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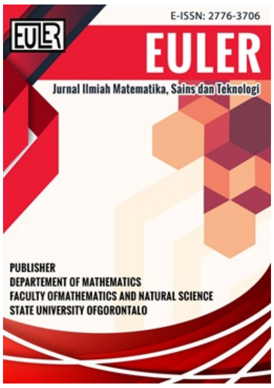

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Research Article

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Optimization of Subject Timetabling Based on Integer Linear Programming Using Microsoft Excel Solver

Ayu Larasati[1,*], **Alma Aulia Hanifah**[1], **Sugiyanto**[2]

[1]*Master's Program in Mathematics Education, Sunan Kalijaga State Islamic University, Sleman 55281, Indonesia*
[2]*Department of Mathematics, Sunan Kalijaga State Islamic University, Sleman 55281, Indonesia*

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ABSTRACT. *Subject timetabling is an essential component of educational management because it involves allocating subjects, teachers, and instructional time while satisfying multiple scheduling constraints. Manual timetabling practices commonly used in schools often result in scheduling conflicts and require considerable effort when timetable revisions are necessary. Therefore, this study aims to develop and implement an Integer Linear Programming (ILP)-based subject timetabling model using Microsoft Excel Solver for MTs Nurul Ummah. The proposed model was formulated using binary decision variables, an objective function that minimizes scheduling penalties, and a set of constraints representing curriculum requirements, teacher availability, subject allocation, and instructional time. The model was implemented using Microsoft Excel Solver to generate a feasible timetable that satisfies the predefined scheduling constraints. The findings demonstrate that Microsoft Excel Solver provides a practical platform for implementing ILP-based subject timetabling in secondary schools without requiring specialized optimization software.*

1. Introduction

Subject timetabling constitutes an essential component of educational management because it is directly related to the effectiveness of the learning process, instructional time management, and the efficient allocation of educational resources [1]. In the field of operations research, subject timetabling is classified as an optimization problem with a high level of complexity because it involves numerous interrelated decision variables and constraints, including teachers, classes, subjects, classrooms, and limited instructional time [2]. Recent studies have demonstrated that non-optimal scheduling systems may lead to timetable conflicts, inefficient allocation of instructional time, and difficulties in managing educational resources [3]. Consequently, subject timetabling has evolved from a purely administrative task into an optimization problem requiring systematic mathematical approaches to support effective educational management.

Despite advances in optimization methods, subject timetabling in many schools is still performed manually using spreadsheets without the support of structured mathematical models [4]. Such manual systems frequently result in scheduling conflicts among teachers, inappropriate subject time allocations, and frequent timetable revisions [5]. Furthermore, even minor schedule modifications often require a complete reconstruction of the timetable, making the process inefficient and time consuming [6]. Rokhim and Saputro [7] reported that the error rate in manual scheduling tends to increase as the number of variables and constraints grows. This condition highlights a gap between scheduling practices in schools and the ad-

*Corresponding Author.

Email : *ayularasati2713@gmail.com* (A. Larasati)
Homepage : http://ejurnal.ung.ac.id/index.php/euler/index / E-ISSN : 2776-3706

vancement of mathematical optimization methods developed within the field of operations research [8].

Based on preliminary observations conducted at MTs Nurul Ummah, the subject timetabling process is still prepared manually using Microsoft Excel without employing any mathematical optimization model. The observations identified teacher scheduling conflicts across several classes, the placement of certain subjects during less preferable instructional periods, and considerable difficulty in revising schedules because modifications to one timetable component affected the overall schedule structure. These findings are consistent with the study of Pratami et al. [1], which stated that manual scheduling systems are highly vulnerable to timetable conflicts and require complex adjustment processes. Similarly, Silvi and Ashril [9] explained that the use of manual methods contributes to low efficiency in allocating instructional time and educational resources.

Over the past decade, research on educational scheduling optimization has evolved from manual approaches toward mathematical models based on integer programming and optimization techniques. Numerous studies have shown that Integer Linear Programming (ILP) is one of the most effective methods for solving educational scheduling problems because it can systematically model discrete decision-making processes through objective functions and linear constraints [10]. Previous studies have shown that ILP provides a systematic framework for representing educational scheduling problems through binary decision variables, objective functions, and linear constraints while accommodating multiple scheduling constraints [11]. Rokhim and Saputro [7] demonstrated that ILP models produce scheduling solutions that are more efficient and less conflict-prone than manual methods. Similarly, Maldonado-Matute et al. [12] reported that ILP approaches effectively optimize class assignments under multiple constraints. Moreover, Gu et al. [8] emphasized that integer programming remains a relevant and effective approach for modern educational timetable optimization.

In practice, ILP models can be solved using various optimization software packages, such as LINGO, Gurobi, and Microsoft Excel Solver [13]. However, programming-based optimization software generally requires advanced technical expertise, making it less accessible for implementation in school environments. Consequently, Microsoft Excel Solver offers a simpler, more practical, and more accessible alternative. Microsoft Excel Solver is capable of solving linear programming and integer programming problems through a spreadsheet interface that is familiar to educational practitioners [14]. In addition to its ease of use, Microsoft Excel is already widely available in schools, making its implementation more economical and practical. Inderawati et al. [15] explained that Microsoft Excel Solver can be effectively utilized to solve various optimization problems on a practical scale . These findings indicate that Microsoft Excel Solver has substantial potential as a medium for implementing optimization models that are both simple and effective in addressing educational scheduling problems [16].

Existing studies have demonstrated the effectiveness of Integer Linear Programming (ILP) for educational timetabling [10–12] and have shown that Microsoft Excel Solver can be used as an accessible optimization tool [14–16]. Unlike previous studies that primarily focused on algorithmic performance or employed specialized optimization software, this study integrates teacher availability, teacher–subject–class assignments, curriculum requirements, and preferred instructional time slots into an implementable ILP framework using Microsoft Excel Solver for practical school deployment. Therefore, this study contributes to the educational timetabling literature by developing an ILP based subject timetabling model that integrates teacher availability, curriculum requirements, subject allocation, and preferred instructional time slots into a single optimization framework implemented using Microsoft Excel Solver.

Rather than proposing a new optimization algorithm, this study demonstrates how an accessible spreadsheet-based optimization tool can support systematic and structured subject timetabling in secondary schools.

Based on the foregoing discussion his study aims to develop and implement an Integer Linear Programming-based subject timetabling model using Microsoft Excel Solver to generate a feasible timetable that satisfies curriculum requirements, teacher availability, subject allocation, and predefined scheduling constraints for MTs Nurul Ummah.

2. Methods

This study employed a quantitative approach using an optimization method based on Integer Linear Programming (ILP) to solve subject timetabling problems at MTs Nurul Ummah, as described below:

2.1. Problem Identification

The initial stage of the study involved identifying problems arising in the subject timetabling process. Based on the preliminary study, several major constraints were identified, including teacher schedule conflicts, imbalanced teaching load distribution, and inappropriate placement of subjects within certain time slots. These issues indicated that the existing scheduling system was not yet optimal and required a mathematical model–based approach to improve efficiency [17, 18]

2.2. Data Collection and Processing

The data collection stage in this study utilized primary data obtained through interviews and observations. Semi-structured interviews were conducted with individuals directly involved in the scheduling process, including the principal, vice principal for curriculum affairs, and subject teachers. This technique aimed to obtain information regarding the constraints, needs, and preferences influencing the instructional scheduling process. In addition, direct observations were carried out to examine the scheduling process and actual field conditions in order to obtain objective, current, and contextual data.

The collected data included course schedules, the number of subjects, the number of teachers along with their teaching hour allocations for each class, subject weights, and the number of instructional hours per week. All data were used as components in the Integer Linear Programming (ILP) model, including the objective function, constraint functions, and decision variables. Furthermore, the scheduling optimization problem was solved using Microsoft Excel Solver.

2.3. Problem Modelling

The collected data were subsequently analyzed to construct a mathematical model of the scheduling problem. At this stage, relevant parameters and constraints, such as the number of classes, the number of subjects, instructional time allocation, and teacher availability, were formulated into the ILP model. The model consisted of binary decision variables, an objective function aimed at minimizing scheduling conflicts, and constraint functions representing the system limitations. The ILP approach was selected because of its capability to model discrete optimization problems and systematically generate optimal solutions [19].

2.4. Problem Solving

The mathematical model that had been developed was solved using the branch and bound method through Microsoft Excel Solver. The branch and bound method is a commonly used technique for solving ILP problems because it can efficiently explore the solution space to identify globally optimal solutions [20]. Microsoft Excel Solver was selected in this study due to its accessibility and practical implementation without requiring specialized optimization software. The optimization results were then analyzed to evaluate the quality of the generated schedule based on the criteria of conflict minimization, balanced teaching load distribution, and efficient utilization of time and classroom resources.

2.5. Conclusion

The final stage of the study involved drawing conclusions based on the results of the analysis. An evaluation was conducted by comparing the scheduling results generated using the ILP method with the manual scheduling method previously implemented by the school. Thus, the effectiveness of the optimization method in improving scheduling quality could be identified. Overall, the research procedures were systematically organized, beginning with problem identification, data collection, mathematical modeling, model solving, and result evaluation, which are presented in the research flowchart in Figure 1.

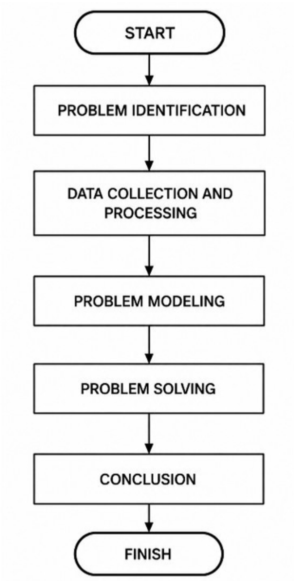

Figure 1. Research method flowchart.

3. Results and Discussion

3.1. Definition of Sets and Index

The initial step in the modeling process is determining the index sets representing the dimensions of the scheduling problem. The sets used in this study are as follows:

H : Set of days in one working week. In this study, six days are used because Sunday is a holiday, therefore: $H = \{1, 2, 3, 4, 5, 6\}$. Information: 1= Monday, 2= Tuesday, 3= Wednesday, 4= Thursday, 5= Friday, 6= Saturday

S : Set of sessions or lesson periods in one day. In this study, there are eight sessions, therefore: $S = \{1, 2, 3, 4, 5, 6, 7, 8\}$.

K : Set of classes (study groups). In this study, there are 11 classes, therefore: $K = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11\}$.

G : Set of teachers, therefore: $G = \{1, 2, 3, \ldots, |G|\}$.
The teacher set G is explicitly incorporated into the decision variables to distinguish teachers assigned to the same subject and to ensure that teacher scheduling conflicts can be mathematically prevented.

M : Set of subjects, therefore: $M = \{1, 2, 3, \ldots, |M|\}$.
These sets are used in constructing the decision variables, objective function, and all constraints in the ILP (Integer Linear Programming) model.

3.2. Model Parameters

Parameters are input values known prior to the optimization process. The parameters used are as follows:

$J_{k,m}$: Number of instructional hours for subject m that must be fulfilled by class k in o-e week according to the curriculum.

T_g : Total teaching hours of teacher g in one week based on teacher workload regulations.

U_g : Maximum teaching hours of teacher g in one day.

$w_{h,s,m}$: Scheduling penalty weight for subject m on day h during session s. Smaller weight values indicate more recommended time slots, while larger weight values indicate less recommended time slots.

$a_{g,m,k}$: Teacher–subject–class assignment parameter, defined as:

$$a_{g,m,k} = \begin{cases} 1, & \text{if teacher } g \text{ is assigned to teach subject } m \text{ in class } k, \\ 0, & \text{otherwise,} \end{cases} \tag{1}$$

$b_{h,s,g}$: Teacher availability parameter, defined as:

$$b_{h,s,g} = \begin{cases} 1, & \text{if teacher } g \text{ is available on day } h \text{ during session } s, \\ 0, & \text{otherwise,} \end{cases}$$

Parameter "$b_{h,s,g}$" is used to ensure that teachers are only scheduled at feasible times.

3.3. Decision Variables

The scheduling decisions are represented using a binary decision variable that simultaneously determines the assigned teacher, subject, class, day, and instructional session. The decision variable is defined as follows:

$$x_{g,m,k,h} = \begin{cases} 1, & \text{if teacher } g \text{ is assigned to teach subject } m \text{ to class } k \text{ on day } h \\ & \text{during session s,} \\ 0, & \text{otherwise.} \end{cases} \tag{2}$$

The inclusion of the teacher index g enables the model to distinguish teachers assigned to the same subject and prevents scheduling conflicts in which one teacher is allocated to multiple classes at the same time. This formulation also ensures consistency between teacher assignment, subject allocation, and class scheduling.

3.4. Objective Function

The objective of the proposed Integer Linear Programming (ILP) model is to minimize the total scheduling penalty. Penalty weights are assigned to instructional periods to encourage the placement of subjects into more appropriate time slots, such as scheduling difficult subjects in earlier sessions and avoiding their placement during the final instructional sessions whenever possible. The objective function is formulated as follows:

$$\min Z = \sum_{h \in H} \sum_{s \in S} \sum_{k \in K} \sum_{m \in M} w_{h,s,m} \cdot x_{g,h,s,k,m}, \tag{3}$$

where $w_{h,s,m}$ denotes the penalty weight associated with assigning subject s to instructional session h on day m, and $x_{g,h,s,k,m}$ is the binary decision variable indicating whether teacher g teaches subject s to class k during session h on day m.

3.5. Constraint Functions

To ensure that the generated schedule is feasible for implementation, the model must satisfy the following constraints:

3.5.1. Curriculum Requirement

$$\sum_{g \in G} \sum_{h \in H} \sum_{s \in S} x_{gmkhs} = J_{km}, \quad \forall k, m. \tag{4}$$

This constraint ensures that every subject is scheduled according to the required number of weekly instructional hours specified in the curriculum.

3.5.2. One Subject per Class

$$\sum_{g \in G} \sum_{m \in M} x_{gmkhs} \leq 1, \quad \forall k, h, s. \tag{5}$$

Each class may only attend one subject during a particular instructional session.

3.5.3. Teacher Conflict

$$\sum_{m \in M} \sum_{k \in K} x_{gmkhs} \leq 1, \quad \forall g, h, s. \tag{6}$$

This constraint prevents a teacher from being assigned to more than one class during the same instructional session.

3.5.4. Teacher Assignment

$$x_{gmkhs} \leq a_{gmk}, \quad \forall g, m, k, h, s. \tag{7}$$

A teacher can only be assigned to teach a subject in a class if the corresponding teacher–subject–class assignment exists.

3.5.5. Teacher Availability

$$x_{gmkhs} \leq b_{hsg}, \quad \forall g, m, k, h, s. \tag{8}$$

Teachers may only be scheduled during periods in which they are available.

3.5.6. Weekly Teaching Workload

$$\sum_m \sum_k \sum_h \sum_s x_{gmkhs} = T_g, \quad \forall g. \tag{9}$$

This constraint ensures that the total number of teaching sessions assigned to teacher g during one academic week is exactly equal to the required weekly teaching workload (T_g) established by the school. By enforcing equality, the model guarantees that each teacher fulfills their assigned teaching responsibility without being under-assigned or over-assigned.

3.5.7. Maximum Daily Teaching Hours

$$\sum_m \sum_k \sum_s x_{gmkhs} \leq U_g, \quad \forall g, h. \tag{10}$$

This constraint limits the maximum number of instructional sessions assigned to each teacher in a single day.

3.5.8. Binary Variable

$$x_{gmkhs} \in \{0, 1\}. \tag{11}$$

The decision variable is binary, where a value of 1 indicates that the corresponding teaching assignment is scheduled, while 0 indicates otherwise.

3.6. Model Solution

Microsoft Excel, through its Solver add-in, was used to implement and solve the proposed Integer Linear Programming (ILP) model with a minimization objective function. The implementation was performed by representing each binary decision variable x_{gmkhs} as a worksheet cell, where each variable indicates whether teacher g is assigned to teach subject s to class k during instructional session h on day m. The objective function was computed using the SUMPRODUCT function between the penalty weight matrix $w_{h,s,m}$ and the binary decision variable matrix x_{gmkhs}.

Microsoft Excel Solver was then employed to minimize the total scheduling penalty while satisfying all model constraints, including curriculum requirements, one-subject-per-class restrictions, teacher conflict prevention, teacher–subject–class assignment, teacher availability, weekly teaching workload, maximum daily teaching hours, and binary decision variable requirements. The instructional hour requirements for each class, which serve as one of the primary input parameters of the optimization model, are presented in the following table:

MTs Nurul Ummah has 24 teachers, 19 subjects, 11 classes, and conducts teaching and learning activities over six school days, from Monday to Saturday. Daily instruction begins at 08:00 and ends at 12:30, with each teaching session lasting 30 minutes. On Fridays, classes conclude after the sixth session to accommodate mandatory religious activities, while on Saturdays, classes end after the seventh session in accordance with the school's curriculum policy. The daily teaching schedule is presented in Table 1.

Each class follows a different weekly subject allocation based on the curriculum, with varying numbers of teaching periods assigned to each subject. Some subjects have zero allocated periods in certain classes because they are not included in the curriculum for those grade levels at MTs Nurul Ummah. In addition, for Grades 8 and 9, the Integrated Science (IPA)

Table 1. Time sessions.

Session	Time
1	08.00 – 08.30
2	08.30 – 09.00
3	09.00 – 09.30
4	09.30 – 10.00
Break	10.00 – 10.30
5	10.30 – 11.00
6	11.00 – 11.30
7	11.30 – 12.00
8	12.00 – 12.30

subject is divided into Physics and Biology, resulting in separate scheduling requirements. The distribution of teaching periods for each subject across all classes is presented in Table 2 to 5.

Table 2. Accumulated data of required weekly instructional hours for grade VII classes.

Subject Code	Subject	Grade VII Class Code				Total Hours Per Subjects
		71	72	73	74	
A	Qur'an Hadith	3	3	3	3	12
B	Aqidah and Akhlaq	0	0	0	0	0
C	Fiqh	0	0	0	0	0
D	Islamic Cultural History (SKI)	2	2	2	2	8
E	Civics Education	2	2	2	2	8
F	Indonesian Language	4	4	4	4	16
G	Arabic Language	2	2	2	2	8
H	English Language	4	4	4	4	16
I	Mathematics	4	4	4	4	16
J	Natural Sciences	4	4	4	4	16
K	Physics	0	0	0	0	0
L	Biology	0	0	0	0	0
M	Social Sciences	2	2	2	2	8
N	Arts and Culture	2	2	2	2	8
O	Physical Education, Sports, and Health (PJOK)	2	2	2	2	8
P	Local Content: Nahwu	11	11	11	11	44
Q	Information and Communication Technology (ICT)	2	2	2	2	8
R	Tahsin and Tahfiz Al-Qur'an (TTQ)	0	0	0	0	0
S	Guidance and Counseling	1	1	1	1	4

Furthermore, the timetable generation process must satisfy several institutional constraints imposed by MTs Nurul Ummah to ensure that the resulting schedule is both feasible and compliant with school policies. These constraints are as follows:

1. Each teacher may teach a maximum of six teaching periods per day.
2. Teacher assignments must comply with each teacher's availability schedule.
3. Some teachers are qualified to teach more than one subject, allowing them to be assigned to multiple subject areas.
4. The Local Content (Nahwu) subject is taught by five different teachers, providing multiple alternatives for teacher assignment.
5. Certain subjects may be scheduled for a maximum of three consecutive teaching periods in a single day.

These institutional constraints were incorporated into the optimization model to ensure that the generated timetable satisfies both curriculum requirements and operational policies while minimizing scheduling conflicts.

The scheduling model formulation was solved using Microsoft Excel Solver, as illustrated in Figure 2 and the final subject schedule is presented in Table 6.

Table 3. Accumulated data of recommended instructional hours for grade VIII classes.

Subject Code	Subject	Grade VIII Class Code			Total Hours Per Subjects
		81	82	83	
A	Qur'an Hadith	3	3	3	9
B	Aqidah and Akhlaq	3	3	3	9
C	Fiqh	3	3	3	9
D	Islamic Cultural History (SKI)	2	2	2	6
E	Civics Education	2	2	2	6
F	Indonesian Language	4	4	4	12
G	Arabic Language	2	2	2	6
H	English Language	4	4	4	12
I	Mathematics	4	4	4	12
J	Natural Sciences	0	0	0	0
K	Physics	2	2	2	6
L	Biology	2	2	2	6
M	Social Sciences	2	2	2	6
N	Arts and Culture	2	2	2	6
O	Physical Education, Sports, and Health (PJOK)	2	2	2	6
P	Local Content: Nahwu	5	5	5	15
Q	Information and Communication Technology (ICT)	2	2	2	6
R	Tahsin and Tahfiz Al-Qur'an (TTQ)	0	0	0	0
S	Guidance and Counseling	1	1	1	3

Table 4. Accumulated data of recommended instructional hours for grade IX classes.

Subject Code	Subject	Grade IX Class Code				Total Hours Per Subjects
		91	92	93	94	
A	Qur'an Hadith	3	3	3	3	12
B	Aqidah and Akhlaq	3	3	3	3	12
C	Fiqh	3	3	3	3	12
D	Islamic Cultural History (SKI)	2	2	2	2	8
E	Civics Education	2	2	2	2	8
F	Indonesian Language	4	4	4	4	16
G	Arabic Language	2	2	2	2	8
H	English Language	4	4	4	4	16
I	Mathematics	4	4	4	4	16
J	Natural Sciences	0	0	0	0	0
K	Physics	2	2	2	2	8
L	Biology	2	2	2	2	8
M	Social Sciences	2	2	2	2	8
N	Arts and Culture	2	2	2	2	8
O	Physical Education, Sports, and Health (PJOK)	2	2	2	2	8
P	Local Content: Nahwu	5	5	5	5	20
Q	Information and Communication Technology (ICT)	2	2	2	2	8
R	Tahsin and Tahfiz Al-Qur'an (TTQ)	0	0	0	0	0
S	Guidance and Counseling	1	1	1	1	4

3.7. Comparison Between Manual Scheduling and the ILP Based Timetable

To evaluate the effectiveness of the proposed Integer Linear Programming (ILP) model, the generated timetable was compared with the manually prepared timetable previously used at MTs Nurul Ummah. The comparison focuses on several key performance indicators, including scheduling conflicts, curriculum compliance, workload distribution, and timetable preparation time. The results are summarized in Table 7.

As shown in Table 7, the ILP-based timetable outperformed the manually constructed timetable across all evaluation criteria. The optimization model successfully eliminated both teacher and classroom conflicts while ensuring that the required instructional hours for every subject were fully satisfied. Furthermore, the workload was distributed more evenly among teachers in accordance with the school's curriculum and operational constraints.

Table 5. Teacher Codes, Subjects, Teaching Hours, and Grade.

Teacher Code	Subject	Teaching Hours	Grade
1	Local Content: Nahwu	15	81, 82, 83
2	Information and Communication Technology (ICT)	22	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
3	Natural Sciences, Biology	30	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
4	Mathematics	26	71, 72, 73, 74, 81, 82, 83
5	Islamic Cultural History (SKI)	22	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
6	Qur'an Hadith	33	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
7	Social Sciences	22	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
8	English Language	20	71, 72, 81, 82, 83
9	English Language	24	73, 74, 91, 92, 93, 94
10	Indonesian Language	28	81, 82, 83, 91, 92, 93, 94
11	Aqidah and Akhlaq, Local Content: Nahwu	20	74, 81, 82, 83
12	Civics Education	22	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
13	Arts and Culture	22	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
14	Physical Education, Sports, and Health (PJOK)	22	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
15	Local Content: Nahwu	22	71, 72
16	Indonesian Language	16	71, 72, 73, 74
17	Aqidah and Akhlaq	12	91, 92, 93, 94
18	Physics	14	81, 82, 83, 91, 92, 93, 94
19	Local Content: Nahwu	20	91, 92, 93, 94
20	Fiqh	21	81, 82, 83, 91, 92, 93, 94
21	Arabic Language	22	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
22	Guidance and Counseling	11	71, 72, 73, 74, 81, 82, 83, 91, 92, 93, 94
23	Mathematics	16	91, 92, 93, 94
24	Local Content: Nahwu	11	72

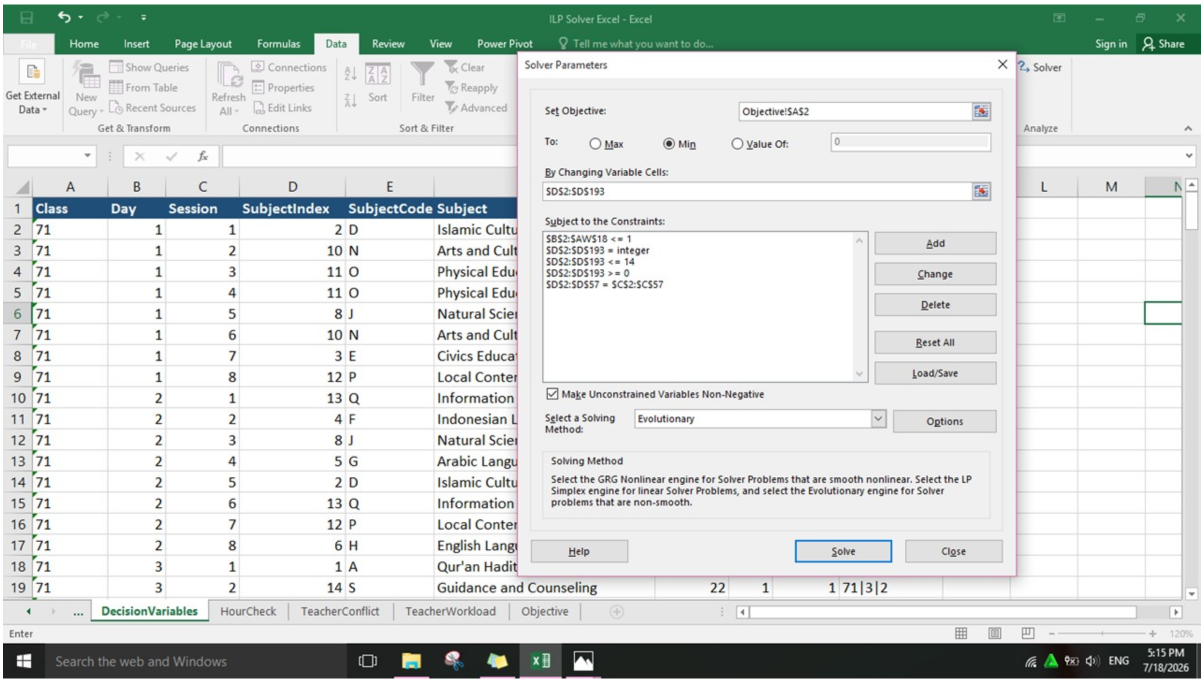

Figure 2. Solver excel.

Another significant improvement was observed in timetable preparation time. While the manual scheduling process required approximately five days due to repeated revisions and conflict resolution, the ILP model generated a feasible timetable in less than one hour. This substantial reduction demonstrates the computational efficiency of the optimization approach and its potential to support school administrators in producing high-quality timetables within a considerably shorter period.

The experimental results indicate that the objective function defined in eq. (3) was suc-

Table 6. Final schedule.

Day	Session	Grade 7				Grade 8			Grade 9			
		71	72	73	74	81	82	83	91	92	93	94
Monday	1	15P	4I	9H	11P	20C	1P	6A	10F	23I	14O	3L
	2	15P	4I	9H	11P	20C	1P	6A	10F	23I	14O	3L
	3	5D	24P	7M	12E	4I	8H	6A	20C	10F	3L	23I
	4	5D	24P	7M	12E	4I	8H	1P	9H	10F	3L	23I
	Break											
	5	8H	5D	15P	3J	13N	7M	1P	9H	17B	10F	21G
	6	8H	5D	15P	3J	13N	7M	20C	6A	19P	10F	21G
	7	2Q	8H	12E	7M	3L	11B	20C	6A	19P	21G	10F
	8	2Q	8H	12E	7M	3L	11B	20C	6A	19P	21G	10F
		71	72	73	74	81	82	83	91	92	93	94
Tuesday	1	15P	24P	4I	11P	10F	13N	5D	23I	3L	9H	14O
	2	15P	24P	4I	11P	10F	13N	5D	23I	3L	9H	14O
	3	3J	21G	14O	9H	6A	10F	8H	17B	20C	23I	7M
	4	3J	21G	14O	9H	6A	10F	8H	17B	20C	23I	7M
	Break											
	5	16F	4I	15P	2Q	8H	3L	11B	17B	5D	18K	9H
	6	16F	4I	15P	2Q	8H	3L	11B	19P	5D	18K	9H
	7	6A	3J	2Q	4I	7M	5D	11B	19P	17B	12E	18K
	8	6A	3J	2Q	4I	7M	5D	22S	19P	17B	12E	18K
		71	72	73	74	81	82	83	91	92	93	94
Wednesday	1	15P	6A	16F	11P	20C	12E	4I	7M	14O	10F	13N
	2	15P	22S	16F	11P	6A	12E	4I	7M	14O	10F	13N
	3	8H	14O	3J	16F	1P	2Q	7M	20C	6A	13N	10F
	4	8H	14O	3J	16F	22S	2Q	7M	20C	6A	13N	10F
	Break											
	5	3J	13N	15P	5D	18K	4I	2Q	21G	10F	23I	17B
	6	3J	13N	15P	5D	18K	4I	2Q	21G	10F	23I	17B
	7	4I	3J	5D	6A	2Q	20C	21G	19P	7M	9H	12E
	8	4I	3J	5D	6A	2Q	20C	21G	19P	7M	9H	12E
		71	72	73	74	81	82	83	91	92	93	94
Thursday	1	15P	24P	16F	6A	4I	14O	3L	10F	9H	7M	23I
	2	15P	24P	16F	22S	4I	14O	3L	10F	9H	7M	23I
	3	4I	7M	6A	11P	10F	1P	14O	3L	13N	2Q	9H
	4	4I	7M	22S	11P	10F	1P	14O	3L	13N	2Q	9H
	Break											
	5	6A	8H	15P	3J	1P	11B	10F	12E	20C	17B	19P
	6	22S	8H	15P	3J	1P	20C	10F	12E	6A	17B	19P
	7	7M	6A	3J	16F	11B	10F	8H	13N	19P	17B	2Q
	8	7M	6A	3J	16F	11B	10F	8H	13N	19P	20C	2Q
		71	72	73	74	81	82	83	91	92	93	94
Friday	1	12E	24P	4I	21G	14O	22S	13N	9H	23I	20C	5D
	2	12E	24P	4I	21G	14O	6A	13N	9H	23I	20C	5D
	3	13N	16F	9H	14O	12E	6A	4I	23I	21G	5D	20C
	4	13N	16F	9H	14O	12E	6A	4I	23I	21G	5D	20C
	Break											
	5	16F	12E	6A	13N	21G	4I	18K	5D	9H	19P	20C
	6	16F	12E	6A	13N	21G	4I	18K	5D	9H	19P	17B
		71	72	73	74	81	82	83	91	92	93	94
Saturday	1	21G	2Q	15P	9H	1P	18K	10F	14O	12E	19P	22S
	2	21G	2Q	15P	9H	1P	18K	10F	14O	12E	19P	6A
	3	14O	16F	15P	4I	11B	1P	12E	2Q	18K	19P	6A
	4	14O	16F	21G	4I	5D	8H	12E	2Q	18K	22S	6A
	Break											
	5	15P	24P	21G	11P	5D	8H	1P	18K	22S	6A	19P
	6	15P	24P	13N	11P	8H	21G	1P	18K	2Q	6A	19P
	7	15P	24P	13N	11P	8H	21G	1P	22S	2Q	6A	19P

cessfully minimized while satisfying all constraints specified in eq. (4) to (10). Consequently, the proposed ILP model produced a conflict-free timetable that complies with curriculum requirements, teacher availability, and institutional scheduling policies. Compared with the

Table 7. Comparison of manual and ILP-Based timetables.

No	Evaluation Aspect	Manual Timetable	ILP Based Timetable
1	Teacher Conflicts	5 Cases	0 Cases
2	Classroom Conflicts	2 Cases	0 Cases
3	Curriculum Hour Mismatches	4 Subjects	0 Subjects
4	Timetable Preparation Time	Approximately 5 Days	Less than 1 Hour

conventional manual approach, the proposed method not only improves scheduling quality but also enhances the transparency and consistency of the decision-making process, as all scheduling decisions are derived from a well-defined mathematical optimization model.

Moreover, the developed model is sufficiently flexible to accommodate changes in curriculum structure, teacher assignments, or class configurations, making it applicable to future academic years and potentially adaptable to other schools with similar scheduling characteristics. Nevertheless, the current model has several limitations. It does not consider teachers' individual scheduling preferences, extracurricular activities, or distinctions between general classrooms and specialized facilities such as science laboratories. These aspects provide promising directions for future research to further improve the practicality and applicability of the proposed scheduling system.

4. Conclusion

This study developed an Integer Linear Programming (ILP) model for optimizing subject scheduling at MTs Nurul Ummah and implemented it using Microsoft Excel Solver. The proposed model integrates curriculum requirements, teacher availability, teacher–subject–class assignments, instructional time allocation, and institutional scheduling constraints into a unified optimization framework. The implementation results demonstrate that the model successfully generated a feasible timetable satisfying all modeled constraints while eliminating the scheduling conflicts identified in the manually prepared timetable. Compared with the manual scheduling process, the ILP-based timetable also ensured that all subjects were allocated their required weekly instructional hours and reduced the time required for timetable preparation.

These findings demonstrate that Microsoft Excel Solver provides a practical and accessible platform for implementing ILP-based subject scheduling in secondary schools without requiring specialized optimization software. Although the proposed model addresses the essential institutional scheduling constraints, future research may incorporate additional constraints, such as teacher scheduling preferences, classroom allocation, and workload balancing, to improve the applicability of the model in more complex educational environments.

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Data availability. The data supporting this study consist of anonymized teacher codes, subject requirements, weekly instructional hours, and scheduling parameters. These data are available from the corre-

sponding author upon reasonable request.

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