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Mathematical Approach: Integer Linear Programming using Branch and Bound Method for Optimizing Defense Facility Requirements in the New Soewondo Airbase

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Abstract— This journal explores the application of Integer Linear Programming (ILP) using the Branch and Bound approach to optimize the defense facility needs at Lanud Soewondo, Hamparan Perak, Deli Serdang. Lanud Soewondo, currently located in Medan, North Sumatra, plans to relocate to enhance flight security and support the defense of the western part of Indonesia. This study involves mathematical modeling with a focus on the number and types of squadrons and personnel requirements at the new Lanud Soewondo. Data from field studies and literature reviews are used to construct the ILP model, which includes combat squadrons, drone-based reconnaissance squadrons, and transport squadrons. The Branch and Bound method is employed to optimize these variables according to the available land area. The research results indicate that the optimal solution using ILP Branch and Bound is 1 combat squadron, 2 drone-based reconnaissance squadrons, and 1 transport squadron. The total land area required is 52 hectares out of the planned 600 hectares, with an optimal personnel requirement of 525 out of the total 577 DSP personnel. The remaining land area of 548 hectares can be allocated for additional facilities, while 52 personnel can be placed outside the squadrons. This study concludes that the ILP Branch and Bound method is effective in planning the optimization of defense facility needs at the new Lanud Soewondo, providing an efficient solution and supporting air defense in the Hamparan Perak region.

Keywords— Hamparan Perak Soewondo Air Force Base, Integer Linear Programming, Branch and Bound, Optimization of Defense Facility Needs..

I. INTRODUCTION

Medan, North Sumatra, has the Soewondo Military Airbase (Lanud Soewondo), which is one of the most important military bases in Indonesia. The recent plan to relocate Lanud Soewondo to the Hamparan Perak area has attracted attention. The reason behind this relocation is that the current location of Lanud Soewondo is too close to residential areas and tall buildings, thus not meeting aviation safety standards (Ministry of Defense of the Republic of Indonesia, 2023). Nevertheless, the government sees the relocation of Lanud Soewondo as part of a strategy to enhance defense in the western part of Indonesia. Hamparan Perak was chosen as the new location because of its crucial role in the defense infrastructure that supports national sovereignty. The plan for the new airbase development covers an area of 1170 hectares. The majority of the land will be used for constructing the airbase, with 600 hectares prioritized for the initial phase of development (Indonesiadefense.com, 2023). Meanwhile, the remaining land will serve as reserves and can be expanded in the future if necessary. Thus, Lanud Soewondo in Hamparan Perak, Deli Serdang, is expected to become the largest airbase in Southeast Asia.

Considering the geographical and strategic environmental factors in Hamparan Perak and its surroundings, there are several nationally important objects that could potentially be targeted. Therefore, strong defense is required to protect these objects. One of the roles of Lanud Soewondo in air defense is to safeguard vital national objects. The operational area of Lanud Soewondo plays a strategic role in ensuring energy resilience for the Medan region and its surroundings. National vital objects (obvitnas) in the energy and mineral resources sector have been identified, as mentioned in Ministerial Decision No. 202 of 2021 of the Republic of Indonesia's Ministry of Energy and Mineral Resources. Some obvitnas located around the Lanud Soewondo area include the Kualanamu Pertamina Aircraft Refueling Depot (DPPU), Polonia DPPU, Extra High Voltage Substation (GITET) in Binjai, GITET Galang, Medan Group Fuel Terminal, and others (Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2021).

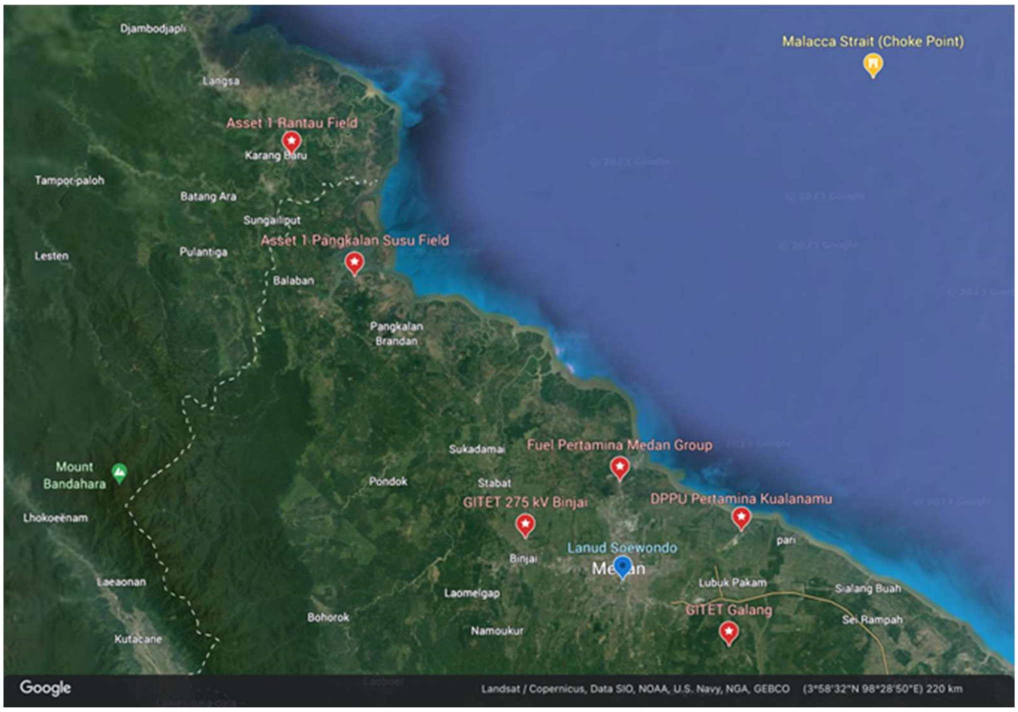

Figure 1. Map identifying National Vital Objects in Lanud Soewondo's task area.
Source: Google Earth project, created: March 28, 2023.

Figure 1 illustrates the complexity of Lanud Soewondo, surrounded by various energy sources that are crucial to maintaining its operational sustainability. As a national vital object, Lanud Soewondo is a strategic national asset that contributes to defense and national stability. This vital object can be a facility or infrastructure that requires maximum protection, as damage to it can have serious implications for the overall security, economy, and stability of the country. Therefore, the need for protection efforts for national vital objects is crucial.

Lanud Soewondo has committed to maintaining the security and stability of its region through the supervision and guidance of personnel and the area. However, the success of these efforts can be further optimized with the support of adequate defense facilities and weaponry systems. In order to maximize the functionality of Lanud Soewondo's working area, the availability of defense facilities is crucial, especially in supporting defense and security equipment (alpalhankam).

This research is directed towards planning the optimization of defense facility needs, especially for Squadrons, to support the operational readiness of alpalhankam in every defense operation, especially those related to air defense. In this context, the research uses a mathematical approach with the Integer Linear Programming (ILP) branch and bound method. The mathematical modeling aims to optimize the number of air squadrons as defense facilities at the new Lanud Soewondo, while determining the personnel needs required for its operations to run efficiently and effectively. This approach is expected to make a positive contribution in ensuring the readiness of Lanud Soewondo in maintaining national security.

II. RESEARCH METHOD

This research is part of the Online Field Work Course conducted by the Indonesian Defense University with support from speakers from Soewondo Air Force Base. The focus of this research is on optimizing the planning of Defense and Security Equipment (Alpalhankam), which includes :

2.1 Data Collection Method

In determining this optimization, various data collection methods are used, including :

a) Field Study

Interview methods are used for direct question-and-answer sessions with leaders and personnel of Soewondo Air Force Base during the Domestic Field Work Lecture (KKDN) organized by the Faculty of Defense Science and Technology, Indonesian Defense University.

b) Literature Study

The literature study method is conducted by exploring relevant books and journals related to the issues to be discussed. This research uses the Branch and Bound Method to calculate and optimize the needs of Defense and Security Equipment (Alpalhankam) in the development plan for the new Soewondo Air Force Base.

2.2 Data Retrieval Method

One of the optimization methods used is linear programming. This method uses variables to achieve the objective function and solve a problem. In general, linear programming consists of two models: the objective function and the constraint function. However, there is also an integer linear programming method, which is one of the linear mathematical models with integer values that produce solutions in integer form.

2.3 Branch and Bound Method

The Branch and Bound Method (Land and Doig, 1960) is an effective algorithm used in various optimization contexts. This algorithm utilizes an approach to divide the acceptable solution area into smaller subdivisions. The solution search process begins by detailing candidate solutions and branching using the search tree structure that depicts possible solutions. At each node in the search tree, a mathematical evaluation of smaller sub-problems is performed until the best solution is found.

The Branch and Bound Method has proven effective in approximating optimal solutions in various cases. This algorithm is used to find optimal solutions in various problem types and planning needs. This approach works by breaking down the main problem into smaller sub-problems, allowing for an efficient search for the best solution. Thus, the Branch and Bound Method has proven to be a strong and efficient approach in addressing various optimization challenges. The main reference in Land and Doig (1960) provides a solid foundation for the use of this method in various applications.

2.4 Related Work

Metode Branch and Bound has become a critical foundation in various research contexts, as outlined by Supatimah & Andriani (2019). They emphasize that the success of the Branch and Bound Method is supported by branching and constraint techniques, making it a highly effective global method for solving various optimization problems. In the same context, the research by Huang L. and his colleagues (2021) discusses the application of machine learning techniques to enhance four critical components in the Branch and Bound algorithm. Supervised learning methods in this study help generate expert-like policies while significantly improving the speed of solution search. Pasaribu, A. H. (2018), in his research, successfully applied the Branch and Bound Method to linear programming to optimize the use of raw materials in the production of jeans at CV. Ridho Mandiri. By detailing decision variables that do not have integer solutions, this method successfully provided an optimal solution that resulted in a 4.3% increase in the company's profit.

Furthermore, through Najmi, H.'s research (2020), it is emphasized that the Branch and Bound Method can be relied upon to assist furniture business operators in optimizing production by considering specific aspects, including achieving maximum profit and determining the optimal quantity of units for each type of furniture product. Meanwhile, Nur & Abdal (2017) highlight the importance of the Branch and Bound Method in solving Integer Linear Programming (ILP) problems. This is relevant because many linear programming problems in daily life require solutions in integer form. Through this approach, the Branch and Bound Method continues to prove its strength as an approach that is not only efficient but also robust in handling various optimization challenges in different contexts. The primary reference to Land and Doig (1960) provides a strong foundation for the use of this method in various applications and further research.

III. Research Results And Discussion

Lanud Soewondo is a Type B Airbase with the primary responsibility for the preparation, implementation, guidance, and operation of all units under its structure, as well as the development of potential in the aerospace field and the provision of operational support for other units. As part of the Indonesian Air Force Operational Command (Koopsau), Lanud Soewondo operates under one of the main commands (Kotama) of the Indonesian Air Force. This formation was announced through the decree of the Air Force Chief of Staff Number: 57/23/Peng/KS/51 on June 15, 1951. At that time, five squadrons were formed, each with specific tasks and responsibilities, to operate aircraft owned by the former Dutch Air Force. In its development, the plan to relocate Lanud Soewondo to Hamparan Perak was initiated with the aim of supporting the development of the Medan city area. Currently, Lanud Soewondo is located in the center of Medan. However, based on the Minister of Transportation Regulation No. 44 of 2005 regarding the Implementation of Indonesian National Standards (SNI) 03-7112-2005, it was revealed that Lanud Soewondo does not meet flight safety standards related to the Flight Operation Safety Area (KKOP). Therefore, relocation to a location that meets flight requirements becomes a necessity.

The Flight Operation Safety Area (KKOP) refers to the land, water, and airspace around the airport used for flight operation activities. Its main goal is to ensure the safety of aviation, as regulated in Law No. 1 of 2009 concerning aviation. An article on the official Indonesian Air Force website discussing KKOP provides an explanation from the Commander of Lanud Abdulrachman Saleh, Air Marshal TNI Andi Wijaya, S. Sos., that a 15 KM radius area from the airport needs to be safeguarded to keep the airspace around the airport free from obstacles, ensuring the safety of aircraft operations and preventing the emergence of new obstacles around the airport. (In Figure 2, the map of the new location of Lanud Soewondo in Hamparan Perak is displayed. Geographically, Hamparan Perak has several important advantages that need to be considered.)

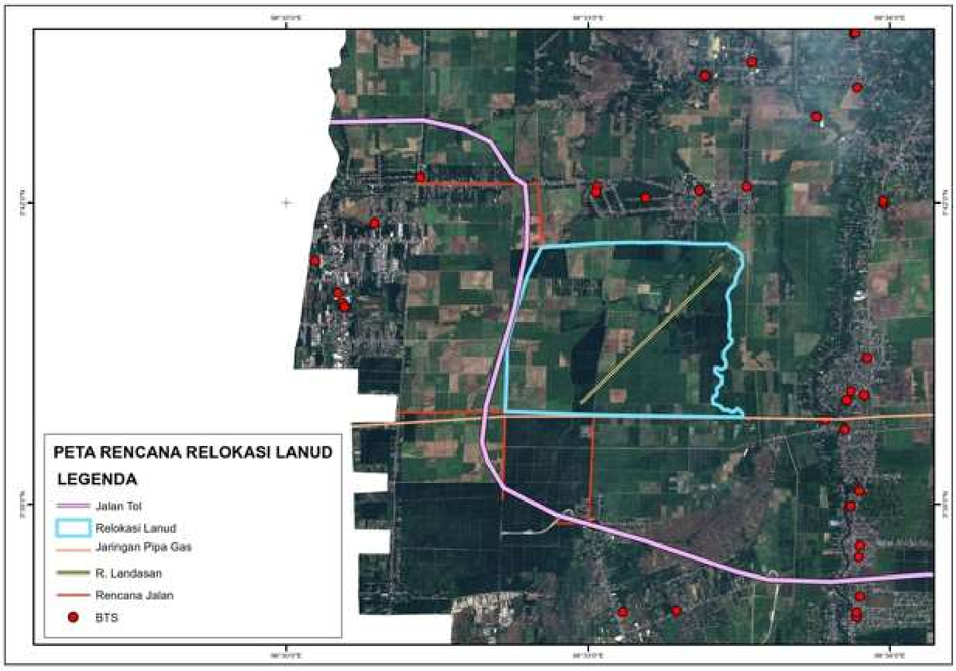

Figure 2. Map of the relocation plan of Soewondo Air Base to Hamparan Perak.
Source: Google Earth project, created: March 28, 2023.

Firstly, Hamparan Perak is renowned for its stable weather, a crucial factor in ensuring safe and efficient flight operations. Additionally, good accessibility is one of the main features of this area, facilitating access to the city center of Medan and other important locations in the vicinity (Utama et al., 2022). Hamparan Perak also offers significant development potential. Its proximity to the economic center of Medan brings additional benefits in terms of connectivity and economic growth. The well-established infrastructure in this area is also a crucial advantage in supporting the development of Soewondo Air Base and enhancing mobility efficiently.

Modeling the needs of Defense and Security Equipment (Alpalhankam) is a complex process in the development of a mathematical model aimed at estimating the needs of tools and equipment in defense and security projects. The primary focus of this modeling is to optimize the use of available resources to achieve predefined objectives. Through careful modeling, optimal plans for defense and security tool and equipment needs can be developed, ensuring efficient resource utilization. This modeling significantly contributes to improving project management efficiency related to defense and security.

This research is conducted as part of the Domestic Work Lecture of the Indonesian Defense University, with a focus on the relocation plan of Soewondo Air Base to the Hamparan Perak area. Relevant data about the land area to be used, totaling 1170 hectares, has been collected. The development will be carried out in two phases, with the first phase including the core development of the airbase covering an area of 600 hectares.

Soewondo Air Base in Hamparan Perak will be equipped with several squadrons, including Combat Squadrons, Drone-based Reconnaissance Squadrons, and Transport Squadrons. The plan is for this airbase to be the largest. Colonel Pnb Reka Budiarsa, as the Commander of Soewondo Air Base, provided information about the personnel strength, especially in the Military sector, which is 346 personnel out of the Priority Scale Data (DSP) of 577 personnel. The presentation session also revealed the land area needed for each squadron, namely 12 hectares for Combat Squadron, 4 hectares for Drone-based Reconnaissance Squadron, and 32 hectares for Transport Squadron. The total number of personnel in each squadron is 205 for Combat Squadron, 55 for Reconnaissance Squadron, and 210 for Transport Squadron.

This data is then used in mathematical modeling and linear programming to identify the number of squadrons and personnel needed for Soewondo Air Base in Hamparan Perak. The linear programming formulation based on this data can be expressed in equations below. The variables defined from the obtained data are as follows :

X_1 : Number of Combat Squadrons

X_2 : Number of Reconnaissance Squadrons

X_3 : Number of Transport Squadrons

There are two constraints that must be satisfied for the created variables, including the land area limit and the total personnel limit according to DSP, so the constraints can be formulated into equations 1 and 2 :

$12X_1 + 4X_2 + 32X_3 \leq 600$ hectares (Air Base Land Area Limit)……………………………………………………………..(1)

$205X_1 + 55X_2 + 210X_3 \leq 577$ personnel (Total Personnel Limit)………..……………………………………………………...(2)

Then, constraints for the development of each squadron are identified, including equations 3 to 5 :

$X_1 \geq 1$……………………………………………………………………………………………..……………………………(3)

$X_2 \geq 1$……………………………………………………………………………………………..……………………………(4)

$X_3 \geq 1$……………………………………………………………………………………………..……………………………(5)

With $X_1, X_2, X_3 \geq 0$…………………………....……………………………………………..………………………………..(6)

Thus, the objective function to be optimized can be formulated with equation 7 as follows :

Max $Z = X_1 + X_2 + X_3$………………………………………………………………………..…………………………………(7)

By formulating linear programming with the appropriate constraints and objective function, we can optimize the allocation of the number of squadrons and personnel at Soewondo Air Base to achieve effective and efficient results in supporting operations and development in the Hamparan Perak area.

3.1 Branch and Bound Modeling for the Needs of the New Soewondo Air Base Squadron

Based on Table 1, the optimum results for Soewondo Air Base in Hamparan Perak are $X_1 = 0$, $X_2 = 2.9455$, $X_3 = 1$, and $Z = 4.95$. Since X_2 has a non-integer value, branching is performed into Branch B (with $X_2 \leq 2$) and Branch C (with $X_2 \geq 3$). The optimal solution for each branch is sought using simplex iteration, and this procedure is repeated until the solution with integer values is found.

Table 1 Iteration results for optimation of the New Soewondo Air Base Squadron

Iteration	Level	Added Constraint	Solution type	Solution value	X1	X2	X3
1	0		Non Interger	4.95	1	2.95	1
2	1	$X_2 \leq 2$	Non Interger	4.25	1.25	2	1
3	2	$X_1 \leq 1$	Non Interger	4.25	1	2	1.25
4	3	$X_3 \leq 1$	Interger	4	1	2	1
5	3	$X_3 \geq 2$	Infeasible				
6	2	$X_1 \geq 2$	Infeasible				
7	1	$X_2 \geq 3$	Infeasible				
Optimal				**4**	**1**	**2**	**1**

Next, the solution for Sub-Problem B with $X_2 \leq 2$ can be written as follows :

Max $Z = X_1 + X_2 + X_3$……………………………………………..…………………………………………………………(8)

$12X_1 + 4X_2 + 32X_3 \leq 600$ hectares……………………………..……………………………………………………………(9)

$205X_1 + 55X_2 + 210X_3 \leq 577$ personnel………….……………………………………………………………………….(10)

$X_1 \geq 1$………………….………………………………………………………………………………………………..(11)

$X_2 \geq 1$………………………..…………………………………………………………………………………………..(12)

$X_3 \geq 1$…………………..………………………………………………………………………………………………..(13)

$X_2 \leq 2$…………………..………………………………………………………………………………………………..(14)

With $X_1, X_2, X_3 \geq 0$……….………………………...……………………………………………………………………...(15)

Therefore, the solution results for the Max Z_B value were found to be 4.25 with (X_1= 1, 25; X_2= 2; X_3=1) and the Z_L value was 4 with (X_1= 1; X_2= 2; X_3= 1). obtained from the rounded solution values. Meanwhile, for sub-problem C with the value $X_2 \geq 3$, the calculations are as follows :

Max $Z = X_1 + X_2 + X_3$………..…………………………………………………………………………………………...(16)

$12X_1 + 4X_2 + 32X_3 \leq 600$ hectares………………………..……………..……………………………………………...(17)

$205X_1 + 55X_2 + 210X_3 \leq 577$ personnel…..…………………...…………………………………………………………….(18)

$X_1 \geq 1$……………………………………….……………………………………………………………………………..(19)

$X_2 \geq 1$……………………………………….……………………………………………………………………………..(20)

$X_3 \geq 1$……………………………………….……………………………………………………………………………..(21)

$X_2 \geq 3$……………………………………….……………………………………………………………………………..(22)

With $X_1, X_2, X_3, \geq 0$……...……………………………………………………………………………………………….(23)

It was found that sub-problem C has an infeasible solution, so sub-problem C was terminated. Afterward, because the value of $X_1 = 1.25$ in Sub-Problem B is still non-integer, branching was done again into Sub-Problem D ($X_1 \leq 1$) and Sub-Problem E ($X_1 \geq 2$). The calculation results for Sub-Problem D are as follows :

Max $Z = X_1 + X_2 + X_3$…..…………………………………………………………………………………………...(24)

$12X_1 + 4X_2 + 32X_3 \leq 600$ hectares ..………………………………………………………………………………...(25)

$205X_1 + 55X_2 + 210X_3 \leq 577$ personnel…………………….………………………………………………………….(26)

$X_1 \geq 1$…………………………..…………………………………………………………………………………………..(27)

$X_2 \geq 1$…………………………..…………………………………………………………………………………………..(28)

$X_3 \geq 1$…………………………..…………………………………………………………………………………………..(29)

$X_2 \leq 2$…………………………..…………………………………………………………………………………………..(30)

$X_1 \leq 1$……..(31)

With $X_1, X_2, X_3 \geq 0$……………...……………………………………………………………………………………...(32)

The solution results were found for the Max Z_D value of 4.25 with ($X_1 = 1$, $X_2 = 2$, $X_3 = 1.2476$). And for the Z_L value, it was obtained as 4 with ($X_1 = 1$, $X_2 = 2$, $X_3 = 1$) after rounding. Furthermore, for the resolution of Sub-Problem E with the value $X_1 \geq 1$, the results are as follows :

Max $Z = X_1 + X_2 + X_3$……………………………..……………………………………………………………...(33)

$12X_1 + 4X_2 + 32X_3 \leq 600$ hectares ……………………………………………………………………………(34)

$205X_1 + 55X_2 + 210X_3 \leq 577$ personnel………………………………………………………………………(35)

$X_1 \geq 1$……(36)

$X_2 \geq 1$……(37)

$X_3 \geq 1$……(38)

$X_2 \geq 3$……(39)

$X_1 \geq 2$……(40)

With $X_1, X_2, X_3, \geq 0$………………………………………………………………………………………(41)

It was found that Sub-Problem E has an infeasible solution, so sub-problem E was terminated. In Sub-Problem D, $X_3 = 1.25$ must be an integer, then branching was done into Sub-Problem F ($X_3 \leq 1$) and Sub-Problem G ($X_3 \geq 2$). In Sub-Problem F, the solution with $X_3 \leq 1$ using the simplex method was found as follows :

Max $Z = X_1 + X_2 + X_3$……………………………………………………………………………………(42)

$12X_1 + 4X_2 + 32X_3 \leq 600$ hectares ……………………………………………………………………………(43)

$205X_1 + 55X_2 + 210X_3 \leq 577$ personnel………………………………………………………………………(44)

$X_1 \geq 1$……(45)

$X_2 \geq 1$……(46)

$X_3 \geq 1$……(47)

$X_2 \leq 2$……(48)

$X_1 \leq 1$……(49)

$X_3 \leq 1$……(50)

With $X_1, X_2, X_3 \geq 0$…………………………………………………………………………………………(51)

The solution results for the Max Z_F value of 4 were found with ($X_1 = 1, X_2 = 2, X_3 = 1$) and for the Z_L value, it is known that $Z_L = 4$ with ($X_1 = 1, X_2 = 2, X_3 = 1$) after rounding. In Sub-Problem F, the generated values are already in the form of integer numbers, so no further branching is needed. On the other hand, the solution for sub-problem G with $X_3 \geq 1$, yielded the following solution :

Max $Z = X_1 + X_2 + X_3$……………………………………………………………………………………(52)

$12X_1 + 4X_2 + 32X_3 \leq 600$ hectares ……………………………………………………………………………(53)

$205X_1 + 55X_2 + 210X_3 \leq 577$ personnel………………………………………………………………………(54)

$X_1 \geq 1$……(55)

$X_2 \geq 1$……(56)

$X_3 \geq 1$……(57)

$X_2 \geq 3$……(58)

$X_1 \geq 2$……(59)

$X_3 \geq 2$……(60)

With X_1, X_2, X_3, ≥ 0………(61)

The solution obtained indicates that Sub-Problem G has an infeasible solution, so sub-problem G is stopped. Thus, the optimal integer solution is $Z_F = 4$ with the respective variables $X_1 = 1$, $X_2 = 2$, dan $X_3 = 1$. Then, from the results of the branching solution calculations, as depicted in Figure 4 below, a comprehensive understanding is obtained.

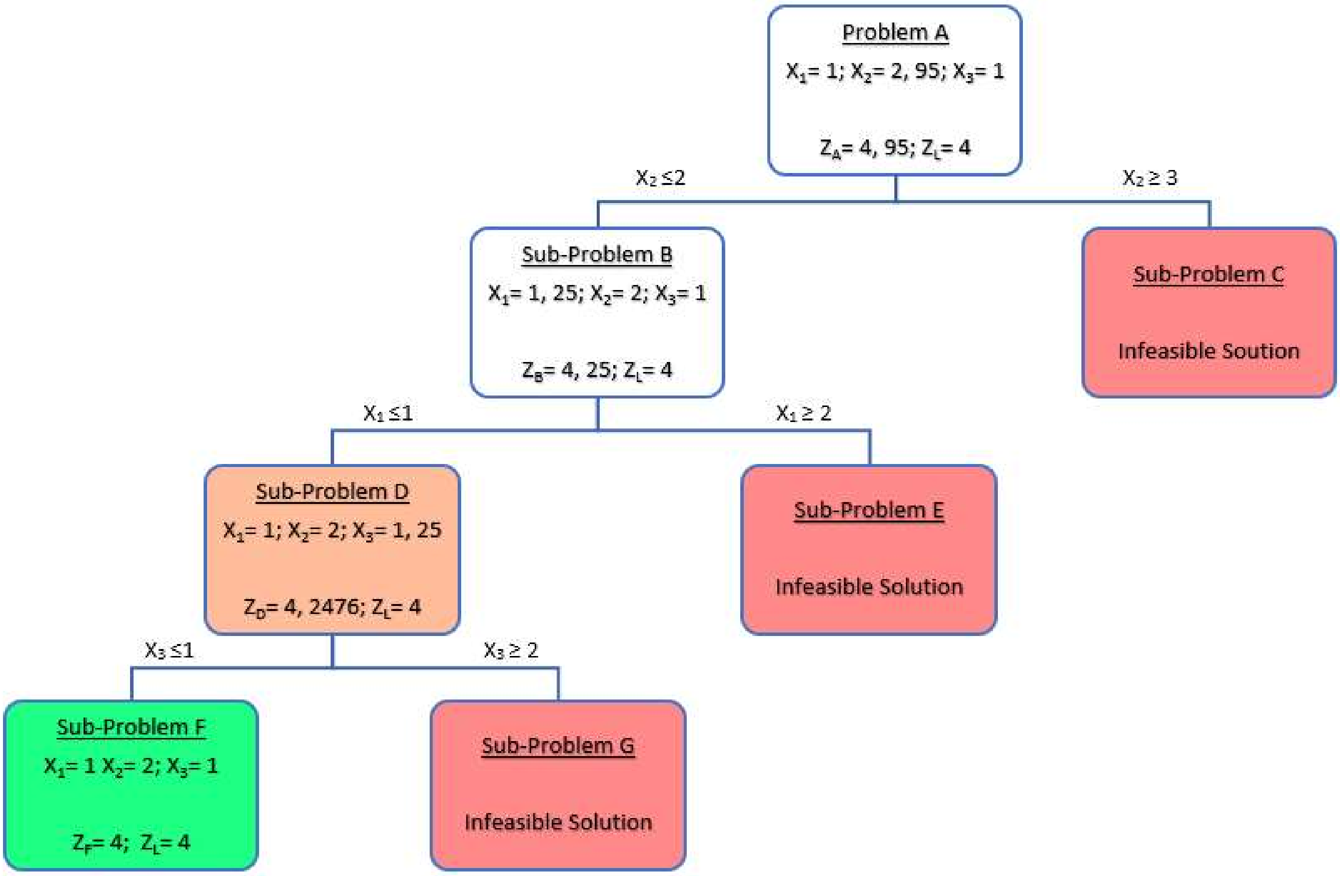

Figure 3. Branch and Bound Optimization Diagram of Lanud Soewondo Squadron

Source: Processed by Researcher, 2023.

From the Branch and Bound Diagram presented in Figure 4 and the calculations performed using the simplex method, it is known that the optimal integer value of the squadron's needs optimization at the new Soewondo airbase in the Silver Expanse with 600 hectares is 1 Fighter Squadron with a total area of 12 hectares, followed by the needs of the Drone-Based Reconnaissance Squadron with 2 squadrons with a total area of 8 hectares, and 1 Transport Squadron with a total area of 32 hectares. So, if the overall optimal area needed is 52 hectares out of the total land area for development of 600 hectares.

Out of this area, there remains 548 hectares of land that can be used in the future for facilities such as runways, command headquarters, or other facilities related to Lanud Soewondo in the Silver Expanse. On the other hand, from the optimization, it is also known that the optimal personnel requirements for each squadron are 205 personnel for the Fighter Squadron, then 110 personnel for the Reconnaissance Squadron, and 210 personnel for the Transport Squadron. Thus, the total optimal personnel requirements for all squadrons amount to 525 personnel out of the total Data Scale of Priority (DSP) of 577 personnel. From the total optimized personnel requirements, there are 52 remaining personnel that can be assigned to the command headquarters at Lanud Soewondo.

IV. Conclusion

Metode Branch and Bound can be used in solving optimization problems, especially in the military defense sector, such as optimizing the squadron requirements in the case study of relocating Lanud Soewondo to Hamparan Perak, Deli Serdang. The solution to the squadron needs optimization calculation using the Branch and Bound method for the new Lanud Soewondo in Hamparan Perak is determined to be Z = 4, with $X_1 = 1$; $X_2 = 2$; $X_3 = 1$. This means that the squadron requirements for the new Lanud Soewondo in Hamparan Perak can be established for a total of 4 squadrons, comprising 1 combat squadron, 2 Drone-based Reconnaissance squadrons, and 1 Transport squadron.

Furthermore, the total optimal land area required for the needs of the 4 squadrons is 52 hectares out of 600 hectares, and the personnel requirement is 525 personnel out of a total DSP of 577 personnel. It is noted that there is a remaining land area of 548 hectares that can be utilized to support the facilities needed by Lanud Soewondo, such as the runway and command headquarters. Additionally, there are 52 personnel who can be assigned outside of the existing 4 squadrons.

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