674	01	504-78-8469
104	MATH	674	01	000-00-002
105	MATH	705	01	000-00-003
106	STAT	528	01	017-62-8627
106	STAT	528	01	023-52-7817

Value Table

Course ID	Day/Time Wgt	Room Wgt	Scen 1	Scen 1	Scen 2	Scen 2
101	1	0	190	191	095	096
102	0.5	0.5	198	201	205	206
103	1	0	203	204	205	206
104	0.8	0.2	190	191	199	200
105	1	0	217	218	203	204
106	0.5	0.5	133	134	160	161
107	0.5	0.5	054	062	070	055
108	0.75	0.25	199	200	217	218
109	0.75	0.25	176	177	133	134
110	1	0	059	060	061	055
111	1	0	127	128	131	132
112	0.9	0.1	055	056	059	060
201	0.8	0.2	089	090	123	124
202	0.9	0.1	119	120	087	088
203	0.8	0.2	123	124	091	092
204	0.5	0.5	245	244	243	241
205	0.9	0.1	091	092	093	105
206	0.7	0.3	089	090	121	122
207	1	0	099	100	091	092
208	0.9	0.1	119	120	121	122
209	1	0	100	098	101	099
210	1	0	123	124	125	093
211	0.9	0.1	087	088	089	090

Figure 4: Updated CODE DATA Sheet

Optimization Subroutine Library (OSL), Mixed Integer Solver

OSL is a powerful mixed integer solver from IBM. It is run on a dedicated WindowsNT workstation in the Center for Modeling, Simulations and Analysis, room 133B in building 640. The solver runs in DOS. The command line to run the solver for the purpose of creating an academic schedule is as follows:

```
oslmslv -maxmin=max -dspace=10000000 -imaxiter=9999999 -maxsols=9999999
<inputfile> outputfile
```

The input filename is the path and filename placed in Cell C6:C7 on the CODE DATA sheet of the problem generator. The user is referred to that section of the manual for

more information. The output filename is user defined and will contain the solution to the Mixed Integer Program. The user is referred to the OSL user manual for further information about OSL.

The solution to the Mixed Integer Program is at the end of the output file. The solution provides the variable names that describe the course scheduled, as well as the day/time scenario and room group to which the course was assigned. The first three digits after the letter 'x' are the course ID. The next three digits give the day/time scenario, and the last digit the room group. Refer to Tables 1 and 2 for definitions of the various room groups and day/time scenarios. The scheduler simply translates the variables into an academic course schedule. The scheduler assigns specific rooms within a particular room group.

If a variable is returned of the form, x122000n, then the course was not scheduled. The scheduler has the choice of scheduling the course manually or rerunning the process. To rerun the process, add or change neutral preferences in the preference entry of the Preference Table for the particular course. The Preference Table is located on the CODE DATA sheet of the problem generator.

Caution: All neutral preferences, for either day/time or rooms, must be in bold font.

Note: Neutral preferences are determined by eliminating the non-preferred day/time scenarios given by the instructor via the electronic questionnaire.

Table 1: Room Groups

Room Group	Classroom Numbers	Capacity
1	60,62	35
2	160-163	30
3	260-263	28
4	172, 176B	35&24
5	64A,164A,176A	10
6	Labs 241,265,121	25
7	Lecture Hall 121	54
8	Lecture Hall 230	54
9	Computer Lab 165	16

Table 2: Day/Time Scenarios

	Days of the Week	Start Times (on the hour)	Scenario ID #
1 Hour Class	M	0800 -1600	001 - 009
	T	0800 -1600	010 - 018
	W	0800 -1600	019 - 027
	R	0800 -1600	028 - 036
	F	0800 -1600	037 - 045
2 Hour Class	M	0800 -1500	046 - 053
	T	0800 -1500	054 - 061
	W	0800 -1500	062 - 069
	R	0800 -1500	070 - 077
	F	0800 -1500	078 - 085
3 or 4 Hour Class	MW	0800 -1500	086 - 093
	TR	0800 -1500	094 - 101
	MR	0800 -1500	102 - 109
	MF	0800 -1500	110 -117
	TF	0800 -1500	118 - 125
3 Hour Class	MWF	0800 -1600	126 - 134
	MTR	0800 -1600	135 - 143
	MTF	0800 -1600	144 - 152
	MWR	0800 -1600	153 - 161
	MRF	0800 -1600	162 - 170
	TWF	0800 -1600	171 - 179
	TRF	0800 -1600	180 - 188
4 Hour Class	MTWR	0800 -1600	189 - 197
	MTWF	0800 -1600	198 - 206
	MTRF	0800 -1600	207 - 215
	MWRF	0800 -1600	216 - 224
	TWRF	0800 -1600	225 - 233
6 Hour Lab	MW	0900	234
	MW	1300	235
	TR	0900	236
	TR	1300	237
3 Hour Lab	M	0900	238
	M	1300	239
	T	0900	240
	T	1300	241
	W	0900	242
	W	1300	243
	R	0900	244
	R	1300	245

APPENDIX I: PREFERENCE TABLE FOR SPRING QUARTER 98 SCHEDULE

101	1	0	190	191	095	096	119	120	**5**	**2**	3
102	0.5	0.5	**198**	**201**	**205**	**206**	**223**	**224**	**5**	**2**	1
103	1	0	203	204	205	206	**201**	**202**	2	**1**	3
104	0.8	0.2	190	191	199	200	189	**198**	2	3	4
105	1	0	217	218	203	204	095	096	5	2	3
106	0.5	0.5	**133**	**134**	**160**	**161**	**178**	**179**	**3**	**1**	2
107	0.5	0.5	054	**062**	**070**	**055**	**063**	**071**	9		
108	0.75	0.25	199	200	217	218	**201**	**219**	5	**4**	2
109	0.75	0.25	176	177	133	134	**178**	**179**	2	**3**	5
110	1	0	059	060	061	055	056	**057**	9		
111	1	0	127	128	131	132	133	134	3	4	2
112	0.9	0.1	055	056	059	060	061	**054**	9		
201	0.8	0.2	089	090	123	124	**121**	**122**	2	1	3
202	0.9	0.1	119	120	087	088	121	122	4	1	7
203	0.8	0.2	123	124	091	092	121	122	2	3	1
204	0.5	0.5	245	**244**	**243**	**241**	**239**	**242**	6	7	8
205	0.9	0.1	091	092	093	105	106	**090**	3	4	2
206	0.7	0.3	089	090	121	122	**091**	**123**	3	**1**	4
207	1	0	099	100	091	092	**101**	**093**	**3**	**4**	**2**
208	0.9	0.1	119	120	121	122	123	124	3	**2**	**1**
209	1	0	100	098	**101**	**099**	**092**	**093**	**5**	**4**	**2**
210	1	0	123	124	125	093	**108**	**109**	5	**1**	**3**
211	0.9	0.1	087	088	089	090	091	092	3	**5**	**4**
212	0.5	0.5	030						7	**8**	
213	0.9	0.1	087	088	091	092	089	090	4	3	2
214	0.5	0.5	011	012	013	029	030	031	**4**	**7**	**8**
215	1	0	087	088	091	092	093		3	2	1
216	0.5	0.5	075	**076**	**073**	**074**	**071**	**072**	6		
217	1	0	093	091	092	089	090	**088**	5	3	2
218	0.75	0.25	203	204	205	206	201	202	6	**4**	**1**
219	1	0	199	200	198	203	204		**5**	**3**	**2**
220	0.99	0.01	203	204	199	200	198		4	3	2
221	1	0	095						**5**	**1**	**4**
222	0.75	0.25	120	121	087	088	**089**	**090**	3	2	**5**
223	0.9	0.1	099	100	121	122	**097**	**098**	3	**5**	**1**
224	1	0	123	124	121	122	091	092	3	5	2
225	0.5	0.5	245	**244**	**243**	**241**	**239**	**242**	6		
226	0.5	0.5	030						8	**7**	
227	0.5	0.5	032	**031**	**033**	**030**	**034**	**029**	6	**4**	**1**
228	0.75	0.25	089	090	119	120	**121**	**122**	3	2	1
229	1	0	119	120	123	124	**087**	**088**	**5**	**1**	**2**
301	0.5	0.5	**207**	**208**	**209**	**210**	**211**	**212**	**1**	**5**	**4**
302	0.8	0.2	199	200	203	204	**205**	**206**	5	**3**	**2**
303	0.5	0.5	**207**	**208**	**209**	**210**	**211**	**212**	**1**	**5**	**4**

304	1	0	231	230	229	228	227	226	**5**	**1**	2
305	1	0	051	052	048	047	046		**3**	**1**	2
306	1	0	236	237	**234**	**235**			9		
307	0.5	0.5	190	191	192	193	**194**	**195**	2	3	[illegible]
308	0.5	0.5	027	026					7	8	
309	1	0	087	088	089	090	091	092	**5**	**1**	4
310	1	0	095	096	097	098	099	100	**5**	**1**	4
311	0.5	0.5	199	200	208	209	**217**	**218**	2	**1**	5
312	0.5	0.5	**226**	**227**	**228**	**229**	**230**	**231**	**3**	**1**	2
313	1	0	199	200	201	202	203	204	2	3	4
314	0.5	0.5	131	132	**130**	**129**	**128**	**127**	2	**1**	3
315	0.5	0.5	241	245	**242**	**244**			**2**	**1**	3
316	1	0	190	191	194	195	189		2	3	1
317	0.5	0.5	**001**	**002**	**003**	**004**	**005**	**006**	**7**	**8**	
401	0.5	0.5	075	076					7	8	
402	0.9	0.1	097	098	099	100	095	096	4	3	2
403	0.9	0.1	087	088	099	100	091	092	4	3	2
404	0.9	0.1	087	088	099	100	091	092	1	2	4
405	0.5	0.5	029	030	038	039	002	003	5	7	8
406	0.9	0.1	226	227	228	229	225		5	4	2
407	0.8	0.2	091	092	099	100	087	088	4	2	3
408	0.7	0.3	091	092	099	100	087	088	4	2	3
409	0.8	0.2	094	086	**126**	**095**	**087**	**096**	4	**3**	**2**
501	1	0	087	088	089	090	091	092	1	2	5
502	0.8	0.2	020	021	011	012	029	030	2	3	**1**
503	0.5	0.5	095	096	099	100	087	088	3	2	1
504	1	0	095	096	097	098	099	100	3	**2**	**1**
505	0.5	0.5	086	126	**087**	**088**	**127**	**128**	3	**2**	**1**
601	0.85	0.15	131	132	127	128	099	100	3	**2**	**1**
602	0.5	0.5	**094**	**095**	**096**	**097**	**098**	**099**	**5**	**4**	**3**
603	0.5	0.5	**086**	**087**	**088**	**089**	**090**	**091**	**5**	**3**	**1**
604	0.5	0.5	**094**	**095**	**096**	**097**	**098**	**099**	**5**	**4**	**2**
605	0.5	0.5	**086**	**087**	**088**	**089**	**090**	**091**	**5**	**3**	**1**
606	0.9	0.1	199	200	087	088	**201**	**089**	3	2	**1**
607	0.5	0.5	**198**	**199**	**200**	**201**	**202**	**203**	**3**	**2**	**4**
608	0.35	0.65	199	200	203	204	190	191	3	2	**4**
609	0.5	0.5	099	100	119	120	230	231	3	2	4
610	1	0	238	239	241	240	234	242	**6**	**7**	**8**
611	0.5	0.5	190	191	192	193	194	195	3	**2**	**1**

APPENDIX J: ED PLANS QUERY FOR SPRING QUARTER 98 SCHEDULE

101	MATH	508	01	002-78-1969
101	MATH	508	01	061-58-6522
101	MATH	508	01	116-56-4832
101	MATH	508	01	226-27-8496
101	MATH	508	01	408-55-1091
101	MATH	508	01	417-19-0228
101	MATH	508	01	445-68-9745
101	MATH	508	01	526-13-8757
101	MATH	508	01	546-45-5750
102	MATH	521	01	077-68-9156
102	MATH	521	01	152-76-8630
102	MATH	521	01	278-88-7980
102	MATH	521	01	550-29-9749
102	MATH	521	01	558-43-9859
102	MATH	521	01	567-75-3710
103	MATH	633	01	000-000-001
104	MATH	674	01	261-73-9432
104	MATH	674	01	312-94-1786
104	MATH	674	01	504-78-8469
104	MATH	674	01	000-00-002
105	MATH	705	01	000-00-003
106	STAT	528	01	017-62-8627
106	STAT	528	01	023-52-7817
106	STAT	528	01	263-63-8302
106	STAT	528	01	399-68-3166
106	STAT	528	01	414-49-4391
106	STAT	528	01	459-79-1577
106	STAT	528	01	460-33-1803
106	STAT	528	01	480-60-4053
107	STAT	528	91	017-62-8627
107	STAT	528	91	023-52-7817
107	STAT	528	91	263-63-8302
107	STAT	528	91	399-68-3166
107	STAT	528	91	414-49-4391
107	STAT	528	91	459-79-1577
107	STAT	528	91	460-33-1803
107	STAT	528	91	480-60-4053
108	STAT	583	01	269-70-2117
108	STAT	583	01	453-13-1389
108	STAT	583	01	529-43-6216
108	STAT	583	01	555-85-8988
109	STAT	696	01	135-66-3641
109	STAT	696	01	145-76-4239
109	STAT	696	01	155-62-9418
109	STAT	696	01	167-52-5679
109	STAT	696	01	197-48-0279
109	STAT	696	01	230-25-4803
109	STAT	696	01	288-58-2383
109	STAT	696	01	298-72-3524
109	STAT	696	01	307-90-7774

109	STAT	696	01	323-80-4274
109	STAT	696	01	334-60-9745
109	STAT	696	01	407-06-8356
109	STAT	696	01	410-43-5582
109	STAT	696	01	426-06-7661
109	STAT	696	01	441-76-2966
109	STAT	696	01	452-37-8068
109	STAT	696	01	452-93-3772
110	STAT	696	91	135-66-3641
110	STAT	696	91	145-76-4239
110	STAT	696	91	155-62-9418
110	STAT	696	91	167-52-5679
110	STAT	696	91	197-48-0279
110	STAT	696	91	230-25-4803
110	STAT	696	91	288-58-2383
110	STAT	696	91	298-72-3524
110	STAT	696	91	307-90-7774
110	STAT	696	91	323-80-4274
110	STAT	696	91	334-60-9745
110	STAT	696	91	407-06-8356
110	STAT	696	91	410-43-5582
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13. ABSTRACT *(Maximum 200 words)*
In 1997, the School of Engineering of the United States Air Force Institute of Technology began exploring ways of automating the academic course scheduling process. The administration desired an expedient approach for course scheduling which supports the institute's mission of "providing scientific and technological education" to officers from all branches of military service, as well as international military forces. The scheduling approach needed to be flexible, efficient, and represent the institute's values and principles. Decision Analysis (DA) and specifically, Value Focused Thinking (VFT), is used to decompose the complex problem of academic course scheduling and determine the factors that are important in a schedule. An MS Excel based Decision Support System generates a Mixed Integer Program (MIP). The MIP formulation combines the institute's goals with facility constraints, faculty preferences, student preferences, and administration guidance to develop an academic course schedule representative of the institute's values.

14. SUBJECT TERMS
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