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Optimizing the Placement of Fighter Aircraft Squadrons Using the Set Covering Problem (SCP) Method in Indonesia

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ABSTRACT

Layout and facility planning are analysis activities, forming concepts, designing systems, and realizing systems for producing goods, services, or military. Indonesia, which has direct borders with three countries, means that Indonesia is often infiltrated. Apart from Indonesia having a limited budget for implementing its work processes, its main problem is determining the location of fighter aircraft squadrons in the national defence system. If the layout of facilities can be planned well, it will determine work efficiency and survival or work success. This research applies mathematical model programming (set covering problem) to overcome this problem with the F-16 Fighting Falcon and Sukhoi SU 27/30 fighter aircraft. Then, the results of the SCP maximize covering capabilities by minimizing the average distance between air bases with the P-Median Problem (PMP). This research shows that the Indonesian Air Force needs an additional seven operational air bases to optimize the covering capabilities of fighter aircraft squadrons. In this study, the total distance travelled by the F-16 Fighting Falcon fighter aircraft was 4,479 km, with an average distance of 497.67 km. The total distance travelled by the Sukhoi SU 27/30 fighter aircraft was 11,398 km, with an average distance of 542.76 km. The average time to reach the target was 15.79 minutes. This research can be used to optimize the defence equipment in the National Air Defense System.

Key Words: Facility Layout Planning, Fighter Squadrons, P-Median Problem, Set Covering Problem.

1. INTRODUCTION

Sishanudnas is an order in implementing Hanudnas operations that aims to ward off all threats using aerial vehicles by involving Hanud elements. Indonesian Air Force, the Indonesian Army and Indonesian Navy elements are capable, and other elements can play a role in the national air defence pattern. Sishanudnas are precautionary and are expected to be able to destroy air threats long before they enter the sovereign territory. For this reason, this system is equipped with a radar capable of arresting (Ground Control Interception/GC), which is offensive and can also function as an early warning. The presence of radar in this system is used to support fighter aircraft operations, which serve as an ambush and destroyer of threats coming from the air.

Technological developments in the Indonesian Air Force in dealing with existing threats are felt in need of improved able targets. This can happen because our economic strength is insufficient for previously agreed needs. Indonesia's defence system is built within the Minimum Essential Force (MEF) policy structure. The development of MEF in meeting Indonesia's defence equipment needs still needs to be considered weak. Data on the needs for fighter aircraft squadrons and their placements spread throughout Indonesia is considered inappropriate by existing title requirements. This can cause many losses, namely not creating a credible national defence system and affecting deterrent factors considered not vital to external parties. So a placement concept is needed which is expected to have implications for the needs of the Indonesian Air Force.

One of the most well-known methods suitable for determining the location of an air defence facility is the Set Covering Problem (SCP). SCP is a form of combinatorial problem that can be modelled in the form of Integer Linear Programming. SCP determines how many facilities and where these facilities are located to cover a particular area. So, in its application, SCP will be used to optimize the placement of fighter aircraft at Indonesian National Armed Force Air Force Bases.

The benefit of this research is that cadets can master and apply it in the life of the Indonesian Air Force related to Industrial Engineering knowledge, especially in applying the SCP method as a form of strategic effort to deploy fighter aircraft belonging to the Indonesian Air Force. For the Indonesian Air Force. In responding to the Development of Principal StrengthsMinimum(MEF) In 2010-2024, this research can provide full support to become a reference for the placement of fighter aircraft squadrons that are determined effectively and strategically so that later they can also be used for the placement of other Indonesian Air Force facilities. Moreover, it can provide broader knowledge and insight for the community, not only in the field military. The Set Covering Problem (SCP) method has been proven to be an application for placing other public facilities requiring a strategic and practical location.

2. LITERATURE SURVEY

Determining the location of a facility is an essential component of strategic facilities planning from the business and military sectors [27]. This matter is linked with the efficiency achieved if the location is chosen regarding costs/expenses that can be minimized or otherwise maximize the accessibility of facilities with other related locations [37]. To determine the optimal location, many studies use qualitative and quantitative decision-making techniques or both simultaneously [34]. Quantitative determination of the optimal location is carried out using mathematical modelling. The factors generally the research objective are minimizing costs and finding the shortest distance from a source to serve several demand points [27]. [4] found a model programming linear, currently known as the set covering model, to maximize the fulfilment of demand points from limited resources.

Airspace is open and expansive and requires a robust air defence system [25]. Effective and efficient air defence results from collaboration between elements of an armed force, which in today's era is better known as Joint, integrating all the defence equipment potential of each unit into an integrated air defence system. [35] in terms of air power, integration has been carried out based on cooperation between dimensions, with the same goal to safeguard and protect the entire nation and the integrity of the Indonesian state.

Elements in Air Defense. In the previous sense, air defence consists of ambush aircraft, medium-range guided missiles, radar, and Air Attack Repellent (PSU) cannons [35], all of which protect strategic state objects. Fighter aircraft are the primary air defence capability. Fighter aircraft are aircraft intended for the military interests of a country. It has a fixed-wing specification designed primarily for air-to-air combat. Its main task is to achieve air superiority in a combat conflict. Having central performance or advantages includes firepower, high speed, and manoeuvrability. The success or failure of a combatant's efforts to gain air superiority depends on several factors, including the skill of the pilot so that by supporting the tactical correctness of the doctrine for deploying fighter aircraft and the number and performance of these fighter aircraft, good air defence will be achieved. The use of air power across the spectrum of conflict ultimately depends on access to secure air bases to provide the critical support necessary to carry out required missions. This requires air bases in appropriate locations with adequate basing facilities [32].

3. OBJECTIVE OF RESEARCH

This research aims to cover the entire Indonesian airspace with the minimum number of selected airfields, support Sishanudnas by protecting all national vital objects with the minimum response time, and maximize protection capabilities by minimizing the maximum travel time to one of the locations within operations tasks. It is hoped that the benefits of this research will be for Cadets to be able to master and apply it in the life of the Indonesian Air Force related to Industrial Engineering knowledge, especially in the application of the SCP method as a form of a strategic effort to place fighter aircraft belonging to the Indonesian Air Force, for the Indonesian Air Force it can be a form of reference for the field of Defense Industrial Engineering in the field of modelling concepts and systems thinking which will later direct further research in the Industrial Engineering Department. Moreover, it can provide broader knowledge and insight for the community, not only in the military field.

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4. RESEARCH METHODOLOGY

4.1 Research Design

This research uses the Set Covering Problem (SCP) method to obtain the minimum number of fighter aircraft squadrons needed to cover all Indonesian airspace. The results of the SCP will later be reprocessed using the P-Median Problem (PMP) to maximize the covering capability of the fighter aircraft squadron. What is meant by maximizing here is reducing the distance that must be travelled and shortening the aircraft's response time to the node that must be protected.

The research framework is the sequence of research steps carried out. Researchers carry out seven steps. Among them are the first with problem identification and the second with problem formulation. In this research, the problem formulation is "How to place an Indonesian Air Force fighter aircraft squadron into an Indonesian National Armed Force FORCE Air Force base appropriately for the needs of the National Air Defense System using the Set Covering Problem (SCP) Method?". The third step is formulating research objectives, followed by the fourth step, data collection. The fifth is data processing, the sixth is data analysis, and the last is the conclusion.

4.2 Method of collecting data

Several techniques are used in the data collection process, including library studies or data collection by looking from library to library and a collection of books, written materials and appropriate sources for the research. In this research, the SCP method and PMP include the name of the author, book publisher and year of publication, so that the content and correctness can be confirmed. The second technique is an interview or conversation that takes place in a systematic and organized manner, which the researcher carries out as an interviewer with a number of people as respondents or interviewees to obtain a number of information related to the problem being studied. Interviews were conducted to obtain data from experience and knowledge that could help research. The third technique is observation or data collection techniques, where researchers go into the field and observe things related to space, place, actors, activities, objects, time, events, goals and feelings. In this observation, the element of subjectivity is enormous, and the results depend on the quality of the researcher's assessment.

4.3 Data Analysis Techniques

Data processing will be described using the Set Covering Problem (SCP) and P-Median Problem (PMP) methods.

4.3.1 SCP Method The results of data processing using the SCP method can be explained as follows:

The minimum number of fighter aircraft squadrons required to cover all Indonesian airspace is seven squadrons, with details of four F-16 squadrons. Squadron placement and areas covered by each base. The average covering distance for an F-16 aircraft is 536.25 km, with the longest being 631 km. Meanwhile, the average covering distance for Sukhoi aircraft is 775 km, with the longest being 778 km.

4.3.2 PMP Method The results of data processing using the PMP method can be explained as follows:

With the number of squadrons, The plane is the same as the SCP method. To get maximum coverage, there is a shift in the placement of squadron fighters. The average covering distance for F-16 aircraft was reduced to 453.5 km, with the longest distance being 591 km. Meanwhile, the average covering distance for Sukhoi aircraft is 640.33 km.

5. Results and Discussion

This research uses a quantitative method to determine the number of facilities and alternative locations for placing Indonesian National Armed Force fighter aircraft squadrons that are most optimal in protecting national airspace, namely the SCP method. The results of this method are then reprocessed using the PMP method to produce maximum coverage of several fighter aircraft squadrons that have been determined using the SCP method. Analysis of the results of data processing is as follows:

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5.1 Speed Data For Each Aircraft

Speed data for each aircraft is needed to determine the covering capabilities of fighter aircraft. The initial assumption is that the turnaround time (time to complete a mission) is 1 hour (Ramadhani, 2022). With the Radius of Action (ROA) for each aircraft being different, the aircraft speed data obtained is as follows

a. F-16 aircraft. The calculations in SCP and PMP use the F-16 fighter's radius of action (ROA) of 350 Nm, equivalent to 648 Km. According to First Marshal Pnb Wastum, the F-16 fighter aircraft has maximum combat capability with a record time of 10 minutes (Ramadhani, 2022). The standard speed of the F-16 fighter aircraft used towards the target is as follows:

$$(648x\ 2)\ x\ 60/(60\text{-}10)=1555.2\ km/hour$$

b. Sukhoi SU 27/30 aircraft. This Sukhoi SU 27/30 fighter aircraft can cover a distance of 450 Nm, equivalent to 833 Km. According to Indonesian National Armed Force First Marshal David Yohan Tamboto, S.Sos. and based on data we obtained from Air Squadron 11. The SU 27/30 fighter aircraft has a maximum combat capability with a record time of 16 minutes. The standard speed of the SU 27/30 fighter aircraft used towards the target is as follows:

$$(833\ x\ 2)\ x\ 60/(60\text{-}16)=2{,}271.81\ km/hour$$

5.2 The Data Processing Results Using The SCP Method

Showed a need for seven fighter aircraft to cover the entire Indonesian airspace, consisting of an offourF-16 squadron and three SU 27/30 squadrons. The blue circle with a plane image towards the right in Figure 4.1. shows the ROA of F-16 aircraft from the airfield selected as the deployment location. Meanwhile, the red circle with the image of the plane to the left shows the ROA of the SU 27/30 aircraft. Placement and covering capabilities can be explained as follows:

5.2.1 F-16 Squadrons Will Occupy The Following Airfields:

a. Sam Ratulangi Air Base (SRI). The presence of the F-16 squadron here, apart from covering the area around the air base, will also cover areas around Leo Watimena (LWM) air base up to Mianggas Island (the outermost island in northern Indonesia), with a total covering distance of 864 km. The furthest distance from this air base is the Mianggas area, with a distance of 482 km, where the plane's travel time to the area is:

$$482/1555.2 \times 60 = 18.6 \text{ minutes}$$

b. Suwondo Air Base (SWO). The F-16 squadron here will cover the area around SWO airfield, Rusmin Nuryadin (RSN), Sutan Sjahrir (SUT), Sultan Iskandar Muda (SIM) and Rondo Island. Including the security of the Malacca Strait, with a total covering distance of 1,910 km. The farthest distance from this air base is the SUT air base area with a distance of 516 km, where the plane's travel time to this area is:

$$516/1555.2 \times 60 = 19.9 \text{ minutes}$$

c. Anang Busro Air Base (ANB). The deployment of the F-16 squadron here is to cover the northern areas of Kalimantan and ALKI 2, including Dhomber Airfield (DMB). The total covering distance is 864 Km. The farthest distance from this air base is the DMB air base area with a distance of 516 km, where the plane's travel time to the area is:

$$516/1555.2 \times 60 = 19.9 \text{ minutes}$$

d. Pattimura Air Base (PTM). The F-16 squadron in this area is used to cover the airspace around PTM airfield itself, up to Haluoleo airfield (HLO) and Dominicus Dumatubun airfield (DMN), as well as the ALKI 3 area, with a total covering distance of 1,189 km. The farthest distance from this air base is the HLO air base area with a distance of 631 km, where the plane's travel time to the area is:

$$631/1555.2 \times 60 = 24.34 \text{ minutes}$$

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5.2.2 SU 27/30 Aircraft Squadron. The SU 27/30 Squadron Will Occupy The Following Airfields:

a. Supadio Air Base (SPO). Apart from protecting the area around the base, which is his responsibility, Sukhoi's placement at the base is to protect the border areas of Indonesia with Singapore and Malaysia, as well as the Natuna Islands area. Apart from that, the aircraft from this airfield is also responsible for securing ALKI 1 and airfield airports in the western region of Indonesia, such as Halim Perdanakusuma (HLM), Husein (HSN), Sri Mulyono Herlambang (SMH), Raden Sajad (RSA), Raja Haji Fisabilillah (RHF), Hang Nadim (HNM), Bunyamin (BUN) and Abdullah Sanusi Hananjoedoeddin (ASH), with a total covering distance of 4,823 Km. The furthest covering area is HSN Air Base, with a distance of 778 km and a maximum travel time of:

$$778/2271.81 \times 60 = 20.55 \text{ minutes}$$

b. Silas Papare Air Base (SPR). The operation of Sukhoi aircraft at this air base is to cover region, both on land and water, including PT Freeport's vital objects in Timika, the Indonesia-Papua New Guinea border, Indonesia-Australia and anticipating threats from the North and South East. The airfields that have become responsible for fighter aircraft flights are Manuhua (MNA), SPR, Johane Abraham Dimara (DMA), Yohanes Kapiyau (YKU) and Liki Islands (the outermost island in North East Indonesia), with a total covering distance of 2,274 Km and the furthest distance to DMA airfield is by distance 661 Km and maximum travel time is:

$$661/2271.81 \times 60 = 17.46 \text{ minutes}$$

c. Zainuddin Abdul Majid Air Base (ZAM). Covering the Sukhoi aircraft squadron area at this air base is to protect ALKI 2 in the South and the Indonesian border in the South East and balance the strength of the Australian Air Force. The airfields covered include Sultan Hasanuddin (HND), Iswahjudi (IWJ), Abdul Rahman Saleh (ABD), Eltari (ELI), Adi Sumarmo (SMO), Mulyono (MUL), Ngurah Rai (RAI), Samsuddin Noor (SAM) airfields. And Dana Island (the outermost island in northern Indonesia). The total covering distance is 4,717 km, with the farthest covering distance being 826 km, namely to ELI airfield.

$$826/2271.81 \times 60 = 21.82 \text{ minutes}$$

By using the SCP method, the first and second objectives of this research can be achieved, namely being able to protect all Indonesian airspace, including border areas, ALKI routes and vital objects from at least one base by minimizing the response time of fighter aircraft and minimizing the number of air bases used for supports the national air defence system. The total covering distance that must be covered from all airfields is 15,877 Km or an average of 529.23 Km, with details of the total covering of the F-16 being 4,479 Km or an average of 497.67 Km and the SU 27/30 being 11,398 Km or an average 542.76 Km. The average total time to reach the target was 15.79 minutes, whereas if calculated according to aircraft type, it was 19.20 minutes for the F-16 and 14.33 minutes for the SU 27/30. If calculated per air base network, the average total time to reach the target is 19.48 minutes for the F-16 and 14.01 minutes for the SU 27/30 or a combined 17.14 minutes. The furthest covering distance is 826 km from ZAM airfield to ELI airfield. Meanwhile, the most significant total covering the distance for SU 27/30 is from the SPO airfield, with a total distance of 4,823 km or an average of 602.88 km. The longest travel time for an F-16 aircraft from the PTM airfield to the HLO airfield is 24.34 minutes.

5.3 Data Processing Using The PMP Method

This shows a shift in the placement of aircraft at six bases that had been selected using the SCP method, and one base, namely the SRI base, only changed the type of aircraft from F-16 to SU 27/30. Detailed explanation is as follows:

5.3.1 F-16 Aircraft Squadron. The F-16 Squadron Will Occupy The Following Airfields:

a. Eltari Air Base (ELI) Although the covering area is only around ELI Air Base and Dana Island, the presence of the F-16 squadron at this air base is prepared primarily to guard Indonesia's border areas with Timor Leste and Australia as well as to balance the strength of the Air Force. This squadron can also guard the ALKI 3 area from the South. The furthest covering distance is to Dana Island, with a distance of 271 Km, with travel time:

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271/1555.2 ×60= 10.46 minutes

b. Sultan Iskandar Muda Air Base (SIM). SIM Airfield was selected as the base for the basesquadronF-16 aircraft. The operation of fighter aircraft at one of Indonesia's leading airfields is intended to increase the ability to cover the airspace of the island of Sumatra up to the SWO airfield area, Rondo Island and the Strait of Malacca in the west. The total covering distance is 505 Km. The farthest distance from this air base is the SWO air base area with a distance of 436 km, where the plane's travel time to this area is:

436/1555.2 ×60= 16.82 minutes

c. Dhomber Air Base (DMB). The placement of the F-16 squadron here is a repositioning of the F-16 squadron, which, using the SCP method, was placed at ANB airfield. This repositioning increases the effectiveness of covering, which previously only had two airfields, increasing to four airfields, namely DMB, ANB, HND and SAM airfields. ALKI 2 security can also be optimized, considering that the location of the DMB base is more central in ALKI 2 compared to the position of the ANB base. The total covering distance is 1,371 km. The furthest distance from this air base is the ANB and HND air base area, with a distance of 516 km, where the plane's travel time to the area is:

516/1555.2 ×60= 19.9 minutes

d. Yohanes Kapiyau Air Base (YKU). The placement of the F-16 Squadron at this airfield is a repositioning of duties and responsibilities previously assigned to the SU 27/30 squadron at the SPR airfield. With its location further west than SPR Air Base, the aircraft covering the radius of this air base also covers the DMN air base area, which was previously the responsibility of the PTM air base. The total covering distance is 2,291 km with distance The furthest is the DMA airfield area with a distance of 591 km, where the plane's travel time to the area is:

591/1555,2 ×60= 22,80 minutes

5.3.2 SU 27/30 Aircraft Squadron. The SU 27/30 Squadron Will Occupy The Following Airfields:

a. Iswahjudi Air Base (IWJ). The deployment of the F-16 Squadron at this air base is to cover Indonesia's territory in the South, which was previously covered by SPO air base and ZAM air base, namely SMO, ABD, MUL, RAI, ZAM, HLM, HSN and ALKI 2 airfields in the Bali Strait. The furthest covering distance is to ZAM Air Base, with a distance of 546 km and a travel time.

546/2271.81 ×60= 14.42 minutes

b. Sam Ratulangi Air Base (SRI). Changing the aircraft type from F-16 to SU 27/30, which is stationed at this airfield, can increase the area cover capacity up to the HLO and PTM airfields. Apart from that, the optimization of squadron placement can be improved by adding responsibility monitoring ALKI 2 and ALKI 3, especially in northern Indonesia. With a total covering distance of 1,749 Km, the furthest cover distance is to HLO airfield, namely 685 Km, with travel time:

685/2271.81 ×60= 18.09 minutes

c. Raja Haji Fisabilillah Air Base (RHF). The placement of SU 27/30 at this air base is a repositioning of SU 27/30, which was previously placed at the SPO air base. With the geographical location of the RHF airfield being more central than the SPO airfield, it can optimize the covering power of the SU 27/30 squadron, especially in the ALKI 1 area and the Malacca Strait. The total covering distance is 3,662 Km, with the farthest covering distance being 690 Km, namely to BUN airfield.

690/2271.81 ×60= 18.22591 minutes/1555.2 ×60= 22.80 minutes

The PMP method aims to maximize the covering capabilities of fighter aircraft squadrons, the number and placement of which have been determined using the SCP method. Maximizing here means reducing the distance to the place of responsibility, which also reduces travel time to the target. From the results of data processing using the PMP method, it was found that the total covering distance that had to be covered from all airfields had decreased to only 12,901 Km or an average of 430.03 Km with details of the total covering of the F-16 being 4,700 Km or an average of

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427.27 Km. and SU 27/30 as far as 8,201 Km or an average of 431.63 Km. The average total time to achieve the target was automatically reduced to 13.26 minutes. Meanwhile, if calculated per aircraft type, it is 16.48 minutes for the F-16 and 11.4 for the SU 27/30.

Meanwhile, the average total time to reach the target per network was 13.49 minutes, with an average of 13.16 minutes for the F-16 and 13.93 minutes for the SU 27/30. The furthest covering distance is 690 km from RHF Air Base to BUN. The most considerable total covering distance is from the RHF airfield, which is 3,662 km. However, the largest average is at the SRI airfield, which has a distance of 557.75 km. The longest travel time is 25.50 minutes, namely the F-16 squadron from DMB airfield to SAM.

6. CONCLUSION

It can be seen from the results obtained in this research that the Set Covering Problem (SCP) Method—is used to complete the first and second objectives of this research. It can be explained that this model tries to find the right combination of the seven bases selected from the SCP method with the seven existing fighter aircraft squadrons. It minimizes the number of additional operational bases to maximize the covering capability of the Indonesian Air Force's fighter aircraft squadrons. The mathematical model was prepared using Microsoft Excel's open solver to obtain results for SRI, SWO, ANB, and PTM airfields for the F-16 main airfield. SPO, SPR and ZAM airfields for SU27/30/35 main airfields. The total covering distance is 4,479 km, with an average distance of 497.67. The total average time to reach the target was 67.69 minutes or 15.79 minutes for the average time per base network. In addition, the P-Median Problem (PMP) method is used to fulfil the third research objective: maximizing the protection capabilities of fighter aircraft by minimizing the overall distance or average distance per network location. So, this model maximizes the results of the SCP model. The mathematical model was also prepared using the Microsoft Excel open solver, obtaining results for ELI, SIM, DMB, and YKU airfields for the F-16 main airfield. IWY, SRI, RHF base for SU27/30/35 main base. The total covering distance is 12,640 km, with an average total distance of 56.85 minutes to reach the target or 13.26 minutes for the average time per airfield network.

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