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TEACHER SCHEDULING OPTIMIZATION WITH LINEAR PROGRAMMING

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Abstract. Scheduling is very important in teaching activities, especially for teachers who have been certified to fulfill their teaching obligations at least 24 hours a week. So it is necessary to prepare an appropriate schedule. This research aims to optimize teacher scheduling at SMK Negeri 1 Pantai Labu using the linear programming method. The data used is data on the number of teachers and classes at SMK Negeri 1 Pantai Labu. Completion of the simplex method, determining the optimum and feasible solution is obtained if the values in the Z row are all positive. Based on the research results, it was found that the minimum number of teachers needed in 1 period (6 days) was 69 teachers, with the minimum number of teachers starting work on the second day being 5 teachers, the minimum number of teachers starting work on the third day being 6 teachers, the minimum number of teachers There were 5 teachers who started working on the fourth day and the minimum number of teachers who started working on the fifth day was 5 teachers.

Keywords: Optimization, Scheduling, Linear Programming, Simplex Method

A. Introduction

Schools as educational institutions have various important aspects, including teaching, teacher competence, and lesson scheduling. Lesson schedule planning plays a crucial role in the smooth running of the teaching and learning process, as it is designed to increase efficiency, support academic activities, and improve the overall quality of education (Kamila, Yerizon, & Dewi, 2018). The preparation of lesson schedules aims to support academic activities, improve teaching quality, and build discipline for students and teachers. A well-structured schedule helps smooth learning so that the teaching and learning process can run optimally (Gunawan Rahmat & Dana, 2024).

Creating lesson schedules requires a high degree of accuracy. Without careful preparation, scheduling can become suboptimal, leading to conflicts between teachers and students. Given the large number of classes and teachers involved, there is a need for a more efficient system that can streamline the scheduling process (Nasution, Sari, & Aprilia, 2020). At present, many schools still rely on manual scheduling using tools like Microsoft Excel, where staff manually input data such as subjects, classes, teacher availability, time slots, and days. While this process is possible, it is time-consuming and requires exceptional accuracy to avoid errors in scheduling, a challenge highlighted by Ginting & Fattah (2019)

Course schedule preparation presents a significant challenge for many schools, particularly those still relying on manual methods, which leads to inefficiencies. This issue can be framed as an optimization problem, which can be effectively addressed through linear programming methods (Wungguli & Nurwan, 2020). Optimization, in this context, refers to the process of achieving the best possible outcome—maximizing available resources and designing the scheduling system for maximum effectiveness. A key challenge in scheduling is ensuring that teachers' teaching hours comply with certification regulations. Failing to meet these requirements can result in teachers being ineligible for professional allowances, as noted by Santi (2016)

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The linear programming method is an analytical technique in planning used to find the optimal solution to a problem (Supranto, 1983). In general, linear programming uses a mathematical model to evaluate various alternative solutions, then choose the best combination. This method helps in designing strategies and policies that consider limited resources and capital in order to achieve goals optimally.

Several previous studies have applied linear programming in optimization, such as in the wood industry of PT Indopal Harapan Murni in 2019. The results showed that the linear programming method had an effect on reducing production. Competition in various industrial sectors, including in teacher scheduling, is getting tighter. Therefore, the application of linear programming in the preparation of teaching schedules in schools can help ensure that the teaching and learning process continues to run smoothly. This strategy supports the provision of educational services that meet the needs of schools and supports the vision towards international standard education (Aprilyanti, S, 2019).

B. Literature Riview

Linear Programming

Linear programming is a branch of mathematics developed based on the basic concepts of linear algebra Linear programming is used to maximize or minimize the objective function, with limited resource factors as constraints. According to S. Hillier and Liebermen in Oyekan & Temisan he general form of LP is as follows:

Max or min

$$Z = C_1X_1 + C_2X_2 + \cdots C_nX_n \quad (1)$$

Subject to:

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n =/\leq/\geq b_1 \quad (2)$$
$$a_{21}x_2 + a_{22}x_2 + \cdots + a_{2n}x_n =/\leq/\geq b_2 \quad (3)$$
$$\ldots. \quad (4)$$
$$a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{1n}x_n =/\leq/\geq b_1 \quad (5)$$
$$x_1, x_2 \ldots\ldots, x_n \geq 0, \text{ simbol } x_1, x_2 \ldots\ldots, x_n\ (x_1) \quad (6)$$

Simplex Method

The simplex method is one of the solution techniques in linear programming that uses an iteration process to find the optimal solution. This process involves determining the feasible points against the objective function to be achieved, with the help of an iteration table until the best solution is found (Basriati, S., & Santi, E. 2018). The calculation of iterations with the simplex method is done in tabular form, where the general form of the problem that has been converted into a standardized form is entered into the simplex table. This table is used to simplify the iteration process in finding the optimal solution (Selvia, Irnanda, & Mahmud, 2018).

Table 1 Simplex Starting Table

Cbi	Var. Basis	X_1	X_2	...	Xn	S_1	S_2	...	Sn	Nk
S_1	Z	$-c_1$	$-c_2$	...	$-c_n$	0	0	0	0	0
S_2	S_1	a_{11}	a_{12}	...	a_{1n}	1	0	0	0	b_1
...	**S_2**	a_{21}	a_{22}	...	a_{2n}	0	1	0	0	b_2
...	**...**	...	...	...	...	...	...	...	...	...
S_n	**S_n**	a_{m1}	a_{m2}	...	a_{mn}	...	...	...	1	b_m

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C. Method

The Flowchart of this research is as follows:

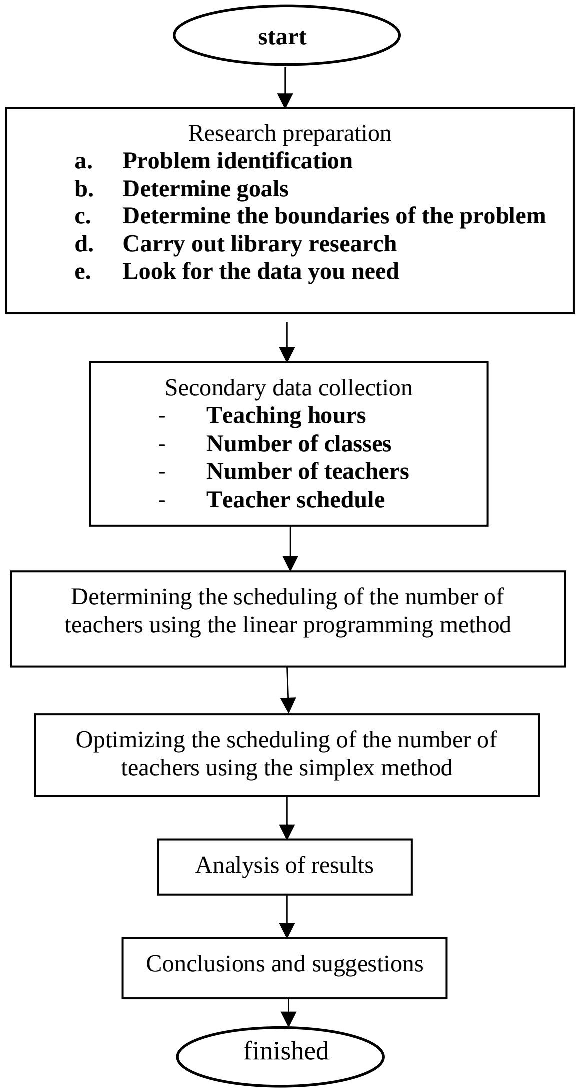

Figure 1. Flow Chart

This research was conducted at SMK Negeri 1 Pantai Labu and is included in the quantitative research type. The data used is sourced from the work map, which is a schedule of learning activities commonly carried out by workers. Research variables refer to certain characteristics, traits, or values of individuals or objects that have variations and are determined by researchers to be analyzed and concluded. In this study, the variables used are decision variables. Decision variables in scheduling are utilized to formulate the objective function and constraint function in mathematical form.

Table 2 Decision Variable

Variable	Description
X_1	Number of teachers who started teaching on day 1
X_2	Number of teachers who started teaching on day 2
X_3	Number of teachers who started teaching on day 3
X_4	Number of teachers who started teaching on day 4

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Variable	Description
X_5	Number of teachers who started teaching on day 5
X_6	Number of teachers who started teaching on day 6

D. Results and Discussion

Teacher scheduling at SMK Negeri 1 Pantai Labu has been computerized by the Administration (TU). This schedule is prepared every semester, with updates every month, then submitted to the Principal at the beginning of the semester for checking and verification. SMK Negeri 1 Pantai Labu operates from 07.30-15.00 so approximately 7.5 hours and has a total number of teachers included in this study, namely classes X TKJ-1, X TKJ-2, XI TKJ, XII TKJ, X Tbsm-1, X Tbsm-2, XI Tbsm, XII Tbsm, X APHP, XI APHP and XII APHP with a total of 45 teachers.

Table 3 Data on Number of Teachers in Each Class

Day	Teacher Quantity	Class Number	Average/Day
Monday	24	11	4
Tuesday	20	11	3
Wednesday	22	11	4
Thursday	19	11	3
Friday	18	11	3
Saturday	24	11	4

Based on the existing data, the author developed a linear equation model for the number of teachers per period (6 days) with the main objective to minimize the number of teachers involved in the scheduling system at SMK Negeri Pantai Labu. This model can be formulated with an objective function that focuses on optimizing the distribution of the number of teachers in each schedule period:

Objective function Min Z = $4X_1 + 3X_2 + 4X_3 + 3X_4 + 3X_5 + 4X_6$

Subject to:

$X_1 + X_2 + X_5 \geq 10$
$X_1 + X_3 + X_5 \geq 11$
$X_2 + X_4 + X_6 \geq 10$
$X_2 + X_3 + X_6 \geq 11$
$X_1 + X_3 + X_4 \geq 11$
$X_4 + X_5 + X_6 \geq 10$

The simplex method is a solution technique in linear programming that is used to solve optimization problems, especially when the solution found is not yet feasible. If the initial solution does not meet the constraints, then the simplex method will be used to find the optimal and feasible solution. The following are the steps in solving problems using the simplex method:

1. Convert the linear program model into standard form by changing all objective functions and constraint functions adding slack variables.

Objective function Min Z = $4X_1 + 3X_2 + 4X_3 + 3X_4 + 3X_5 + 4X_6$

Subject to:

$X_1 + X_2 + X_5 \geq 10$
$X_1 + X_3 + X_5 \geq 11$
$X_2 + X_4 + X_6 \geq 10$

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$X_2 + X_3 + X_6 \geq 11$
$X_1 + X_3 + X_4 \geq 11$
$X_4 + X_5 + X_6 \geq 10$

Table 4. 1st Iteration Result

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK
1	S_1	1	1	0	0	1	0	-1	0	0	0	0	0	10
1	S_2	1	0	1	0	1	0	0	-1	0	0	0	0	11
1	S_3	0	1	0	1	0	1	0	0	-1	0	0	0	10
1	S_4	0	1	1	0	0	1	0	0	0	-1	0	0	11
1	S_5	1	0	1	1	0	0	0	0	0	0	-1	0	11
1	S_6	0	0	0	1	1	1	0	0	0	0	0	-1	10
	Z_{min}	3	3	3	3	3	3	-1	-1	-1	-1	-1	-1	0

Because this is the first iteration then directly from the existing initial data, because $\boldsymbol{Z_{min}}$ there are still negative values then we continue with iteration 2

Table 5. Determining the 2nd Iteration Key Column

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK
1	S_1	1	1	0	0	1	0	-1	0	0	0	0	0	10
1	S_2	1	0	1	0	1	0	0	-1	0	0	0	0	11
1	S_3	0	1	0	1	0	1	0	0	-1	0	0	0	10
1	S_4	0	1	1	0	0	1	0	0	0	-1	0	0	11
1	S_5	1	0	1	1	0	0	0	0	0	0	-1	0	11
1	S_6	0	0	0	1	1	1	0	0	0	0	0	-1	10
	$\boldsymbol{Z_{min}}$	3	3	3	3	3	3	-1	-1	-1	-1	-1	-1	63

Table 6. Determining the 2nd Iteration Key Row

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK	Rasio
1	S_1	1	1	0	0	1	0	-1	0	0	0	0	0	10	$\frac{10}{1} = 10$
1	S_2	1	0	1	0	1	0	0	-1	0	0	0	0	11	$\frac{11}{1} = 11$
1	S_3	0	1	0	1	0	1	0	0	-1	0	0	0	10	
1	S_4	0	1	1	0	0	1	0	0	0	-1	0	0	11	
1	S_5	1	0	1	1	0	0	0	0	0	0	-1	0	11	$\frac{11}{1} = 11$
1	S_6	0	0	0	1	1	1	0	0	0	0	0	-1	10	
	$\boldsymbol{Z_{min}}$	3	3	3	3	3	3	-1	-1	-1	-1	-1	-1	63	

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Table 7. Determining the Key Value 2nd Iteration

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK
1	S_1	1	1	0	0	1	0	-1	0	0	0	0	0	10
1	S_2	1	0	1	0	1	0	0	-1	0	0	0	0	11
1	S_3	0	1	0	1	0	1	0	0	-1	0	0	0	10
1	S_4	0	1	1	0	0	1	0	0	0	-1	0	0	11
1	S_5	1	0	1	1	0	0	0	0	0	0	-1	0	11
1	S_6	0	0	0	1	1	1	0	0	0	0	0	-1	10
	Z_{min}	3	3	3	3	3	3	-1	-1	-1	-1	-1	-1	63

Table 8. Replacing the Outgoing Variable with the Entering Variable 2nd Iteration

Entry variable

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK
1	S_1	1	1	0	0	1	0	-1	0	0	0	0	0	10
1	S_2	1	0	1	0	1	0	0	-1	0	0	0	0	11
1	S_3	0	1	0	1	0	1	0	0	-1	0	0	0	10
1	S_4	0	1	1	0	0	1	0	0	0	-1	0	0	11
1	S_5	1	0	1	1	0	0	0	0	0	0	-1	0	11
1	S_6	0	0	0	1	1	1	0	0	0	0	0	-1	10
	Z_{min}	3	3	3	3	3	3	-1	-1	-1	-1	-1	-1	63

Exit Variable

Table 9. Find New Value in Key Row

X_1	1	1	0	0	1	0	-1	0	0	0	0	0	10
	$\frac{1}{1} = 1$	$\frac{1}{1} = 1$	$\frac{0}{1} = 0$	$\frac{0}{1} = 0$	$\frac{1}{1} = 1$	$\frac{0}{1} = 0$	$\frac{-1}{1} = -1$	$\frac{0}{1} = 0$	$\frac{0}{1} = 0$	$\frac{0}{1} = 0$	$\frac{0}{1} = 0$	$\frac{0}{1} = 0$	$\frac{10}{1} = 10$

Thus, the value in the key row changes to:

Table 10. Finding the New Value in the 2nd Iteration Key Row

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK
1	X_1	1	1	0	0	1	0	-1	0	0	0	0	0	10
1	S_2	1	0	1	0	1	0	0	-1	0	0	0	0	11
1	S_3	0	1	0	1	0	1	0	0	-1	0	0	0	10
1	S_4	0	1	1	0	0	1	0	0	0	-1	0	0	11
1	S_5	1	0	1	1	0	0	0	0	0	0	-1	0	11
1	S_6	0	0	0	1	1	1	0	0	0	0	0	-1	10
	Z_{min}	3	3	3	3	3	3	-1	-1	-1	-1	-1	-1	63

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Table 11. Find New Value on Another Base 2nd Iteration

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK
	X_1	1	1	0	0	1	0	-1	0	0	0	0	0	10
1	S_2	0	-1	1	0	1	0	1	-1	0	0	0	0	1
1	S_3	0	1	0	1	0	1	0	0	-1	0	0	0	10
1	S_4	0	1	1	0	0	1	0	0	0	-1	0	0	11
1	S_5	0	-1	1	1	-1	0	1	0	0	0	-1	0	1
1	S_6	0	0	0	1	1	1	0	0	0	0	0	-1	10
	Z_{min}	0	0	3	3	1	3	2	-1	-1	-1	-1	-1	33

The iteration calculation is repeated until all values in row x become positive or 0. Based on the calculation results at the 8th iteration, it can be seen that all base variables have changed, the results of which can be seen as follows:

Table 12. Finding the New Value on Another Base 8th Iteration

Cbi	Var. Basis	X_1	X_2	X_3	X_4	X_5	X_6	S_1	S_2	S_3	S_4	S_5	S_6	NK
	X_5	0	0	0	0	1	0,5	0	-0,5	0	0	0,5	-0,5	5
	X_3	0	0	1	0	0	0,5	0	0,5	1	-1	-0,5	-0,5	6
	X_1	1	0	0	0	0	-1	0	-1	-1	1	0	1	0
	X_2	0	1	0	0	0	0,5	0	-0,5	-1	0	0,5	0,5	5
	X_4	0	0	0	1	0	0,5	0	0,5	0	0	-0,5	-0,5	5
	S_1	0	0	0	0	0	0	1	-2	-2	1	1	1	0
	Z_{min}	0	0	0	0	0	0	0	0	0	0	0	0	69

From the results of the 8th iteration contained in Table 12, it can be seen that all values in row X have positive values and 0, the 8th iteration is optimal, so the calculation is complete. Thus, the optimum and feasible results are presented in Table 18 below:

Table 13. Simplex Table Optimization Results

Decision Variable	Final Results
X_5	5
X_3	6
S_6	0
X_2	5
X_4	5
S_1	0
Z_{min}	69

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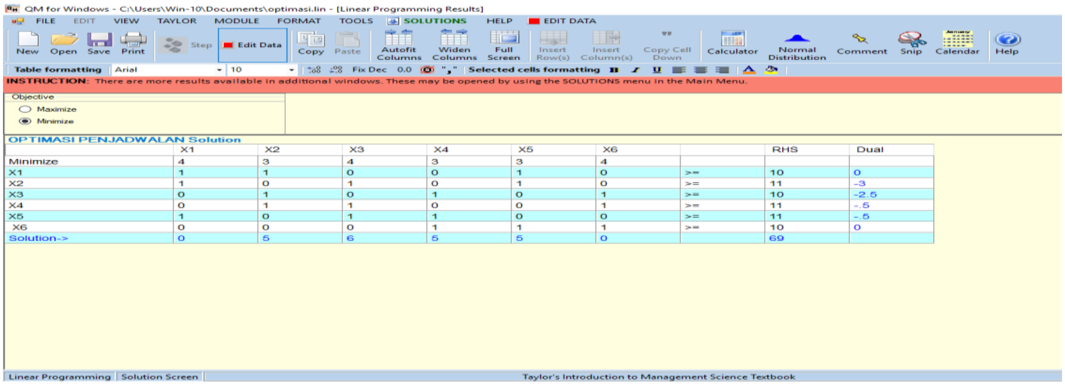
Based on Table 13 above, it can be concluded that the minimum number of teachers needed in 1 period (6 days) is 69 teachers with x_1 the minimum number of teachers starting work on the second day is 0 teachers, x_2 the minimum number of teachers starting work on the second day is 5 teachers, x_3 the minimum number of teachers starting work on the third day is 6 teachers, x_4 the minimum number of teachers starting work on the fourth day is 5 teachers and x_5 the minimum number of teachers starting work on the fifth day is 5. While on the 6th day there are no teachers who start their duties, this does not cause a shortage of teachers because the needs on that day are covered by teachers who start working from the first day to the fifth day.

In addition to manual calculations using the simplex method, the POM-QM for Windows application can also be used to simplify the process. The use of this tool serves as an alternative and comparison to manual calculations using the simplex method. The following are the steps of data processing using POM-QM [21]. The results using the POM-QM for Windows application are as follows:



	X1	X2	X3	X4	X5	X6		RHS	Dual
Minimize	4	3	4	3	3	4			
X1	1	1	0	0	1	0	>=	10	0
X2	1	0	1	0	1	0	>=	11	-3
X3	0	1	0	1	0	1	>=	10	-2.5
X4	0	1	1	0	0	1	>=	11	-.5
X5	1	0	1	1	0	0	>=	11	-.5
X6	0	0	0	1	1	1	>=	10	0
Solution->	0	5	6	5	5	0		69	

Figure 2 Linear Programming Optimal Result Display

Data processing using the POM-QM application has the same results as manual calculation of the simplex method with optimal results, namely showing the minimum number of teachers needed in 1 period (6 days) as many as 69 teachers with x_1, namely the minimum number of teachers who started working on the second day as many as 0 teachers, x_2 namely the minimum number of teachers who started working on the second day as many as 5 teachers, x_3 is the minimum number of teachers who start working on the third day as many as 6 teachers, x_4 is the minimum number of teachers who start working on the fourth day as many as 5 teachers, x_5 is the minimum number of teachers who start working on the fifth day as many as 5 teachers, and on the 6th day there are no teachers who start working, but that does not mean that there will be teacher vacancies on the 1st and 6th days because they can already be covered by working teachers.

Linear programming (LP) can be used to solve scheduling problems by optimizing the allocation of time or resources to a set of tasks or activities. In this context, LP helps determine the optimal time to complete tasks by minimizing total time or maximizing resource utilization, while adhering to constraints such as resource capacity, task order, and available time. The LP objective function aims to maximize or minimize specific criteria (such as time or cost), while the constraints ensure that the solution is realistic and applicable in real-world conditions. Examples of its applications include worker scheduling, machine maintenance, or production scheduling (Winston, 2004).

The use of linear programming (LP) in education policy, especially at the school level, can significantly enhance decision-making regarding resource allocation, scheduling, and time management. LP helps optimize the use of limited resources, such as classrooms and teachers, by efficiently allocating them based on constraints like available time and teacher workload.

For example, LP can assist in creating an optimal class schedule that avoids conflicts, ensures proper time allocation for each subject, and minimizes idle time. This leads to more effective teaching, better use of resources, and an overall improvement in the learning environment. Additionally, LP can support educational policies that aim for a fair distribution of resources and time, ultimately improving the quality and efficiency of the educational process (Winston, 2004; Taha, 2017).

E. Conclusion

Based on the research and analysis that has been done regarding the scheduling of study teachers at SMK N. 1 Pantai Labu Linear Programming, it can be concluded that the calculations and analysis carried out show that the linear programming calculations used with manual calculations with the simplex method and using the POM QM for Windows application program have the same calculation results and there is no difference, where the results show that the minimum number of teachers needed in 1 period (6 days) is 69 teachers with x_1, namely the minimum number of teachers who start working on the second day as many as 0 teachers, x_2 is the minimum number of teachers who start working on the second day as many as 5 teachers, x_3 is the minimum number of teachers who start working on the third day as many as 6 teachers, x_4 is the minimum number of teachers who start working on the fourth day as many as 5 teachers and x_6 is the minimum number of teachers who start working on the fifth day as many as 5 teachers.

Based on the conclusions previously presented, the authors provide suggestions so that SMK N. 1 Pantai Labu can implement more optimal scheduling in accordance with the solutions obtained through calculations using linear programs. With a minimum number of 70 teachers, it is expected to reduce ineffectiveness in performance, so that the learning process can run more efficiently and optimally.

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