Academic Scheduling

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Abstract. As the cost of higher education rises, it is becoming increasingly important for colleges and universities to examine how well they are meeting student needs. In addition to the quality of instruction being offered, this includes the availability of courses required to fulfill student degree objectives. One of the greatest unanticipated costs facing many college students is having to pay an extra semester's or year's tuition because they were unable to take all of the courses required for graduation within the expected (usually four year) time frame. A primary goal of university academic scheduling processes should, therefore, be to maximize the probability that all students will receive the courses they require to meet their degree requirements in a timely manner.

It is essential for university administrators who are responsible for the creation of the schedule of classes and the assignment of students to these classes to understand the effects of their decisions on the operation of the university. They can be far reaching: from the educational opportunities created or denied students, to the budgetary bottom line of making efficient use of resources. The purpose of this article is to relate some of these effects so that the reader can better meet student needs.

1 The Schedule of Classes

Both aspects of the scheduling process—creation of the schedule of classes and assignment of individual students to classes—are important to maximizing the student's chance of receiving the courses she requires for a degree. The process starts with building a schedule of classes that helps expand the choice of courses available to the student.

The schedule of classes represents a coordination of the staff, facility, and time resources necessary to offer instructional courses. The choice of courses available to a student is a function of how all of these resources are managed. A limited number of faculty are qualified to teach any given course. The number and size of rooms available are also a constraint. Careful attention to curricular requirements and the relationship between the times courses are taught is essential to avoiding potential conflicts. Making full use of available time is also critical.

E. Burke, M. Carter (Eds.): PATAT'97, LNCS 1408, pp. 223-236, 1998.

2 The Academic Week and Scheduling Time Patterns

The length of the academic week and variations in time patterns used in constructing a schedule of classes play important roles in the effectiveness of the academic schedule. The academic week is the set of days and times during which instructional activity occurs. It may include or exclude the noon hour, evenings, or weekends. Some campuses have different academic weeks for programs geared to different populations (e.g. daytime hours on weekdays for "traditional" students and evenings and/or weekends for working members of the community). In this case, the principles discussed below can be applied to each academic week. Overlaps will provide both additional course opportunities and additional resource constraints. Longer academic weeks provide greater opportunity to avoid scheduling conflicts.

Time patterns are the configurations of days and hours to be used in setting up the schedule of classes, such as MWF 9:00. If a standard set of patterns is chosen, with compatible starting and ending times, schedules will fit together more easily. If patterns are dissimilar, more conflicts will occur within a given academic week. Patterns of hours for laboratory classes vary greatly from those for lectures or recitations but should still be chosen wisely to fit together with one another in the best possible manner (e.g. all three–hour labs are scheduled from 8–11 a.m., 11 a.m.–2 p.m., or 2–5 p.m.). Curricula that require many laboratory hours of instruction have space and time frameworks that are more complex and require an academic week with more available time patterns than do curricula without laboratory classes.
Most institutions have a five or ten minute break between class periods, but some have adopted fifteen or twenty minute breaks. The effect of longer class breaks is a major reduction in instructional time if class periods are shortened, or a reduction in the number of class periods available in the academic week. Institutions should carefully examine the rationale behind such policies. Isolated lateness to classes should not precipitate a campus–wide policy of longer breaks when relocating a class might solve the problem. Planning for campus buildings should include consideration of travel times between instructional facilities. While course offerings in specialized curricula may be located on the perimeter of campus, scheduling core courses to outlying rooms is more likely to create difficulties.

3 Scheduling Rationale

While it may seem desirable to build a schedule that accommodates faculty and student time preferences to the greatest extent possible, this generally works contrary to the primary goal of meeting student course needs. Since there is a tendency by all to avoid the least popular days or hours, such a policy effectively collapses the

schedule into a shorter academic week and increases the probability of conflicts. Effort is required to broaden the times utilized in order to satisfy the diverse course needs of the total student population.

The tendency to queue at prime times, is neither academically sound nor economically appropriate. Figure 1 offers a simplified illustration. If all courses were taught at one time, a student's choice of courses would be limited to one per term. Consequently, his ability to progress toward a degree would be severely hampered. Staff and facility requirements would also be at a maximum since a different instructor and room would be required for each course and section offered. On the other hand, if all courses were taught at different times, students could select any set of courses offered with no conflicts in hours. Their ability to progress would be limited only by their own capabilities. In addition, staff and facility resources could be minimized. Theoretically, since there would be no time conflicts, one extraordinarily talented professor could teach all courses. Similarly, if one room were suitable for all of the courses offered, only one room would be required.

In general, an institution that operates on a twenty-hour week is much more restrictive in its course selectivity and less effective in its use of staff and space than an institution that operates on a forty–hour week. That is, the effectiveness of the master schedule of classes is dependent on the distribution of classes over as broad a weekly time base as institutional policy will permit. The more usable hours in the academic week, the more effective the system. Such a schedule will provide a greater selectivity of courses and more utilization of staff and space resources.

In practice, neither of the extremes in Figure 1 is a viable plan for scheduling. Even the "distributed" extreme is limited by the number of hours in the academic week as compared to the number of courses offered. There must certainly be more than one course per period if there are more than forty one–hour courses in a forty hour academic week. If there are, say, two hundred courses, at best there will be five courses per period. More typically there would be thirteen three–hour time patterns in a forty hour academic week, requiring that fifteen to sixteen courses be offered each pattern of hours and thus increasing the probability of conflicts between courses. Further, as the time patterns become more varied and complex, such as required for a chemistry course with a one–hour lecture, two separate one–hour recitation sessions, and one three–hour laboratory, it becomes quite apparent that even fifteen to sixteen courses per time pattern would be a bare minimum, and more than likely many more courses will need to be offered at a given period, again increasing the probability of conflicts.

The interrelationship of time patterns, length of academic week, and number of course offerings becomes more apparent as the complexity increases. A liberal arts curriculum with very limited numbers of laboratory periods and many regular class periods can operate with a much greater potential for a wider selection of courses

within a given academic week than can a curriculum that has relatively more complex time patterns, such as those found in the scientific and technical fields. Curricula with

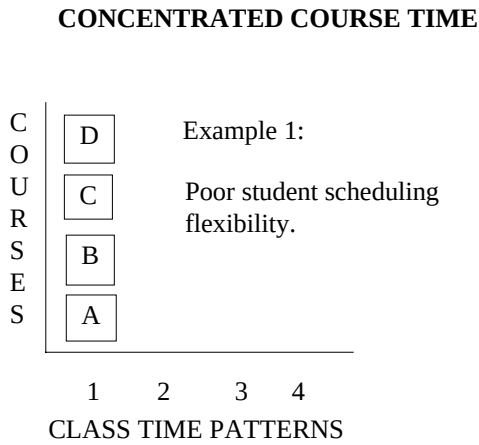

Figure 1. A Scheduling Philosophy

complex time patterns require a longer academic week to obtain the same flexibility of course selection as less complicated curricula.

Large single–section courses, especially those required by students from many curricula, must be scheduled with great care. The time selection for such a course will influence schedules in all of the associated curricula and preclude other courses from utilizing the selected time pattern. The direct cost per credit hour for the course may be low, but its affect on other courses may make its true cost to the university prohibitively expensive. One rule of thumb is to encourage at least two time periods for such a course, thus providing scheduling alternatives. In general, single–section courses, especially those with large enrollments, restrict course selection.

Multiple–section courses offer more opportunities for non–conflicting schedules than do the large single–section courses. Scheduling officers should offer as many different standard time patterns as possible for multiple section courses. In most cases, if enrollments in the sections are kept balanced, hour conflicts in student schedules will be minimized. Multiple–section courses, in effect, increase the potential for greater course selectivity.

The planning of the schedule of classes and the ultimate assignment of students to classes are interdependent. A well–conceived master schedule can fail if the more popular sections of multiple–section courses are allowed to fill and close prematurely before all students are registered. As sections close, the flexibility offered by multiple sections is reduced; and as registration proceeds, more and more students find fewer patterns of courses that will fit together to make an acceptable schedule of classes. In practice, therefore, all sections of multiple section courses should be kept open as long as possible by balancing student course requests among all the sections. When this procedure is used, the last student to register will have essentially the same choice of courses as was afforded the first student to register. The penalty for not observing this practice is to deny certain students their choice of courses.

3.1 Theoretical Considerations

To further illustrate the importance of the relationship between the academic week and the time patterns, it is useful to examine the probabilities of developing nonconflicting schedules using a uniform distribution of courses with random selection. Questions are frequently raised about the length of the academic week and the effect that the distribution of hour patterns has on the probability of obtaining a nonconflicting schedule. In answer to the first question, assume a simplified situation in which the

academic week is divided into disjoint patterns of uniform length (e.g. MWF 9:00), and where each course meets for exactly one pattern per week. The actual length of a period is immaterial, though an example might be a forty–hour week with eight one–hour periods on Monday, Wednesday, and Friday and five ninety–minute periods on Tuesday and Thursday. In this example; let **K** equal the number of time patterns available in the academic week, let **N** equal the total number of courses offered by the institution, and let **M** equal the average number of courses taken by each student. If it is assumed that the **N** courses are uniformly distributed over the **K** time patterns, it is reasonable to ask what the probability would be for a student to randomly select **M** courses without a conflict. Using the formula for conditional probability

$$\mathbf{P}_{\text{no conflict}} = \prod_{i=1}^{M} \frac{N - \frac{N}{K}(i-1)}{N - i + 1}$$

some representative values may be derived, as shown in Table 1.

Table 1. Probabilities of Developing Non–Conflicting Schedules

K = Time Patterns Available	M = Time Patterns to Be Scheduled						
	6	7	8	6	7	8	
10	0.18	0.07	0.02	0.15	0.06	0.02	
11	0.22	0.11	0.04	0.19	0.09	0.03	
12	0.26	0.14	0.06	0.22	0.11	0.05	
13 ----------	0.30	0.17	0.08	0.26	0.14	0.06	← 40-hr wk
14	0.33	0.20	0.11	0.29	0.17	0.08	
15	0.37	0.24	0.13	0.32	0.19	0.10	
16	0.40	0.27	0.16	0.35	0.22	0.12	
17	0.43	0.30	0.19	0.37	0.24	0.14	
18 ----------	0.46	0.32	0.21	0.39	0.26	0.16	← 55-hr wk
19	0.48	0.35	0.24	0.42	0.29	0.18	
20	0.51	0.38	0.26	0.44	0.31	0.20	
	N = 100 Courses Offered			N = 3,200 Courses Offered			

* Assuming an even distribution of courses with random selection.

A review of these values indicates that the *number of courses offered* has less influence on conflicts than does the *number of time patterns selected* by the students. If there are thirteen time patterns available and the student is choosing six time patterns (courses) from an array of 100 courses, then the probability is 0.30. If the student chooses from an array of 3,200 courses, the probability only drops to 0.26. However, if the *number of courses selected* from a set of 100 courses increases from six to eight, the probability of no conflicts drops significantly, from 0.30 to 0.08. A drop of the same magnitude occurs for the example where the array of courses is 3,200.

These data reaffirm that it is much more difficult to schedule students with "full" academic loads than it is to schedule part–time students within a given academic week. The data also suggest that planning the master schedule is only somewhat more difficult for institutions with many courses than for those with few courses. In each instance, the complexity remains virtually unchanged, but the volume of work increases.

Within a well–constructed schedule of classes, the courses are not randomly arranged, nor do the students randomly select their courses. The probability of obtaining a conflict–free schedule can still be greatly increased when the courses are distributed throughout the hours of the day and the days of the week. In addition, as the number of non–conflicting time patterns increases, the probability of no conflict improves significantly and in an exponential fashion.

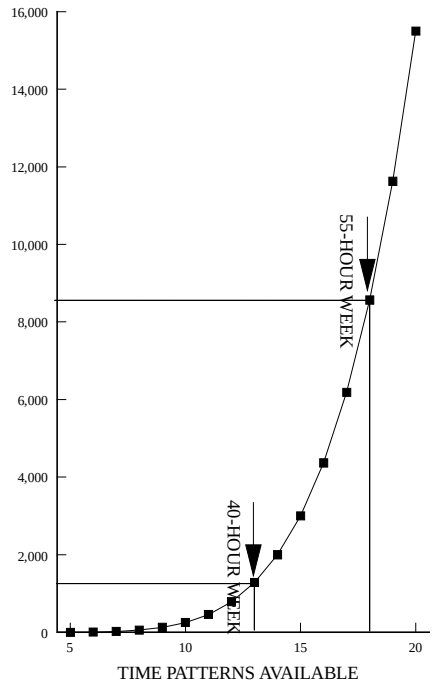

Figure 2. Course–Time Combinations
(Combinations of N courses Taken Five at a Time)

Figure 2 shows the significant increase in possible course–time combinations that occurs as the number of time patterns or hours (**N** possible courses) in the academic week increases. For example, if there are thirteen discrete periods in the academic week, a student taking five courses would have 1,287 possible course–time combinations. If the academic week is increased to eighteen discrete periods, 8,568 possible combinations would exist for the same student. While calculated for

theoretical situations, these data serve to highlight the point that the length of the academic week and the time patterns of hours have a direct and significant impact upon the institution's ability to plan a schedule of classes which meets as nearly as possible the diverse course requirements of students.

Table 2. Probabilities of Developing Non–Conflicting Schedules[1]

Effects of Skewing the Distribution of Courses Within the Available Time Patterns

Time Pattern	Six Possible Distributions of 30 Course Offerings Within Five Time Patterns					
1	6	5	4	3	2	1
2	6	5	5	4	4	3
3	6	6	6	6	6	6
4	6	7	7	8	9	9
5	6	7	8	9	10	11
Probability	0.53	0.52	0.51	0.47	0.44	0.38

Comparative Values When an Additional Time Pattern is Available

Time Pattern	Five Possible Distributions of 30 Course Offerings Within Six Time Patterns				
1	5	4	3	2	1
2	5	4	3	3	2
3	5	4	4	4	3
4	5	6	6	6	7
5	5	6	7	7	8
6	5	6	7	8	9
Probability	0.62	0.60	0.57	0.55	0.47

[1]Assuming a skewed distribution of courses. Both examples assume three courses per student will be randomly selected out of the total of thirty courses offered.

The effects of skewing the distribution of courses over the available class periods are also worthy of study (see Table 2.) As the skew (or uneven distribution) increases, the probability of conflicting schedules also increases. As the number of available class periods is decreased, the probability of conflicts increases even further. Therefore, from a course selectivity standpoint, it is highly desirable to distribute courses evenly over an academic week, thus providing for the largest number of nonconflicting time patterns. If choices must be made, courses that are taken in sequence (or otherwise not taken during the same term) may be scheduled at the same time, whereas courses that may be taken during the same term should be scheduled at different times.

3.2 Comments and Suggestions

Lost Weekends: Some institutions are experiencing significant shifts towards shorter academic weeks. This trend, while somewhat expected in institutions with heavy use of Saturday classes, has progressed in some institutions to the point where Friday afternoons (and even Friday mornings) are now void of classes. The results are more scheduling conflicts, longer times to graduation and pressure for additional funds to build classroom facilities. These events may be termed lost weekends. If not observed early and guarded against, this trend is very difficult to reverse since no one wants to be last in line, or on the last period, or on the last half day, etc.

Too Few Better Than Too Many?: Many an administrator has heard the cry for more classroom space. This cry may be quite sincere if the hours of room use are approaching the hours available in the scheduling week, or if there are other special constraints. Care must be taken to sift through these requests to find the reason for the problem. In the general case, however, when there has been a fair allocation of classroom facilities, each department will have an adequate number of time periods for its classes. The availability of additional rooms will not increase the number of classes offered, but it will promote departments being more selective with the time periods they use—resulting in more classes and an increase in conflicts at "prime" times. With fewer classrooms, there will be a better distribution of class times and fewer conflicts.

Centralization of Classrooms*:* All classrooms should be centrally scheduled and managed, with a firm commitment of adequate resources for their continued upkeep and modernization. This will minimize complaints of differences in quality of rooms about campus. Usually staff will choose to remain and teach in their building at the less popular hours than to move outside the building for a preferred time. Good facilities help to promote this interchangeability of rooms.

Scheduling Large Enrollment Multiple–Section Courses: Take advantage of courses with large enrollments and many sections. These offer a multitude of opportunities and can be scheduled at all time patterns, fill in normal void periods in the master schedule, minimize conflicts in hours and, in general, attain an extremely high level of utilization with minimal conflicts. This is true of both class as well as laboratory sessions. It has also been found that in these high enrollment courses irregular hour patterns such as MTh, TF, and WSa work well and do not increase the level of conflict in hours.

Scheduling Single Section Courses: Take care to use as much of the academic week as possible to minimize possible conflicts. Keep as many courses away from each other as possible within a curriculum to minimize conflicts and only put the most unlikely courses (or known sequence courses) together at the same time.

Scheduling Large Single Section Lecture Courses: These courses can be both economical and expensive. While the credit hour cost may be low, any course required by all students or the majority of them idles all other course activities and facilities on the campus—and should be handled with care and understanding. In the past, ROTC programs had a significant impact on many of the land grant institutions due to the required corps drill period for all male undergraduate students.

Given the same length academic week, an institution with few, if any, multiple–section courses will have a higher level of conflicts between courses than an institution with many multiple–section courses. In other words, given the same level of hour conflicts between courses, multiple–section courses reduce the need for an expanded academic week whereas large single–section courses increase the need for an expanded academic week.

It is important to hold to standard time patterns, but exceptions must be allowed when teaching pedagogy prevails. In this event, request possible alternative time patterns and choose actual time period that best reduces the possibility of conflict.

Scheduling strategies that might be employed:

1. Schedule all multiple lecture and laboratory sections so that student course enrollments will be distributed approximately equally between mornings and afternoons and between the MWF and TTh sequences.
2. Four–hour multiple–section courses with large enrollments meeting four days a week should be scheduled equally over the five following combinations: MTWTh; MTWF; MTThF; MWThF; TWThF.
3. Departments should be strongly encouraged to schedule noon–hour classes, although they should not schedule two required single–section courses or both sections of a two–section course at, say 11:30 and 12:30.
4. Departments adding lecture courses and sections above the total number offered the previous year (term) should schedule the added sections in the low–use time blocks. No increase in peak–period use should be permitted. Likewise, if possible, reductions (cancellations) should come from the peak periods—not the low—volume periods.

4 Conclusion

The creation of an institution's schedule of classes and the policies it uses for assigning students to these classes play a vital role in the ability of its students to receive the courses they need to advance toward their degree objectives. Efforts toward creating an academic schedule which maximizes the students' chance of receiving the courses they need can, therefore, create a cost savings for students as well as more efficient operations for the college or university. This may require some changes in policies and result in a perception of inconvenience by staff and students who have not been scheduled to a preferred time. Students generally appreciate that this is less of an inconvenience than not being able to take a required course however. Effective scheduling policies will also provide some choice of times for students with special needs.

Appendix: Purdue Academic Scheduling System (PASS): Overview

The basic objective of Purdue's student scheduling system is to maximize the probability for all students to receive their first choice of courses which have been selected to meet their educational requirements and interests. Fundamental to the system is the policy of providing students with choice of courses rather than choice of times, and all energies are directed toward scheduling all students, the first as well as the last, into the courses of their first choice. This procedure is in contrast to many registration systems wherein students select both courses and times, usually on a "first come, first served" or on some priority basis.

To accomplish this scheduling objective, it is necessary to first build a Master Schedule of Classes which utilizes all hours of a broadly defined academic week in order to minimize queues of course offerings at any hour. Such a schedule will provide for greater course selectivity than one that queues at popular hours and is restricted to a limited academic week.

Secondly, it is necessary to keep in balance the number of course spaces remaining in the time patterns used by a course throughout the student scheduling process. This procedure prevents the early closing of classes offered at popular times.

Use of standard time patterns campus wide is another important operational policy, which facilitates the development of non-conflicting schedules. When departments teach courses in common blocks of time, fewer time conflicts are likely to arise when building student schedules, thus allowing more students to take the courses they need.

Development of the Master Schedule of Classes

The first step in the scheduling process involves class schedule coordination of academic resources on campus. The coordination of courses, instructional personnel, space, and related resources to develop a workable Master Schedule of Classes within the established operating week and calendar is the joint responsibility of the Office Space Management and Academic Scheduling (SMAS), school counseling offices, and the individual university departments. The objective of this management team is to properly coordinate the schedule of academic resources, instructional personnel, academic space, and time, in a manner, which will effectively meet the curricular needs of the students.

Curriculum deputies represent student counseling areas and are responsible for 1) estimating the demands their students will place on courses in the various departments throughout the university, and 2) coordinating with the departments the establishment of non-conflicting times for courses their students are likely to elect. In essence, the curriculum deputies project the curricular needs of students and act in their behalf to see that the students' needs are met.

Departmental schedule deputies represent subject matter areas and departments of instruction. They are responsible for 1) reviewing the total course demand upon the department in order to balance the requests against available staff and space resources, and 2) developing a compatible departmental schedule within available time constraints. In essence, they manage the department's resources and are responsible for their efficient utilization.

This deputy system of management, is a decentralized form of management, which allows each of the various schools and departments to have a voice in the determination of their unique departmental schedules and the school's establishment of appropriate curricular offerings, while being monitored within the framework of centrally developed scheduling procedures and policies of the university.

The master schedule is reviewed by SMAS, checked for consistency, fairness and adequacy, simulated on the computer to test against actual students requests, modified as needed, and ultimately released as the operating schedule for the University. Adjustments in the master schedule occur throughout the registration period to accommodate student demands and changing departmental requirements.

Scheduling

When about half of the students have registered for a semester, actual scheduling begins. In the scheduling process, students are assigned to the times of their selected courses which have the most open spaces remaining in order to keep the maximum number of time options open for students scheduled later in the registration process.

In order to schedule the most students and to achieve a well-balanced schedule, multiple passes through the student requests are made. To accommodate this, student course requests are collected and periodically submitted for scheduling as an overnight batch procedure.

During schedule revision, all course drops are processed prior to the day's batch of new course requests. This makes class time openings available, giving more students a greater chance of receiving the courses they want.

Although undergraduates are not allowed to select course times except under special circumstances, there are mechanisms that can be used when students have a legitimate need to be free from class for certain blocks of time. If course instructors are known in advance, students may indicate an instructor preference, which will be honored if possible.

In order to protect student's health, the scheduling algorithm attempts to include an hour lunch break in each student's schedule.

Output from the scheduling process includes a schedule for the student who was scheduled or a detailed reject analysis explaining why a student could not be scheduled. Departments are provided with course status reports and summaries of scheduling activity throughout the scheduling process.

Scheduling Vision

Once the schedule of classes is public, students could use computers to enter their course requests and other information. Along with the schedule of classes, additional information about courses, the student's course history and curriculum requirements would be on-line to aid with decision-making.

Once submitted by the students, the request could be forwarded electronically to the student's advisor for approval. The level of interaction with students could be

determined by each advisor. Approved scheduling requests would be electronically submitted into the subscription system. Perhaps special permission requirements could be handled in an electronic fashion as well.

Batch scheduling would take place during the advanced registration period. This allows modifications to the master schedule to accommodate as many student scheduling requests as possible, thus allowing more students to take the courses they need.

During the delayed registration period, an on-line scheduling system would be in place. During this time, students and advisors could access and request changes to a student's schedule electronically. The system would immediately try to schedule that request. The user would receive an immediate response: either a new schedule or an analysis explaining the rejection of the request. Up-to-date course status information would be available to system users at all times. Management query tools would be included to allow users to get answers to many different kinds of questions.