Courses timetabling problem by minimizing the number of less preferable time slots

M. Oktavia, A. Aman and T. Bakhtiar

Division of Operations Research, Department of Mathematics, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia

Abstract. In an organization with large number of resources, timetabling is one of the most important factors of management strategy and the one that is most prone to errors or issues. Timetabling the perfect organization plan is quite a task, thus the aid of operations research or management strategy approaches is obligation. Timetabling in educational institutions can roughly be categorized into school timetabling, course timetabling, and examination timetabling, which differ from each other by their entities involved such as the type of events, the kind of institution, and the type and the relative influence of constraints. Education timetabling problem is generally a kind of complex combinatorial problem consisting of NP-complete sub-problems. It is required that the requested timetable fulfills a set of hard and soft constraints of various types. In this paper we consider a courses timetabling problem at university whose objective is to minimize the number of less preferable time slots. We mean by less preferable time slots are those devoted in early morning (07.00 – 07.50 AM) or those in the late afternoon (17.00 – 17.50 AM) that in fact beyond the working hour, those scheduled during the lunch break (12.00 – 12.50 AM), those scheduled in Wednesday 10.00 – 11.50 AM that coincides with Department Meeting, and those in Saturday which should be in fact devoted for day-off. In some cases, timetable with a number of activities scheduled in abovementioned time slots are commonly encountered. The courses timetabling for the Educational Program of General Competence (PPKU) students at odd semester at Bogor Agricultural University (IPB) has been modelled in the framework of the integer linear programming. We solved the optimization problem heuristically by categorizing all the groups into seven clusters.

1. Introduction
The timetabling is one of the problem that often encountered in arranging the assignments at an organisation includes educational institutions. When we want to solved problem used a design of mathematical model, then we need to consider in depth the various kinds of constraints related to their policies or regulations. Thus, being able to create a timetable that is as ideal as possible.

Even though not so complicated as in the university, timetabling issues at the school level are still interesting to be studied because it can provide the solution with a better quality. Such as the research conducted by Birbas et al. [1] which solved the problem assignments of optimal working shift from each teacher. The problem is modelled using an integer programming framework. Cangaiovic and Schreuder [9] proposed a special case of a teacher-class timetabling problem. This case is considering a partial request between the topics in the curriculum and specific requirements based on their daily lectures. The problem is modelled as a discrete lexicography model with heuristic procedure. This method is a combination of two different approaches, specifically: on the level of public used a specific heuristic approach and at the level of daily used graph colouring method. Another timetabling problem at the high school level covered by Saviniec et al. [9] that applied the three algorithms of
Iterated Local Search (ILS) includes two operators of new neighbourhood which be proposed to solve the problem from literature heuristically. This study examined seven cases. The results showed that this method is effective and efficient to solve the problem, because these methods are able to find the optimal solution for all cases.

The 0-1 integer programming model of timetabling problems at the university presented by Daskalaki et al. [2]. The objective function of the problem formulation is to minimize the cost function. This model is used to solve timetabling cases at the Department of Engineering for five years with a large number of lectures and lecturers. Dimopoulou and Miliotis [3] reported the results of the design and implementation of PC-based computer systems to help the construction of a combined schedule of lectures and exams at the university. The difficulties to be found is the limited availability of classroom space and increase the flexibility of the courses that can be elected by students, which makes the problem becomes very tight. The system used integer programming (IP) model that assigned the course in a specific both the time slot and room. This study has been successfully applied at the Athens University of Economics and Business. In other cases, Schimmelpfeng and Helber [7] solved timetabling problems using integer programming that has been implemented at the Economics and Management Faculty of Hannover University. A problem of determining the course time slot in a faculty studied by Ismayilova et al. [5] also developed timetabling of courses as integer programming problem with the multi-objective functions. The model is designed considering both the administration’s and instructor’s preferences. Both modelling and solving such problem are difficult task due to the size, the varied nature, and conflicting objectives of the problem. Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) is used to consider the purpose of different and contradictory.

The courses timetabling problem at university with large numbers of students is a difficult task, particularly to ensure that there are no courses which overlap. Most timetabling prepared manually, or at least with the aid of a spreadsheet program. However, the manual process requires verification number of experts (e.g. lecturers and supervisors) before it can be approved. Thus, several researchers solved the problem with heuristically analysis. In this research, proposed a solution of the courses timetabling problem at university. Various soft and hard constraints of timetabling parameters considered, such as the number of subjects, tutorials, classrooms, teachers, students, and workloads. Simulated annealing method is used to obtain optimal solutions and sub-optimal. Illustration was applied to the timetabling problem of Tamhidi Program in Universiti Sains Islam Malaysia as a case study [12]. Hertz [8] defined the daily quantum as a number of total period that scheduled into consecutive period a day for each chapter. Daily quantum has a minimum and maximum number of courses each day, so there are no arbitrary chapter on every single day. The completion of this problem using Tabu Search Method for obtaining a schedule of feasible lectures. Studenovsky [11] arranged the University Course timetabling Problem (UCTP). In particular, this study presented UCTP into two issues, as the timetabling of time slot and the timetabling of room. Researchers proved that in this case UCTP is a polynomial form that be reduced.

Hanum et al. [4] considered a capacitated timetabling problem of the invigilator exam. By using the framework of Goal Programming in formulating the problem, where a number of constraints associated with this type of exam, exam controller type, time availability, and several other preferences classified into primary and secondary constraints. The model was applied into a simple case of the exam invigilator in the Department of Mathematics, Bogor Agricultural University. A study at the University Malaysia Pahang done by Kahar and Kendall [6] modelled the capacitated examination problems with calculating the distance between the rooms and divided the test in several rooms. Construction heuristically is built to produce solution with good quality for real world problems that be encountered. Fahriion and Dollansky [10] proposed both the room and lecturer based on the faculty educational plan and the selection of fixed assignment. To speed up the process of finding a solution, then is made the of priority scheme assumption of simple heuristic.

In this paper, we consider the courses timetabling of Educational Program of General Competence (PPKU) that be carried out by the Directorate of PPKU used manual timetabling system. The constraint that often hamper the timetable process is there are no warnings at software Microsoft Excel if courses timetable is overlap. So that, the schedule-makers must made the timetabling carefully and
checking manually in order to obtain a schedule that can be applied without any courses those collide. Because of the currently timetabling method is still using manual method, it will hinder the directorate to produce the timetable of courses would be desirable.

Therefore, the authors tried to design the courses timetabling of PPKU at first semester with framework of integer linear programming to minimize the number of courses at less preferred time slots. The design of this model, hoping to eliminate some types of schedules those less effective, such as the tutorial day that be scheduled before its lecture day for each of the corresponding subjects, and subjects which has two classes of tutorial those be held on different both the day or time slot.

The outline of the paper is as follows: The problem formulation and the corresponding mathematical model are presented in Section 2. Section 3 provides an illustrative example. Section 4 develops the solution approach and numerical results. Some conclusions drawn from the study are presented in Section 5.

2. Problem formulation
The timetabling model involves about 3600 students of PPKU that has been organized into 34 groups, when each group will take a different set of courses. Every group is then classified into seven classes, each class will take the same set of courses. Among 34 groups, we have 9 groups of agriculture class, 9 groups of science and technology class, 6 groups of economy and management class, 2 groups of social and humanity class, 5 groups of flora, fauna, and human class, 2 groups of chemical and biochemical class, and 1 group of international class. Overall, it is offered 35 different courses that will be organized in 26 large rooms of capacity 130, 7 small rooms of capacity 80, 1 Laboratory of Biology, 1 Laboratory of Physic, 1 Laboratory of Chemistry, 1 mosque for Islamic Religious Education tutorial, and 1 gymnasium for sport. The courses will be scheduled at six work days (Monday-Saturday) with eleven time slots a day. Duration of each time slot is fifty minutes.

Each group is scheduled to follow a number of courses. Each group those are in the same class will take same of courses. Each course has different time of face to face. A few courses must be scheduled only once time of slot, but should be scheduled more than once time at respectively time slot for anyone else. There are courses those be accompanied by tutorial or practicum. For the subjects those be accompanied by tutorial, implementation of the lecture day should come before its tutorial day for each of the corresponding subjects. Each tutorial those has two classes are scheduled on the same both of the day and time slot for the same subjects, but at the different of rooms. Timetabling is designed certainly that each course which be taken by each group are timetabled once a week. The learning activities are not recommended on Friday (11.00 AM - 13.00 PM). The courses on the less preferred time slots are expected to be avoided or be minimized. The number of courses at every day should be limited, so that students can be absorbing the materials of learning optimally.

Modelling of the problem is encountered by defined a few of indices, parameters, and variables. Further described the constraints in the form of mathematical equality or inequality which gave a demonstration of rules and regulations which applicable at that institution. Recently presented the objective function which stated the purpose of optimization that will be established.

2.1 Parameters
Let

\[ I = \{ i : i = 1, 2, \ldots, p \} \] be the set of days,
\[ J = \{ j : j = 1, 2, \ldots, q \} \] be the set of time slots,
\[ U_b = \{ (i, j) : (i, j) = 1, 2, \ldots, u_b \} \] be the set days and time slots which have been used by previously cluster at Laboratory of Biology,
\[ U_p = \{ (i, j) : (i, j) = 1, 2, \ldots, u_p \} \] be the set days and time slots which have been used by previously cluster at Laboratory of Physics,
\[ U_c = \{ (i, j) : (i, j) = 1, 2, \ldots, u_c \} \] be the set days and time slots which have been used by previously cluster at Laboratory of Chemistry,
\[ K = \{ k : k = 1, 2, \ldots, r \} \] be the set of groups,
\[ L = \{ l : l = 1, 2, \ldots, s \} \] be the set of courses,
\[ \tilde{L}_k = \{ \tilde{l}_k : \tilde{l}_k = 1, 2, \ldots, \tilde{s} \} \] be the set of courses which should be taken by group \( k \),
2.3 Decision variables

- $\bar{L}_k = \{l_k : l_k = 1, 2, \ldots, s \}$ be the set of courses which should not be taken by group $k$.
- $L_k = \{l_k : l_k = 1, 2, \ldots, s \}$ be the set of lectures which should be taken by group $k$.
- $\bar{T}_k = \{t_k : t_k = 1, 2, \ldots, s \}$ be the set of tutorial one which should be taken by group $k$.
- $T_k = \{t_k : t_k = 1, 2, \ldots, s \}$ be the set of tutorial two which should be taken by group $k$.
- $L_o = \{l_o : l_o = 1, 2, \ldots, s_o \}$ be the set of tutorial one that have one class.
- $L_t = \{l_t : l_t = 1, 2, \ldots, s_t \}$ be the set of tutorial one that have two class.
- $N = \{n : n = 1, 2, \ldots, t \}$ be the set of rooms.
- $N_b = \{n_b : n_b = 1, 2, \ldots, u \}$ be the set of large rooms, $n_b \in n$.
- $N_s = \{n_s : n_s = 1, 2, \ldots, v \}$ be the set of small rooms, $n_s \in n$.
- $N_p = \{n_p : n_p = 1, 2, \ldots, w \}$ be the set of practicum rooms, $n_p \in n$.
- $t = \{t : t = 1, 2, 3\}$ be the time of face to face.
- $M$ be the big number.
- $\gamma_{m_{\min}}$ be the minimum number of courses that might be assigned to each group during the day.
- $\gamma_{m_{\max}}$ be the maximum number of courses that might be assigned to each group during the day.
- $s_{esi\,1_{\min}}$ be the minimum number of courses at first time slot that might be assigned to each group during the week.
- $s_{esi\,1_{\max}}$ be the maximum number of courses at first time slot that might be assigned to each group during the week.
- $s_{esi\,11_{\min}}$ be the minimum number of courses at last time slot that might be assigned to each group during the week.
- $s_{esi\,11_{\max}}$ be the maximum number of courses at last time slot that might be assigned to each group during the week.
- $d_i$ be the time of face to face for courses $l$.

2.2 Objective functions

- Minimize $S_1$, where $S_1$ is the courses of early morning (07.00 AM - 07.50 AM)

$$\sum_{l} \sum_{k} \sum_{i} \sum_{n} x_{lkijn} = S_1, \quad \forall j = 1, j \in J$$

- Minimize $S_6$, where $S_6$ is the courses of lunch break time (12.00 AM - 12.50 AM)

$$\sum_{l} \sum_{k} \sum_{i} \sum_{n} x_{lkijn} = S_6, \quad \forall j = 6, j \in J$$

- Minimize $S_{11}$, where $S_{11}$ is the courses of late afternoon (17.00 AM - 17.50 AM)

$$\sum_{l} \sum_{k} \sum_{i} \sum_{n} x_{lkijn} = S_{11}, \quad \forall j = 11, j \in J$$

- Minimize $R$, where $R$ is the courses of Wednesday meeting (10.00 AM - 11.50 AM)

$$\sum_{l} \sum_{k} \sum_{n} x_{lkijn} = R, \quad \forall i = 3, j = 4 - 5, i \in l, j \in J$$
• Minimizing $S$, where $S$ is the courses of Saturday.

$$\sum_{i} \sum_{k} \sum_{n} x_{l_{k}i_{n}} = S, \quad \forall i = 6, j \in J$$

Formulation of the integer linear programming model of the problem under consideration is given below.

Minimize

$$S_1 + S_6 + S_{11} + R + S$$

2.4 Constraints

Based on the terms and conditions of the timetabling, then there are several constraints as follow.

$$\sum_{i_{k}} \sum_{n} x_{l_{k}i_{n}} \leq 1, \quad \forall i, j, k$$

$$\sum_{i_{k}} \sum_{n} x_{l_{k}i_{n}} \leq 1, \quad \forall i, j, n$$

$$\sum_{i} \sum_{j} \sum_{n} x_{l_{k}i_{n}} = d_{l}, \quad \forall l, k$$

$$\sum_{j} \sum_{n} x_{l_{k}i_{n}} = y_{l_{k}i_{n}} d_{l}, \quad \forall l, k, i, n$$

$$x_{l_{k}i_{n}} \leq x_{l_{k}i_{n}}, \quad \forall l, k, i, 1 \leq t \leq d_{l}, n$$

$$x_{l_{k}i_{n}} + x_{l_{k}i_{n}} \leq x_{l_{k}i_{n}}, \quad \forall l, k, i, j + t \leq 10, 1 \leq t \leq d_{l}, n$$

$$x_{l_{k}i_{n}} \leq x_{l_{k}i_{n}}, \quad \forall l, k, i, 1 \leq t \leq d_{l} - 1, n$$

$$\sum_{i} \sum_{n} y_{l_{k}i_{n}} = 1, \quad \forall l_{k}, n_{b}$$

$$\sum_{i} \sum_{n} y_{l_{k}i_{n}} = 1, \quad \forall l_{k} = 2, k = 1, i = 1$$

$$\sum_{i} \sum_{n} x_{l_{k}i_{n}} - M \left( \sum_{i} \sum_{n} x_{l_{k}i_{n}} \right) \leq 0, \quad \forall i, j, k$$

$$x_{l_{k}i_{n}} = 0, \quad \forall l_{k}, k, i, 5, j = 5 \& 6, n$$

$$x_{l_{k}i_{n}} = 0, \quad \forall l_{k}, k, i, j, n$$

$$x_{l_{k}i_{n}} = 0, \quad \forall l_{k}, k, i, j, n = n_{s}, n_{p}$$

$$x_{l_{k}i_{n}} = 0, \quad \forall l_{k}, k, i, j, n = n_{s}, n_{p}$$

$$x_{l_{k}i_{n}} = 0, \quad \forall l_{k}, k, i, j, n = n_{b}, n_{s}$$

$$\sum_{i} \sum_{j} \sum_{n} y_{l_{k}i_{n}} \leq 4 \quad \forall k, i$$

$$\sum_{i} \sum_{j} \sum_{n} x_{l_{k}i_{n}} \leq 4 \quad \forall k, j = 1$$

$$\sum_{i} \sum_{j} \sum_{n} x_{l_{k}i_{n}} \leq 4 \quad \forall k, j = 11$$

$$\left( \sum_{k} x_{3k,i,j} + \sum_{k} x_{9k,i,j} + \sum_{k} x_{23k,i,j} + \sum_{k} x_{33k,i,j} \right) = 1, \quad \forall i \leq 5, j = 1$$
The constraint sets (7) ensure that each group is scheduled to follow exactly one course on its time slot for every day. The constraint set (8) guarantees that each room used by exactly one group on its time slot for every day. Based on the capacity and utility, we can categorized the rooms into several types, as follow.

- Large rooms: useable for lectures (the courses which be delivered by lecturers, not by assistants. Where those being assistants are students from second, third, or fourth levels. We can called as mainly courses), tutorials (the courses which be delivered by assistants. But, a few tutorial be delivered by lecturers. We can called as additional courses). Each tutorial has one class or two classes.
- Small rooms: useable for a tutorials that has two classes.
- A Laboratory of Biology: useable for practicums of Biology.
- A Laboratory of Physics: useable for practicums of Physics.
- A Laboratory of Chemistry: useable for practicums of Chemistry and Elementary Chemistry.
- An Al-Hurriyyah Mosque: useable for tutorial of Islamic Educational.
- A Gymnasium: useable for practicums of sport.

The constraint set (9) and (10) guarantees that each course should be scheduled based on the time of face to face for each group and each course are scheduled exactly once a day respectively. The constraint set (11.1), (11.2), and (11.3) respectively guarantees that each course with time of face to face just over one hour are scheduled at respectively time slots. There are three possibilities conditions for scheduled each course with time of face to face more than one hour as follow.

- The courses might be scheduled in the first slot,
- The courses might be scheduled not both in the first and the last slot, or
- The courses might be scheduled in the last slot.

The constraint sets (12.1) ensure that each course which be taken are scheduled exactly once a week, the constraint sets (12.2) guarantees each course those be accompanied by tutorial, then the lecture day is scheduled before tutorial day for each of the corresponding subjects. For example, lecture Biology would be taken by group P1 be scheduled at Monday in one of large rooms, we defined as constraint (12.2). For another courses be scheduled at the fixed time like we listed at Table 5. The constraint sets (13) ensure that the tutorial one and the tutorial two held on the same both the day and time slot. There are no courses on Friday at 11.00 AM - 13.00 PM which is stated on the constraint sets (14). The constraint sets (15) ensure that if there are subjects those should not be taken for each group, so they will not be scheduled. The constraint set (16.1), (16.2), (16.3), and (16.4) respectively guarantees that each mainly courses are not scheduled on the small rooms and laboratories, each tutorial those has one class is not scheduled on the small rooms and the laboratories, each tutorial those has two classes are not scheduled on the laboratories, and each practicum are not scheduled on the large and small rooms. The constraint set (17), (18), and (19) guarantees that each student attend minimum two courses and a maximum four courses for every day, each student attend minimum two courses and a maximum four courses at the first time slots for every day, and each student attend minimum two courses and a maximum four courses at the last time slot every day respectively. The constraint sets (20) ensure that each laboratory starts at 07.00 AM in Monday - Friday, this constraint is applied to Cluster One through Cluster Three. The constraint set (21.1), (21.2) and (21.3) respectively guarantees that each group not used Laboratory of Biology, Laboratory of Physics, and Laboratory of Chemistry both on the days and time slots those had been scheduled for the
previously clusters. The constraint sets (22) ensure that each mainly course with the same subject are scheduled maximum four times on same of the day and time slot, it is associated with the availability of the lecturers. The constraint sets (23.1) and (23.2) ensure that $x_{ikjn}$ and $y_{ikin}$ decision variable integer zero or one.

3. An application—a demonstrative example

We consider a particular problem with 35 courses, 34 groups, 6 days, 11 time slots, and 6 lecturers. The courses that must be taken by each group is shown in Table 1.

| Index Number | Course Type of Course | $d_t$ | Group
|--------------|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1            | Pengantar Kewirausahaan | P     | -     | -     | -     | Int   | PK    | QK    | R6    | S2    | T5    | U2    | PK    | QK    |
| 2            | Biologi K              | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 3            | Biologi P              | P     | 3     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 4            | Biologi Umum K         | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 5            | Biologi Umum P         | P     | 3     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 6            | Ekonomi R1             | R1    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 7            | Ekonomi R2             | R2    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 8            | Fisika K               | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 9            | Fisika P               | P     | 3     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 10           | Pendidikan K           | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 11           | Agama Islam R          | R     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 12           | Bahasa Indonesia R1    | R1    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 13           | Bahasa Indonesia R2    | R2    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 14           | Pengantar Ilmu Pertanian | R     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 15           | Pendidikan K           | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 16           | Agama Islam R          | R     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 17           | Bahasa English R1      | R1    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 18           | Bahasa English R2      | R2    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 19           | Pendidikan K           | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 20           | Pendidikan R1          | R1    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 21           | Pancasila R2           | R2    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 22           | Kimia K                | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 23           | Kimia P                | P     | 3     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 24           | Sosioledi R1           | R1    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 25           | Sosioledi R2           | R2    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 26           | Sosioledi R3           | R3    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 27           | Pengantar K            | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 28           | Matematika R1          | R1    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 29           | Matematika R2          | R2    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 30           | Matematika R3          | R3    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 31           | Fisika Umum K          | K     | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 32           | Fisika Umum P          | P     | 3     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 33           | Fisika Dasar P         | P     | 3     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 34           | Fisika R1              | R1    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |
| 35           | Fisika R2              | R2    | 2     | ✓     | ✓     | ✓     | ✓     | PK    | QK    | R6    | S2    | T5    | U2    |

Note: $d_t$ = time of face to face, K = Lecture, R1 = The tutorial 1, R2 = The tutorial 2, and P = Practicum.
4. The solution
Because of the desired result is not obtained by once modeling, thus we break down the problem into seven clusters where each cluster consists of several groups and rooms so there are no intersection between one room and the others. Each program of the clusters will be ran by gradually process. The partition of the members and the rooms which can be used by each cluster is shown in Table 2 and Table 3 respectively. However, every laboratory can be used by all of cluster at the different both of day and time slot.

| Table 2. Members of each cluster. |
|-----------------------------------|
| Index Number | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 |
|---------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1             | P1        | P2        | P3        | P4        | P5        | P6        | P8        |
| 2             | Q1        | Q2        | Q3        | Q4        | Q5        | P7        | P9        |
| 3             | R1        | R2        | R3        | R4        | R5        | Q6        | Q8        |
| 4             | S1        | S2        | U1        | U2        | Int       | Q7        | Q9        |
| 5             | T1        | T2        | T3        | T4        | T5        | R6        |           |

| Table 3. Room for each cluster. |
|---------------------------------|
| Index Number | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 |
|---------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1             | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      |
|               | 101       | 105       | 109       | 203       | 207       | 211       | 215       |
| 2             | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      |
|               | 102       | 106       | 110       | 204       | 208       | 212       | 216       |
| 3             | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | RTL       |
|               | 103       | 107       | 201       | 205       | 209       | 213       | 2.05      |
| 4             | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | ICCR      | LAB       |
|               | 104       | 108       | 202       | 206       | 210       | 214       | BIO       |
| 5             | RTL       | RTL       | RTL       | RTL       | RTL       | RTL       | LAB       |
|               | 1.01      | 2.01      | 2.02      | 2.03      | 2.04      |          | FIS       |
| 6             | LAB       | LAB       | LAB       | LAB       | LAB       | LAB       | LAB       |
| 7             | LAB       | LAB       | LAB       | LAB       | LAB       | LAB       | AlHur     |
| 8             | LAB       | LAB       | LAB       | LAB       | LAB       | LAB       | Gym       |
| 9             | AlHur     | AlHur     | AlHur     | AlHur     | AlHur     | AlHur     |           |
| 10            | Gym       | Gym       | Gym       | Gym       | Gym       | Gym       |           |

In reality there are still exist the tutorial’s day that become before its lecture’s day for each of the corresponding subjects as listed in Table 4.

| Table 4. Class which tutorial before its lecture. |
|---------------------------------------------------|
| Course                                   | Group |
|-------------------------------------------|-------|
| Pengantar Matematika                      | Q8    |
| Pengantar Matematika                      | R1    |
| Bahasa Indonesia                          | T4    |
| Pengantar Matematika                      | U1    |
With operations research modeling is expected there are no such that conditions. Therefore, the authors conducted a lecture and tutorial time scheduling so that making lectures held on the day before the day of the tutorial for each of the corresponding subjects as attached in Table 5. At modeling of mathematic be presented in constraint twelve.

Table 5. The schedule time of the lecture and tutorial day for each of the corresponding subjects to each cluster.

| Index Number | Course Type of Course | Course | Cluster |
|--------------|-----------------------|--------|---------|
| 1            | K                     | Pengantar Kewirausahaan | Monday | Tuesday | Wednesday |
| 2            | K                     | Biologi | Monday | Tuesday | Wednesday |
| 3            | K                     | Biologi Umum | Monday | Tuesday | Wednesday |
| 4            | R1                    | Ekonomi Umum | After Monday | After Tuesday | Wednesday |
| 5            | R2                    | Fisika | Monday | Tuesday | Wednesday |
| 6            | R1                    | Pendidikan | Monday | Tuesday | Wednesday |
| 7            | R2                    | Agama Islam | Monday | Tuesday | Wednesday |
| 8            | R1                    | Bahasa Indonesia | Monday | Tuesday | Wednesday |
| 9            | R2                    | Pengantar Ilmu Pertanian | Monday | Tuesday | Wednesday |
| 10           | K                     | Kewirausahaan | Tuesday | Wednesday | Monday |
| 11           | R                     | Agama Islam | After Tuesday | After Wednesday | After Monday |
| 12           | R1                    | Bahasa Indonesia | After Tuesday | After Wednesday | After Monday |
| 13           | R2                    | Pengantar Ilmu Pertanian | After Tuesday | After Wednesday | After Monday |
| 14           | R1                    | Pendidikan | After Tuesday | After Wednesday | After Monday |
| 15           | R2                    | Pancasila | After Tuesday | After Wednesday | After Monday |
| 16           | K                     | Kimia | Wednesday | Monday | Tuesday |
| 17           | K                     | Bahasa Inggris | Tuesday | Wednesday | Monday |
| 18           | R1                    | Pendidikan | After Tuesday | After Wednesday | After Monday |
| 19           | R2                    | Pancasila | After Tuesday | After Wednesday | After Monday |
| 20           | K                     | Kimia | Wednesday | Monday | Tuesday |
| 21           | K                     | Kimia | After | After | Monday |
| 22           | K                     | Sosiologi Umum | After Wednesday | After Monday | After Tuesday |
| 23           | K                     | Kewirausahaan | After Tuesday | After Wednesday | After Monday |
| 24           | K                     | Matematika | After Wednesday | After Monday | After Tuesday |
| 25           | K                     | Landasan Matematika | After Wednesday | After Monday | After Tuesday |
| 26           | R2                    | Fisika Umum | Wednesday | Monday | Tuesday |
| 27           | R2                    | Kimia Dasar | Wednesday | Monday | Tuesday |

5. Conclusions
Our result, whose summary is provided in Table 6, reveals that timetabling based on operations research may reduce the number of course sessions which scheduled in less preferable time slots. For instance, now there are only 19 course sessions scheduled in the early morning slot, which is
equivalent to a 68 percent reduction compared to that produced manually. Moreover, a hundred percent reduction attained for managing late afternoon sessions.

Table 6. The number of less preferable time slots by manual and operation research methods.

| Less Preferable Time Slot | Time          | Number of sessions | Reduction |
|----------------------------|---------------|--------------------|-----------|
| Early morning              | 07.00 – 07.50 | Manual Method 59   | OR Method 19   | 68%     |
| Lunch break time           | 12.00 – 12.50 | Manual Method 22   | OR Method 3    | 86%     |
| Late afternoon             | 17.00 – 17.50 | Manual Method 10   | OR Method 0    | 100%    |
| Wednesday meeting          | 10.00 – 11.50 | Manual Method 30   | OR Method 10   | 67%     |
| Saturday                   | all time      | Manual Method 9    | OR Method 7    | 22%     |

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