

## Time Efficiency and Match Optimization in Scheduling Pencak Silat Matches: A Case Study of the Sleman Regency Student Pencak Silat Championship in 2023

### Eficiencia del tiempo y optimización de partidos en la programación de partidos de Pencak Silat: un estudio de caso del campeonato estudiantil Pencak Silat de Sleman Regency en 2023

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**Abstract.** The issue of this research is that many pencak silat matches in Indonesia still use manual calculations in several districts/regencies, then the calculation data is inputted into the system. This will take a lot of time, so the pencak silat match schedule spends a lot of time. The data used is the number of parties at the Sleman Regency Student Pencak Silat Championship in 2023. This research aims to find calculations to maximize the number of parties/matches/match numbers per day in a martial arts match. The method that can be used is the Preemptive Multiple Bounded Knapsack Problem (PMBKP). PMBKP involves distributing the quantity of different types of items to a group of knapsacks with their respective priorities and capacity limits. The PMBKP results obtained in the 2023 Sleman District Pencak Silat Championship problem using the Branch and Bound algorithm are 175 parties on the first day, 133 parties on the second day, 128 parties on the third day, 127 parties on the fourth day, and 72 parties on the fifth day. These results can be said to be effective if applied to pencak silat matches that aim to nurture achievements, such as introductions and district/regency level matches.

**Keywords:** Pencak Silat, Competition, Sports Schedule

**Resumen.** El problema de esta investigación es que muchos partidos de pencak silat en Indonesia todavía utilizan cálculos manuales en varios distritos/regencias, luego los datos de cálculo se ingresan en el sistema. Esto llevará mucho tiempo, por lo que el calendario de partidos de pencak silat requiere mucho tiempo. Los datos utilizados son el número de partidos en el Campeonato Estudiantil Pencak Silat de Sleman Regency en 2023. Esta investigación tiene como objetivo encontrar cálculos para maximizar el número de partidos/partidos/números de partidos por día en un partido de artes marciales. El método que se puede utilizar es el problema preventivo de mochila delimitada múltiple (PMBKP). PMBKP implica distribuir la cantidad de diferentes tipos de artículos a un grupo de mochilas con sus respectivas prioridades y límites de capacidad. Los resultados del PMBKP obtenidos en el problema del Campeonato Pencak Silat del distrito de Sleman de 2023 utilizando el algoritmo Branch and Bound son 175 partidos el primer día, 133 partidos el segundo día, 128 partidos el tercer día, 127 partidos el cuarto día y 72 fiestas el quinto día. Se puede decir que estos resultados son efectivos si se aplican a partidos de pencak silat que tienen como objetivo fomentar los logros, como presentaciones y partidos a nivel de distrito/regencia.

**Palabras clave:** Pencak Silat, competición, calendario deportivo.

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Fecha recepción: 05-06-24. Fecha de aceptación: 18-06-24

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### Introduction

The combination of art and fighting elements are united in the sport of pencak silat. Basically, pencak silat is self-defense using all parts of the body and when demonstrated it will look beautiful to look at (Sudiana, et al., 2023). Pencak silat has become one of Indonesia's indigenous cultures after being designated by UNESCO at the 14th session in Bogota, Colombia (Sampurna et al, 2021; UNESCO 2024). Pencak silat developed in Indonesia along with the diversity of cultures in each region. Pencak silat has a basic movement technique of attack, evasion, parry, and avoidance (Suwirman et al., 2021). Indonesia consists of various tribes and cultural customs that are different on each island. Cultural differences between islands are a form of diversity that cannot be separated from social life, and this can increase the potential for conflict in Indonesia (Akrim, 2023; Anwar, 2021). According to the Big Indonesian Dictionary (KBBI) conflict is a form of dispute or disagreement between two individuals, between individuals and groups, or groups and groups. Indonesia is known as a country with plural indigenous cultures. In Indonesia, indigenous tribal groups are divided on each island. Even on large islands there are more than two cultural tribes. For example, on

the island of Java there are Central Javanese culture, West Javanese culture (Sunda), Jakarta culture (Betawi), and so on. Then on the island of Kalimantan, there are indigenous tribes such as the Banjar ethnic group, Dayak Bakumpai, Dayak Baraki, Dayak Maanyan, and so on. Each diverse cultural group has its own prejudices and viewpoints. So that every time there is a phenomenon, each cultural group has its own perspective (Sumarsono, et. al., 2003). These different perspectives can lead to unfavorable prejudices between the cultures. One example of a conflict that has occurred in Indonesia is the dispute between the Dayak ethnic group in Sampit (Kalimantan) and the Madurese ethnic group in 2001. This is based on the Dayak tribe's point of view that the Madurese (migrants) do not want to understand and do not comply with the customs of the local Dayak tribe and the Madurese are considered to have a rude attitude (Pati, 2003). So that there are often quarrels that cause casualties. Although the conflict has been resolved, there needs to be "something" that can unite all cultures in Indonesia to prevent the same conflict from happening again. One effort is to preserve the cultural values of pencak silat. Pencak silat fosters a sense of love for the country "Indonesia" which means giving respect to all the cultures in Indonesia. In fact, pencak silat is a manifestation of the combined diversity that exists in Indonesia.

Pencak silat, these cultural differences form the diversity of movement techniques in pencak silat so that each region has its own characteristics. The combination of cultural elements, physical exercise, and mental balancing/emotional control is always in a positive state because pencak silat is a sport related to physical contact fighting, if it is not controlled, it will make pencak silat lead to bad things such as violence. These things makes pencak silat rooted and strong in Indonesian citizens (Alfiansyah, 2018; Imtihansyah et al., 2024). Pencak silat is a martial art sport that is growing throughout Southeast Asia and is starting to be targeted for entry into the Olympics (Hadiana, et al., 2022)

Along with the times pencak silat has become a widely competed achievement sport and requires coaches to understand the components that are the basis of a training process without neglecting the fitness of athletes (Farhat, et al., 2022; Duda, et al., 2020). The coach basically determines the design and arrangement of a detailed training program for athletes in accordance with the aspects of training, namely the factors of physical ability, mastery of basic techniques, application of tactics, and mental toughness starting from the training process to the main competition. Determination of the appropriate training program by the coach can help athletes reach the peak of achievement (Syaifulah & Doewes, 2020). Physical fitness is one of the main components to see the athlete's ability to follow an intense training program because basically good physical condition in a match is very necessary (Sudirman, et al., 2022) Moreover, for now pencak silat matches are more intense to be held. Athlete fitness maintenance needs to be considered more by the coaches. Pencak silat movements during the match are dynamic, fast, and athletes are required to have good endurance (muscle and cardiovascular) to complete a match (Sudiana, et al., 2023).

Currently, many pencak silat competitions are held and are developing in every region in Indonesia, even starting to spread to the Asian and international levels (Subekti et al., 2020). The basic technical movements of pencak silat consist of attack techniques for punches, kicks, application of stances, parries, dropping techniques, sweeping techniques, scissor techniques, and locking techniques (Kumaidah, 2012). It should be understood that the basic physical biomotor components that need to be considered in pencak silat are endurance, strength, speed, coordination, and flexibility. In addition, there is a combination of basic physical biomotor components such as power, balance, agility, and stamina which are also factors that build the physique of athletes. (Hariono, 2006; Suwirman, et. al., 2021; Karo-Karo, et. al., 2022). According to the latest pencak silat competition regulations, currently pencak silat has 5 class categories that are contested, namely the fighting category, single artistic category, double artistic category, team artistic category, and solo creative category (PERSILAT, 2024)). Each category has its own characteristics (Aga, et al., 2023) The fighting category generally competes between two athletes from different teams fighting for points

by attacking punches and kicks (with power and clarity) towards the opponent's body protector and knocking down the opponent (Doewes, et al., 2022; Anifah, et al., 2023). The single, double, team, and creative solo categories are categorized as artistic categories. Single artistic is a category performed by one athlete by demonstrating standard single art moves with a total of 14 moves that have a total of 100 movements. Double artistic category is a move performed by two athletes with the same team demonstrating attack-defense choreography. Team artistic category is a move performed by three athletes who demonstrate the standard team moves with a total of 14 moves consisting of a total of 100 movements. Solo creative artistic category is a move performed by an athlete by demonstrating the choreography of a series of moves (PERSILAT, 2024). However, many pencak silat matches in Indonesia still use manual calculations. Manual calculation is an assessment made by the judges by writing scores on paper. When the writing of the score is complete, there are officers who will go around the arena to take each judge's paper. Then all the judges' scoring papers are given to the chairman of the match and the calculation is done manually. After some time, the calculation is completed and the number of scores to determine the winner is known. All of these processes are repeated in every match. In contrast to digital calculations, each judge only needs to give a score from the application available on the device (in the form of a Tablet) which is automatically summed up in total and connected to the monitor in front of the match chairman so that they immediately know the number of scores and winners in the match number. When viewed from the use of duration, manual calculation uses more time in each match compared to digital calculation. Manual calculation wastes more time, so the pencak silat match schedule consumes a lot of time. This research aims to maximize the amount of match number per day in pencak silat used mathematics formulation especially Preemptive Multiple Bounded Knapsack Problem. It is hoped that the results of this research can be a solution for organizing pencak silat match events so that matches are held with effective and efficient time.

## **Literature Review**

### *Rules of the Pencak Silat Match*

The previous artistic category pencak silat rules used a pool/group system, where the winner of each pool/group would go to the final round and the winners in the final round would be sorted from the highest point earner to get a ranking. But currently, the system used in the latest version of pencak silat is to use the knock out system in the fighting and artistic categories (Irawan, et al., 2021). This system has a condition that the number of numbers competed meets the  $2^n$  number sequence (2, 4, 8, 16, and so on). If the number of participants does not meet this requirement, the bye system is used. The fighting and artistic categories (singles, doubles, team, and creative solo) have different scoring systems. Fighting category scoring is centered on the points earned by each athlete led by one referee

and judged by three judges. The athlete with the higher points will be the winner of that match number and will be entitled to the next round. Artistic category scoring applies a 9.00 to 10.00 numerical scale with the calculation of the median number of the ten judges. The median is the middle value in a series of numbers given, in this context it will be the middle value of the 10 judges who judge. Once the median value is found, the average value of the median number is calculated (PERSILAT, 2024).

The match duration of the fighting and artistic categories has a difference. In the fighting category is 2 minutes with 3 rounds for youth and adult categories and 1 minute 30 seconds with 3 rounds for early childhood and pre-teen. The time used is 2 minutes clean which means when the referee stops the match, the time will stop. Each age group has a 1-minute break between rounds. The artistic category is competed with a duration of 3 minutes per performer with a time tolerance of approximately 5 seconds for youth and adults, and approximately 10 seconds for the early age category (PERSILAT, 2024). In the early age and pre-adolescent categories, the single category has separate stances, namely empty hands and weapons. Age group differences are used because of course because the biomotor abilities of each age group are different, especially in the early age category to avoid the risk of unwanted injuries (Barth, et al., 2020; Zaremski, et al., 2017)

#### *Approximate Match Duration*

The rules for organizing pencak silat competition events are listed in the latest pencak silat competition regulations revised version 2024. Starting from the equipment needed to the number of match devices (PERSILAT, 2024). In some events this year, the number of participants affects the duration of the event itself. The more participants who take part, the longer the duration of the event lasts. To estimate the duration of the match, you must see the duration of each match number. Judging from the duration of the match in the match category there are 3 rounds with 2 minutes per round and 1 minute rest per round (Sad, et al., 2023). Every time the referee stops the match, the time also stops. In fighting category matches there are rules for respectful greetings when athletes enter and leave the match (PERSILAT, 2024). Through observations of various matches that have been carried out, if calculated in one match the fighting category takes approximately 15 minutes if there are no incidents, protests, and time-consuming referee/judge changes. Furthermore, the art category uses a knockout system that brings together two athletes who each demonstrate moves in 3 minutes alternately. When entering and leaving the arena, each athlete salutes the chairman of the match. The duration of time in one artistic category match is approximately 15 minutes not including incidents, protests, and changes of judges. It is estimated that in 1 hour, there will be 3-4 match numbers. The sessions allowed in pencak silat matches are 2 sessions, namely the morning session and the afternoon session. Each session has an effective time of 4 hours so that each session gets 16

matches. The final result in 1 day is approximately 32 matches.

#### *Technical Meeting*

Technical meetings are needed to minimize unwanted events that occur during the implementation of the match (Jones, et al., 2020). Looking at several pencak silat championships that have been held, technical meetings are held before the drawing of the chart. Matters discussed during the technical meeting can change the match rules in a minor way for the common interest and are approved by more than 50% of the participants who take part in the technical meeting. Participants who do not participate in the technical meeting are considered to agree to follow the applicable decisions. Based on field observations, in championships at the regional level there are often adjustments related to match times due to the large number of participants participating in the championship. Basically, the fighting category uses 2 minutes of "clean" time, meaning that every time the referee stops the match, the time will be stopped (PERSILAT, 2024). However, this can be adjusted by using 2 "dirty" minutes which means that every time the referee stops the match, the time will still run. Then for the artistic category, the thing that often happens is adjustments related to the knockout system which is changed to a pool/group system. This adjustment is submitted to the technical meeting forum which then the audience can provide feedback. After discussion, the results will be determined at that time to become a guideline when the match starts.

The estimated time of the event is important for the organizing committee to understand. The calculation of match duration is key in a martial arts championship. Even though it has been estimated, there are still some obstacles that may occur during the implementation of the match. There needs to be a mathematical calculation to understand more deeply about the duration of a pencak silat match. The number of arenas used also plays a role in streamlining the duration of each match number. The more arenas used, the more match numbers that will be held. It is necessary to conduct a match observation study to learn effective and efficient calculations regarding the duration of a match.

#### *Technical Meeting of Sleman Regency Student Pencak Silat Championship in 2023*

The selection process for Sleman Regency pencak silat athletes was held by participating in the Sleman Regency Student Pencak Silat Championship in November 2023. Before the the event was held, a technical meeting was held on Saturday, November 18, 2023. As for the results of the technical meeting related to the match, there were several adjustments that were agreed upon by the participants. The time of the competition is 5 days starting from November 20 to 24, 2023. Participants totaled more than 700 (early age, pre-teen, and teen) athletes so it was necessary to adjust each match. Weigh-in starts at 07.00 WIB and the match will start at 08.00 WIB. The match categories use 1 minute 30 with 3 rounds for high school then 2 rounds for early childhood and pre-teen. The adjusted match category

time is carried out in the preliminary, semifinal, and final rounds.

The early age group and pre-teen artistic categories have been adjusted. The single category competed are separated into empty hands and weapons. The performance time for empty hand and weapon stances is 1 minute 30 seconds. The double artistic category is separated into empty hand and weapon stances. The double artistic empty hand stance is given 1 minute 50 seconds and the double weapon stance is given 1 minute 50 seconds. The team artistic category is separated into stances 1-6 and stances 7-12 with a time of 1 minute 50 seconds each. The results of the technical meeting above were approved by the forum so that further data will be processed by the organizing committee with a note that if there are adjustments again, all officials will be gathered again to discuss.

The scheduling of pencak silat matches aims to run matches optimally and maximize the number of matches that can be held. This requires a balance between time efficiency and the number of matches held. Schedule planning should consider arrangements that minimize the time between matches while ensuring as many matches as possible can be held in the time available. Research on sports scheduling is increasingly intense, covering a wide range of sports such as soccer, rugby, ice hockey, and now pencak silat. Pencak silat match scheduling is interesting because of its complexity involving many participants and matches.

One method to maximize the amount of match numbers each day is using Knapsack problem. The Knapsack Problem (KP) is a well-known problem in mathematics and computer science (Kellerer, et al., 2004). It involves selecting items to maximize their combined value without exceeding a weight limit. Imagine you have a backpack (knapsack) with a weight capacity and a list of items, each with a weight and value. The challenge is to fill the knapsack with the most valuable combination of items without going over the weight limit. This problem is important because it has many real-world applications, such as optimizing resources in various fields, including cryptography and mathematics (Assi & Haraty, 2018). In Sleman Regency Student Pencak Silat Championship, the method that can be used is Preemptive Multiple Bounded Knapsack Problem (PMBKP). PMBKp involves distributing quantities of different types of items to a group of knapsacks with their respective priorities and capacity limits. The goal is to optimize the distribution by considering the size, value, and upper limit of the items, while respecting the knapsack priorities (Ambarwati et al., 2024). This research aims to find calculations to maximize the amount of match numbers per day in a pencak silat match.

## Method

**Definition 1. (Preemptive Multiple Bounded Knapsack Problem (PMBKP))**

Consider a collection of  $n$  different types of items and a group of knapsacks denoted as  $M = \{1, \dots, m\}$ . Each item

of type  $j$  has a weight  $w_j \in Z^+$ , a value  $v_j \in Z^+$ , and an availability limit  $b_j \in Z^+$ . Each knapsack  $i$  has a capacity  $W_i \in Z^+$ . There are  $m$  priorities, with  $p_i$  representing the priority of knapsack  $i$  for  $i = 1, \dots, m$ . The problem is to allocate the quantity  $x_{ij}$  of item type  $j$  to each knapsack  $i$ , for  $j = 1, 2, \dots, n$ , considering their priorities.

The canonical form for the PMBKp is subject to (Ambarwati, et al., 2024)

$$\max Z = \sum_{i=1}^m \sum_{j=1}^n v_j x_{ij}$$

$$\begin{aligned} p_i: \sum_{j=1}^n w_j x_{ij} &\leq W_i \quad (i = 1, 2, \dots, m) \\ \sum_{i=1}^m x_{ij} &\leq b_j; \quad j = 1, 2, \dots, n \\ x_{ij} &\in \mathbb{N}_0 \end{aligned}$$

The PMBKp starts by forming the canonical form of the problem. The solution process begins with the highest priority. This approach involves solving the problem for the highest priority first. The results obtained for this priority are then used as input to solve the problem at the next priority level. This process is repeated sequentially according to priority, with each set of results being used as the basis for solving the next priority level. This process continues until the  $(m - 1)$ -th priority is addressed, after which the results from the  $(m - 1)$ -th priority are integrated into the solution process for the  $m$ -th priority. All solutions from the first to the  $m$ -th priority are collected to provide a solution for the PMBKp. The PMBKp can be solved using the Branch and Bound algorithm.

Branch and Bound algorithm is an algorithm that breaks a large problem into smaller, more manageable problems, solves these smaller problems, and then combines the solutions to solve the original problem. If the problem is divided into smaller parts, the maximum value of each part can be found, and the maximum value of the entire problem is the maximum of these part values. Branch and Bound algorithm is represented using an enumeration tree (Wolsey, 2020). For example, if the solution in  $P_0$  with the value  $a_2 = 3.4$  is fractional, branching is done by creating new constraints, namely  $a_2 \leq 3$  and  $a_2 \geq 4$ . After obtaining solutions for  $P_1$  and  $P_2$ , they are re-evaluated. If the value of  $a_1$  is fractional, new constraints are created with the integer values below and above it. The process ends when an integer solution is obtained for each branch. An illustration of solving

using the Branch and Bound Method can be seen in the Figure 1.

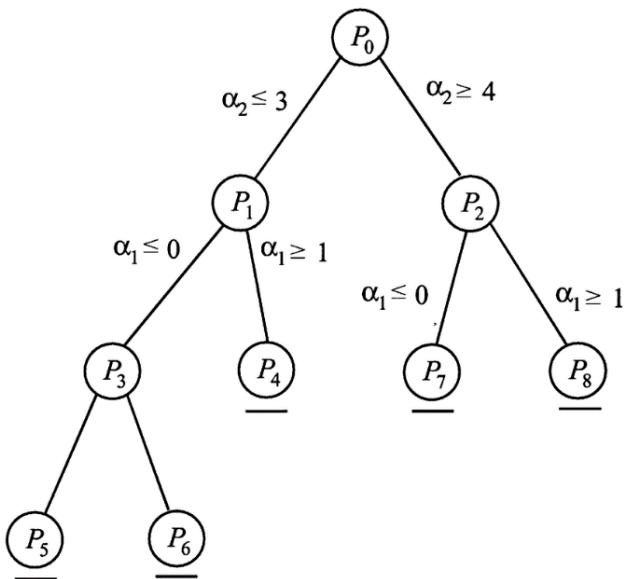


Figure 1. An illustration of enumeration tree of Branch and Bound algorithm

The Branch and Bound algorithm in solving the knapsack problem relies on two important factors that facilitate the process (Winston, 2022). First, the initial stage involves Linear Programming Relaxation, with the knapsack problem transformed into Linear Programming. The solution from this Linear Programming is then obtained to ensure that the result is in fractional or integer form. If the solution is fractional, the next step is to perform branching. Second, the branching process involves branching the fractional solution values to the nearest higher and lower integers. These two values are then included in the original problem constraints and tested to obtain a solution. This branching process continues until an optimal result with integer values is obtained. The steps for solving using the Branch and Bound algorithm can be seen in the Figure 2. Software that can be used to solve the Branch and Bound method is LINDO. In this case study, LINDO 6.1 is used.

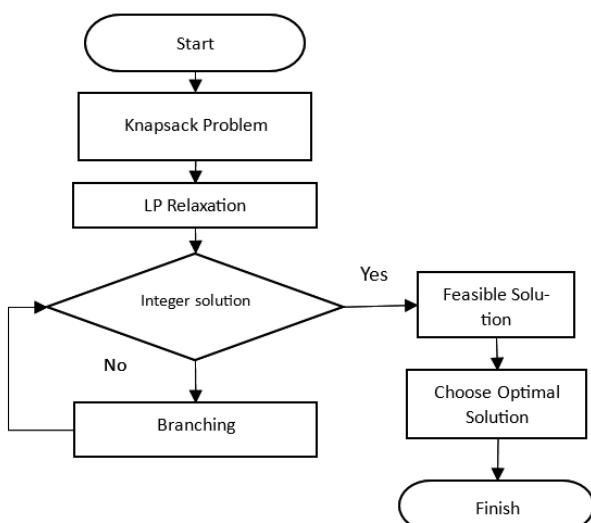


Figure 2. The steps for solving using the Branch and Bound algorithm

## Result

In the Sleman Regency Student Pencak Silat Championship in 2023, there are 3 levels: early age, pre-teen, and teen. Each level consists of 2 categories: fighting and artistic. For the early age level, there are 154 fighting matches and 32 artistic matches. For the pre-teen level, there are 237 fighting matches and 13 artistic matches, and for the teen level, there are 187 fighting matches and 12 artistic matches. The time used in the fighting category for the early age level is 5 minutes per match, and for the artistic category, it is 6 minutes per match. For the pre-teen level, the time required for the fighting category is 8 minutes per matches, and for the artistic category, it is 6 minutes per matches. For the teen level, the time required for the fighting category is 8 minutes per match, and for the artistic category, it is 9 minutes per match. The number of arenas used in this competition is 2 arenas.

The time used for the competition each day is as follows: on the first day, 7.5 hours; on the second day, 8.5 hours; on the third day, 8.5 hours; on the fourth day, 8.5 hours; and on the fifth day, 6 hours. Since 2 arenas are used in this competition, the total competition time is as follows. On the first day, the total competition time is 15 hours = 900 minutes. On the second day, the total competition time is 17 hours = 1020 minutes. On the third day, the total competition time is 17 hours = 1020 minutes. On the fourth day, the total competition time is 17 hours = 1020 minutes. On the fifth day, the total competition time is 12 hours = 720 minutes. This problem can be formulated in the PMBKP as follows.

Let:

$x_1$ : fighting match for early age level

$x_2$ : artistic match for early age level

$x_3$ : fighting match for pre-teen level

$x_4$ : artistic match for pre-teen level

$x_5$ : fighting match for teen level

$x_6$ : artistic match for teen level

$x_{ij}$ : match for  $j$ -th category in  $i$ -th day

$p_i$ : priority of day  $i$

The canonical form of the PMBKP for scheduling match events within the competition time to maximize the total number of events without exceeding the maximum capacity is as follows: subject to

$$\max Z = \sum_{i=1}^5 x_{i1} + x_{i2} + x_{i3} + x_{i4} + x_{i5} + x_{i6}$$

$$p_1: 5x_{11} + 6x_{12} + 8x_{13} + 6x_{14} + 8x_{15} + 9x_{16} \leq 900$$

$$p_2: 5x_{21} + 6x_{22} + 8x_{23} + 6x_{24} + 8x_{25} + 9x_{26} \leq 1020$$

$$p_3: 5x_{31} + 6x_{32} + 8x_{33} + 6x_{34} + 8x_{35} + 9x_{36} \leq 1020$$

$$p_4: 5x_{41} + 6x_{42} + 8x_{43} + 6x_{44} + 8x_{45} + 9x_{46} \leq 1020$$

$$p_5: 5x_{51} + 6x_{52} + 8x_{53} + 6x_{54} + 8x_{55} + 9x_{56} \leq 720$$

$$\begin{aligned} \sum_{i=1}^5 x_{i1} &\leq 154 \\ \sum_{i=1}^5 x_{i2} &\leq 32 \\ \sum_{i=1}^5 x_{i3} &\leq 237 \\ x_{ij} &\in N_0 \end{aligned}$$

$$\begin{aligned} \sum_{i=1}^5 x_{i4} &\leq 13 \\ \sum_{i=1}^5 x_{i5} &\leq 187 \\ \sum_{i=1}^5 x_{i6} &\leq 12 \end{aligned}$$

The results of the PMBKP obtained in the 2023 Sleman Regency Pencak Silat Championship using the Branch and Bound algorithm are as follows: 175 matches on the first day, consisting of 154 fighting matches for early age level, 8 artistic matches for early age level, and 13 artistic matches for pre-teen level. On the second day, there are 133 matches, consisting of 22 artistic matches for early age level, 110 fighting matches for pre-teen level, and 1 fighting matches for teen level. On the third day, there are 128 matches, consisting of 2 artistic level for early age level and 126 fighting matches for teen level. On the fourth day, there are 127 fighting matches for pre-teen level, and on the fifth day, there are 72 matches, consisting of 60 fighting matches and 12 artistic matches for teen level. These results can be applied to the pencak silat competition aimed at talent scouting, mass participation, and district-level competitions.

## Discussion

In the context of maximizing the number of matches in pencak silat competitions, the knapsack problem is used to formulate the issue into a mathematical model, specifically the Preemptive Multiple Bounded Knapsack Problem (PMBKP). The knapsack is compared to a match day, so the five match days in the Sleman Regency Student Pencak Silat Championship in 2023 correspond to five knapsacks. Each day has a maximum match time limit, representing the knapsack's capacity, with the sequence of match days indicating the knapsack's priority. Matches from each category are considered items to be included in the knapsack, with their duration as the weight, the importance of the matches as the value, and the number of matches as the item availability. Since the importance of each match in the Sleman Regency Student Pencak Silat Championship in 2023 is the same, the value of the items is also the same. Therefore, the problem of dividing the matches can be simplified by formulating it within the PMBKP. This provides a clearer picture of solving the match allocation issue, with the knapsack, items, and their properties representing the constraints involved in the process.

The use of PMBKP in the context of dividing pencak si-

lat competition matches highlights the uniqueness of this approach in tackling complex problems. Through the application of the knapsack concept, the discussion offers a clearer and more visual comprehension of how to arrange match schedules within specific constraints, including the number of match days and the available time capacity (Van Bulck & Goossens, 2023). The main uniqueness of this approach is its ability to simplify complex problems into a mathematical formulation, thus allowing decision-makers to more easily plan match schedules while considering existing constraints (Garnica Caparrós et al., 2022). Therefore, the uniqueness of the findings from this discussion lies in their ability to provide new insights and effective problem-solving tools in the context of sports event organization and planning.

Several challenges can be identified in applying the results of this research in a practical context. In formulating the mathematical model, assumptions are used to solve the problem. First, this research may face challenges in accurately adapting the knapsack model to reflect the true complexity of the distribution of pencak silat competition schedules. This is because the assumptions used in forming the PMBKP only simplify some of the factors involved, such as considering match duration, number of matches, match time, and the order of match days. In real situations, there are several conditions that may not be able to accommodate all relevant aspects of schedule management, such as athlete preferences, organizational interests, or other logistical considerations.

Second, there are challenges in adapting the knapsack model to account for the importance value of each match, such as the division of match stages like preliminaries, semifinals, and finals. Some matches may be more important or have a more significant impact than others, and this needs to be considered more deeply in decision-making (Alardani, 2023). Third, the implementation of the results of this research may face challenges in integrating well with existing systems or processes in setting pencak silat competition schedules. Changing or adapting existing processes can be complex and requires strong collaboration between domain experts and decision-makers (Shaban & Alkallak, 2021).

Fourth, there is the challenge of validating the effectiveness of the knapsack model in a real context. To validate this effectiveness, the PMBKP concept can be applied to other similar competitions, since the research results from the Sleman Regency Student Pencak Silat Championship in 2023 data were taken after the competition had finished. Given these challenges, it is important to conduct further research and development of the knapsack model by considering match stages like preliminaries, semifinals, and finals, and to accommodate all relevant aspects of schedule management. Then, it is also important to involve variables such as sports organization and service quality in matches, because until now these variables have only focused on athlete performance (Prayoga et al., 2024; Abdhi et al., 2024). This research needs to be tested in realistic scenarios to ensure that the results can make a meaningful contribution to

the practical regulation of pencak silat competition schedules.

## Conclusion

Preemptive Multiple Bounded Knapsack Problem (PMBKP) is an allocation problem where various types of items must be distributed into a group of knapsacks that have their respective capacity limits and priorities. The goal is to optimize allocation by taking into account the weight, value, and upper limits of each item, while considering the priority of each knapsack. The PMBKP algorithm starts by changing the formulation into canonical form, then continues by solving the problem with the highest priority first. The results of the highest priority solution are then used as input to solve problems at the next priority level, and this process continues sequentially according to priority. The problem of dividing pencak silat competition parties is that every match day is considered a knapsack that needs to be filled with competition parties. The matches are considered as items to be included in the 100 knapsack, with the match duration of each match as a weight for each item. The value of each item is considered the same as there is no difference in value across all match categories, the number of matches in each category is determined as item availability. The PMBKP results obtained in the 2023 Sleman Regency Pencak Silat Championship problem using the Branch and Bound algorithm were 175 parties on the first day, 133 parties on the second day, 128 parties on the third day, 127 parties on the fourth day, and 72 parties on the fifth day. These results can be said to be effective if applied to pencak silat competitions which aim to foster achievement, such as introductory competitions and sub-district/district level competitions.

## Acknowledgements

The authors would like to thank “Lembaga Pengelola Dana Pendidikan (LPDP)” for financial support so that the article can be completed. The opinions expresses here in are those of the authors and do not necessarily reflect the views of funding agency.

## Conflict Of Interest

This study contains no material that could be considered a conflict of interest by the authors.

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