Course timetabling in a higher educational institute offering multiple programs with intermediate changes

Example:

Let an institution of higher education has four schools of different specialization. Each of these schools offers multiple programs, both at undergraduate and postgraduate levels, of various duration. Their detail is as follows:

School of Engineering (s_1)

Four years of an undergraduate degree in

Computer Science and Engineering (CSE)	$(p(s_1)_1)$
Mechanical Engineering (ME)	$(p(s_1)_2)$
Civil Engineering (CE)	$(p(s_1)_3)$
Electronics and Communication Engineering (ECE)	$(p(s_1)_4)$

Two years of a postgraduate degree in

Computer Science and Engineering (CSE)	$(p(s_1)_5)$
Mechanical Engineering (ME)	$(p(s_1)_6)$
Civil Engineering (CE)	$(p(s_1)_7)$
Electronics and Communication Engineering (ECE)	$(p(s_1)_8)$

School of Management (s_2)

Three years of an undergraduate degree in

Business Administration (BBA)	$(p(s_2)_1)$
Bachelor's in commerce (BCOM)	$(p(s_2)_2)$

Two years of a postgraduate degree in

Business Management (BM)	$(p(s_2)_3)$
Human Resource Management (HRM)	$(p(s_2)_4)$
Rural Management (RM)	$(p(s_2)_5)$
Master's in Commerce (MCOM)	$(p(s_2)_6)$

School of Law (s_3)

Three years bachelor's degree in law (LLB)	$(p(s_3)_1)$
Two years master's degree in law (LLM)	$(p(s_3)_2)$

School of Basic Sciences (s_4)

Five years integrated master's degree in

Physics	$(p(s_4)_1)$
Chemistry	$(p(s_4)_2)$
Mathematics	$(p(s_4)_3)$

Two years master's degree in

Physics	$(p(s_4)_4)$
Chemistry	$(p(s_4)_5)$
Mathematics	$(p(s_4)_6)$

Objective:

To construct the course timetable for two semesters so that it can be used for the whole year. The same schedule will then be repeated in subsequent years.

Problem Description:

Assume that an institute of higher learning has multiple schools of specialization offering various programs at undergraduate and postgraduate levels. Further, each program offers multiple courses (or study subjects) in each semester.

Along with the usual objectives (of our multi-objective optimization problem), faculty resource utilization will be added as an additional objective. Our proposed model should also have the flexibility for any intermediate change.

Formulation:

The objectives of our multi-objective optimization problem are:

1) Allocations of courses to faculty as per their specialization and expertise.
2) Assignment of lecture to an appropriate timeslot first and then to a suitable room.
3) Maximum utilization of faculty resources.

Let the university have m (= 4) schools, offering multiple programs of study at various levels, denoted by a set S and defined as $S = \{s_1, s_2, \dots, s_m\}$.

Now, each of these m schools offers various programs of study. Let P_{s_i} denotes a set consisting of all the programs offered by the school s_i and is defined as $P_{s_i} = \{p(s_i)_1, p(s_i)_2, \dots, p(s_i)_n\}$. Here, n is the total number of programs offered by school s_i.

Now, the total number of programs (TNP) over all the schools can be given as follows:

$$TNP = \sum_{i=1}^{m} |P_{s_i}|$$

where $|P_{s_i}| \leftarrow$ # Programs offered by the school s_i. $[TNP = 8 + 5 + 2 + 6 = 21]$

Next, each program has a number of study subjects (or courses) comprised of various lectures. All the courses (or subjects) of program $p(s_i)_j$ are denoted by a set C_{ij} and defined as

$$C_{ij} = \begin{cases} 1, & \text{if the subject belongs to } j^{th} \text{ program of } i^{th} \text{ school} \\ 0, & \text{otherwise.} \end{cases}$$

Also, $C_{ij} = \{c_1, c_2, \dots, c_{N_{ij}}\}$, where $N_{ij} \leftarrow$ # course (or subjects) of j^{th} program of i^{th} school.

This implies that the total number of courses (TNC) offered by the university over all the schools is,

$$TNC = \sum_{i=1}^{m} \sum_{j=1}^{|P_{s_i}|} C_{ij}$$

Next, each course (or subject) consists of several lectures. Suppose TNL is the total number of lectures,

$$TNL = \sum_{i=1}^{m} \sum_{j=1}^{|Ps_i|} \sum_{k=1}^{N_{ij}} \ell_{ijk}$$

Where $\ell_{ijk} = \begin{cases} 1, & \text{if lecture belongs to } k^{th} \text{ course of } j^{th} \text{ program and } i^{th} \text{ school} \\ 0, & \text{otherwise.} \end{cases}$

Each of these lectures will be taken by a faculty member. The set of faculty members is denoted by F and defined as $F = \{f_1, f_2, \dots, f_q\}$, where q is the total number of faculty members.

The weekly working load of a faculty is given as $\min_{f_i} \leq WL_{f_i} \leq \max_{f_i}$ and must be satisfied. Here $\min_{f_i}$ and $\max_{f_i}$ represent the minimum and maximum working load for faculty f_i.

We also need to find the various parameters for faculty productivity. It can be broadly categorized into three classes:

- Teaching activities
- Research activities
- Institutional development activities

In our proposed algorithm, we also need to incorporate flexibility for changes. One such example is that if any faculty member leaves the institution in between the semester (due to some unavoidable circumstances), then how to fill the gap created by the faculty?

Assumption:

Room constraint(s) can be exempted by assuming that the university has sufficient rooms and laboratories of various capacities and features.

If #rooms $= \alpha$, #faculty $= \beta$, and #timeslots/week $= \gamma$, then the maximum number of lectures scheduled in week $= \gamma \times \min(\alpha, \beta)$.

The UCTP is a weekly scheduling problem consisting of the allocation of several lectures for a number of courses within a given number of periods and a set of rooms.

Used terminology:

Event: An event refers to a lecture, tutorial, or laboratory for each course. It is a scheduled meeting between a group of students and faculty.

Days: Number of weekly teaching days (generally 5 or 6).

Timeslot: A time interval in which each event is scheduled. Each day is divided into a fixed number of timeslots (in general, 7 or 8 timeslots per day).

Period: A period is a pair of days and timeslots. The total number of scheduling periods per week is the product of the number of days in a week and timeslots per day.

Resource: Used by events, such as equipment, rooms, faculties, groups of students, timeslots, etc.

Constraint: A restriction or limitation in the scheduling of events. These constraints are categorized into two classes: hard and soft.

Course: Each course consists of a fixed number of lectures scheduled in distinct periods; it is attended by a given number of students and taught by a teacher.

Program: A program (or a set of curricula) consists of a group of courses with common students. Here, conflicts between courses are resolved according to the curricula and not based on student enrollment data.

School: Consists of several programs of similar streams, such as engineering, basic science, management, etc.

Faculty: Each faculty (or lecturer or teacher) has his own preference to teach each course among the courses of his expertise.

Each group (set of students with the same curriculum or enrolled in the same program) is scheduled to follow several courses. Each such group will take the same set of courses. Each course has a different time of face-to-face.

Hard Constraints:

1) All lectures of a course must be scheduled, and they must be assigned to distinct periods.
2) A teacher can teach at most one course at any period.
3) Two lectures cannot occur in the same room at the same time.
4) Lectures of courses taught by the same teacher or in the same curriculum must all be scheduled during different periods, i.e., there should not be any period having an overlapping of students or teachers.
5) The workload of a teacher should be within the defined limit.

Soft Constraints:

1) The number of students attending the course should not exceed the capacity of the room hosting the lecture.
2) Predefined courses should be scheduled in a given timeslot.
3) A teacher can have the opportunity to select specific periods for their lectures.
4) The number of free periods should be as minimum as possible for students. If they are, then they should be at the end of the day.
5) A student should not have a single event in a day.