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Cost-Benefit Analysis of Medium Altitude Long Endurance Unmanned Aerial Vehicle (MALE UAV) Operator Training

September 2023

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ABSTRACT

To increase its capability, the Indonesian Navy is migrating from small unmanned aerial vehicles (UAV) to medium altitude long endurance (MALE) UAVs. A review of the literature suggests three approaches to train MALE UAV operators effectively. The first option does not require enrolling the candidate in manned aircraft flight training. The second option requires 40 hours of manned aircraft flight training prior to MALE UAV training. The third option requires 250 hours of training on manned aircraft. Each option reflects its organization's priorities, such as cost savings over risk mitigation. This study presents an ex-ante cost-benefit analysis (CBA) of three courses of action (COA) for MALE UAV operator training to determine the minimum requirement for manned aircraft flight training to include, if any. The input data for the CBA is acquired from the Indonesian flying school's private sector. The mishap rate as a proxy of the output is derived from the historical data from MALE UAVs of the U.S. Army and the U.S. Air Force during fiscal years 2008–2022. The CBA shows that the most effective COA is to require 40 hours of manned aircraft flight training because it yields the most significant benefit, as measured by the lowest predicted Class A mishap and justifiable expenditures in time and money. Therefore, I recommend the Indonesian Navy take this as a short-term policy. Follow-on quantitative analysis and a randomized controlled trial is needed to set long-term policy.

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I want to give a big thank you to Professor Jesse Cunha and Professor Oleg Yakimenko for helping me with my master's thesis. They gave me great advice and support as I worked on this project. My thesis is about unmanned aerial vehicles (UAVs) and how they relate to Manpower System Analysis. It might sound complicated, but it's really about studying how technology like UAVs and the people who use them come together. I found that even though UAVs and Manpower System Analysis seem different, they actually fit together in an interesting way. This thesis is all about finding that balance. Looking at things from an economic perspective, it's important to make sure that the time and money we spend on training for medium altitude long endurance (MALE) UAVs make sense for the people who pay taxes in Indonesia. So, every dollar I talk about in this thesis is carefully thought about to make sure it's used in the best possible way. I want to say thank you again to Professor Cunha and Professor Yakimenko. Their help and advice made a big difference, and I'm really grateful for their support as I worked on this thesis.

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LIST OF ACRONYMS AND ABBREVIATIONS

CPL	Commercial Pilot License
HALE	High Altitude Long Endurance
IFR	Instrument Flight Rule
IR	Instrument Rating
MALE	Medium Altitude Long Endurance
PPL	Private Pilot License
RPA	Remotely Piloted Aircraft
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rule

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I. INTRODUCTION

Providing Medium Altitude Long Endurance Unmanned Aerial Vehicle (MALE UAV) operators with manned aircraft flight training in the military is a subject of debate within the field of UAV operations. There are arguments both in favor of and against this practice, each with its own set of advantages and disadvantages.

A comprehensive cost-benefit analysis is essential to determine whether the advantages gained from manned aircraft flight training of operators outweigh the associated drawbacks. While enhanced situational awareness, emergency handling skills, and redundancy are potential benefits, the practicality of these advantages must be evaluated against the resources required for training and the specific operational demands of MALE UAV missions. Prioritizing the optimization of automation system utilization, UAV-specific training, and mission planning remains vital to efficiently allocate resources and ensure safe, effective, and cost-efficient MALE UAV operations.

As the Indonesian Navy has committed to increase its capability by adding MALE UAVs to its existing small UAVs, it is imperative that decision makers also determine who will be qualified to operate these new acquisitions and what will be the minimum flight training requirements for these operators. The decision about whether to integrate manned aircraft flight training into MALE UAV operator training should be informed by a thorough assessment of its potential benefits, drawbacks, and the specific operational context. Balancing the advantages gained with the costs incurred is essential for achieving optimal training outcomes. Therefore, this study attempts to answer the following questions:

- What are the tradeoffs in cost and benefits of different requirements related to manned aircraft flying hours for MALE UAV operators in the U.S. Army and the U.S. Air Force?
- What is the ideal starting point for the training pipeline for the Indonesian Navy's future MALE UAV operators?

The literature reviewed for this study encompassed topics ranging from the Indonesian Navy's need to adopt MALE UAVs to the global perspective on the required qualifications and training for MALE UAV operators. It also included a case study from the U.S. Air Force and the U.S. Army, which operate MALE UAVs. Scholars and practitioners have explored the potential benefits of equipping UAV operators with insights from manned aviation, such as improved situational awareness, crisis management skills, and a holistic understanding of flight dynamics. Conversely, the literature also delved into the challenges of reconciling the operational dissimilarities between traditional aircraft and UAVs, including issues related to human factors, skill transferability, and cost-effectiveness.

Some literature offered training recommendations for MALE UAV operators; however, these recommendations did not address critical factors such as the associated costs and benefits. Manned aircraft training requires extra money and time, so the U.S. Armed Forces are trying to balance their operational needs with available resources. This leads to variations among the U.S. service branches in the number of hours of manned aircraft training provided to MALE UAV operators. This variation between service branches emerged over time as the flight automation technology increased and the operational demand rose exponentially. The literature discussed the different approaches to manned aircraft training provided before MALE UAV operator training but did not explain the tradeoffs associated with each approach. Thus, my thesis tries to provide a tradeoff analysis of manned aircraft training of varying durations.

The thesis employs a Cost – Benefit Analysis (CBA) methodology to quantify and monetize the input and output of each alternative studied. Three Courses of Action (COA) are possible for determining basic flight training requirements for MALE UAV operators in the Indonesian Navy, and these COAs are examined based on historical examples and current practice in the U.S. Armed Forces. The input data is derived from out-of-pocket cost and opportunity cost. The out-of-pocket cost is acquired from the cost of flight training at Indonesian Flying School to simplify the direct cost involved. In lieu of actual output data from the Indonesian Navy, this study uses the past data from the U.S. Air Forces and the U.S. Army related to the MALE UAV operation and training. The findings show that requiring 40 hours of manned aircraft flying training is the optimal choice as it offers the biggest net benefit.

Requiring 40 hours of manned aircraft flight training for MALE UAV operators has proven to deliver the highest net benefit while maintaining a medium level of difficulty in recruitment. Similarly, this requirement results in an average retention rate, even though the high attrition during training must be compensated for. As long as there is no exponential surge in demand, the Indonesian Navy could set this training policy for operators at the beginning of the MALE UAV acquisition process. My recommendation is Indonesian Navy take this action immediately for its short-term agenda. After that, the Indonesian Navy could proceed with experimental research to more accurately validate the correlation between the length of manned aircraft flight training and the quality of MALE UAV operators.

The thesis is organized into five chapters. In Chapter II, I review the literature surrounding regulations, qualifications and training, variations in manned aircraft training, and case studies of the U.S. Army's MQ1- C Gray Eagle vis-à-vis the U.S. Air Force MQ1-B Predator. Chapter III introduces the cost-benefit analysis methodology used to assess the tradeoffs involved. Chapter IV describes the result and interpretation of CBA result. In Chapter V, I draw conclusions from the analysis and make recommendations for the Indonesian Navy.

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II. BACKGROUND AND LITERATURE REVIEW

This chapter provides background information on the Indonesian Navy's requirement to acquire MALE UAVs and a literature review from some studies related to the manned aircraft flight training requirement for MALE UAV operators. With the increasing demand for MALE UAVs, the responsibility of operators to ensure the safety of unmanned operations has become crucial. This literature review aims to investigate the training requirements and qualifications for MALE UAV operators, highlighting the significance of comprehensive training to mitigate risks and ensure the successful execution of missions.

A. THE NEED FOR MALE UAVs IN THE INDONESIAN ARMED FORCES

While the Indonesian Navy currently operates the ScanEagle Small UAV, this military service needs a larger UAV platform for effective maritime operation. A study conducted by Nugroho et al. (2022) revealed that based on effectiveness criteria, the Indonesian Navy requires a High Altitude Long Endurance UAV as the top priority, followed by Medium Altitude Long Endurance UAVs for maritime operations. As a first step, the focus of the Indonesian government has been on acquiring MALE UAVs due to their affordability. Although the government initially made efforts to procure MALE UAVs through research activities, such as the building of the MALE UAV Elang Hitam project, such efforts have been discontinued (Rahmat, 2022), and the current option is to purchase from foreign manufacturers. The global market for MALE UAVs is dominated by advanced countries such as the United States, which offers the MQ1 UAV (Mc Leary & Hudson, 2021); China, which offers the CH4 UAV (Rahmat, 2018); and Turkey, which offers the Anka UAV (Cetiner, 2023).

Indonesia's defense capabilities, aligned with the broader Indo-Pacific strategy, have positioned the country favorably to potentially acquire the MQ1C Gray Eagle UAV from California-based General Atomics Aeronautical Systems. The need for drone capabilities to bolster naval and coast guard maritime security aligns with Indonesia's strategic objectives. Furthermore, the potential sale of UAVs to Indonesia offers geostrategic advantages for the United States, given its shift in focus from the Middle East to the Indo-Pacific region. Indonesia has emerged as a significant strategic partner country, further reinforcing the potential for approval of the UAV acquisition. Given the fact that the U.S. government also plans to sell the MQ1C Gray Eagle to Ukraine (Stone, 2023), it is increasing the opportunity for Indonesia to be the next buyer of this MALE UAV. An illustration of NATO classifications for UAVs is provided in Figure 1. The MQ1C Gray Eagle is classified as MALE UAV.

Class	Category	Normal Employment	Normal Operating Altitude	Normal Mission Radius	Primary Supported Commander	Example Platform
Class III (> 600 kg)	Strike/ Combat*	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre	Reaper
	HALE	Strategic/National	Up to 65,000 ft	Unlimited (BLOS)	Theatre	Global Hawk
	MALE	Operational/Theatre	Up to 45,000 ft MSL	Unlimited (BLOS)	JTF	Heron
Class II (150 kg - 600 kg)	Tactical	Tactical Formation	Up to 18,000 ft AGL	200 km (LOS)	Brigade	Hermes 450
Class I (< 150 kg)	Small (>15 kg)	Tactical Unit	Up to 5,000 ft AGL	50 km (LOS)	Battalion, Regiment	Scan Eagle
	Mini (<15 kg)	Tactical Subunit (manual or hand launch)	Up to 3,000 ft AGL	Up to 25 km (LOS)	Company, Platoon, Squad	Skylark
	Micro** (<66 J)	Tactical Subunit (manual or hand launch)	Up to 200 ft AGL	Up to 5 km (LOS)	Platoon, Squad	Black Widow

Figure 1. NATO UAV Classification. Source: Szabolcsi (2016).

As the Indonesian Navy expands its capabilities from small UAVs to include MALE UAVs, it must also conduct a comprehensive examination of the training requirements for operators of these new platforms. In fact, a study conducted by (Ristanto et al., 2020) indicates that the Indonesian Navy currently lacks the facilities and curriculum for UAV operator training. Therefore, it is crucial to begin by conducting a study on whether there is a need to train these operators to fly manned aircraft.

Given the shift towards incorporating MALE UAVs into the Indonesian Navy's operations, there is a pressing need to establish training facilities and curriculum for UAV operators. In the absence of Indonesian regulations regarding MALE UAV operator basic qualifications and training requirements, it is necessary to seek guidance from global institutions such as the North Atlantic Treaty Organization (NATO) or from partner countries such as the United States that have experience with MALE UAVs (Ristanto et al., 2020). Conducting a study on the value, if any, of training MALE UAV operators to fly manned aircraft will contribute to enhancing the curriculum for the Indonesian Navy's MALE UAV training program. This study aims to help ensure that operators are adequately prepared to operate MALE UAVs in maritime environments.

B. QUALIFICATIONS AND TRAINING RECOMMENDATIONS

The ongoing debate regarding whether to integrate manned aircraft flight training within military MALE UAV operator programs centers on the balance between traditional piloting skills and the evolving demands of automation technology. The supporting sources highlight the increasing role of automation in UAV operations, underscoring the importance of training operators to effectively manage automation systems. Contrasting sources emphasize the value of piloting skills in enhancing situational awareness, decision making, and risk assessment, particularly in scenarios where automation might fail or prove inadequate.

In the context of military MALE UAV operations, it becomes crucial to strike a balance between these perspectives. Integrating elements of manned aircraft flight training could equip operators with essential skills while also fostering adaptability, decision making capability, and resilience in the face of unexpected challenges. The overarching objective remains to optimize the training program to ensure efficient and secure military MALE UAV operations while aligning with the evolving landscape of automation technology.

Qi et al. (2018) studied the training requirements for various types of UAVs and concluded that UAV operators beyond the tactical level should possess a four-year degree in aviation or engineering and also specialized training. Studying UAV operators, they categorized unmanned aerial systems into seven types based on altitude. Furthermore, they considered completion of professional pilot training, acquisition of aeronautical knowledge, and accumulation of sufficient flight hours in manned aircraft necessary. This skill set also includes the capability to coordinate with other aircraft for sharing the airspace. According to the authors, MALE UAV training should encompass theoretical instruction, simulator training, practical experience with small UAVs, and specialized training involving manned aircraft certifications such as a private pilot license, commercial pilot license, and instrument rating. Similarly, a recent study has demonstrated that the performance indicator for the operators of MALE UAVs is similar to that for manned aircraft pilots (Barron et al., 2016). Although their research on the skills and training required for UAV operators is helpful, Qi et al. (2018) and Barron et al. (2016) did not discuss the costs of such training, which can increase greatly as more in-person flying time is required.

While numerous regulations exist to define the training framework for UAV operators, Szabolcsi (2016) identified several unresolved issues that still require further investigation. The role of training in modern UAV systems cannot be overstated, as it ensures safe flights and mission success. UAV operators are integral components of unmanned aircraft systems, and their proficiency is crucial in mitigating risks associated with technical system failures. Consequently, both military and civilian UAV operators have taken the initiative to establish minimum training requirements for safe flight and ground operations.

According to Szabolcsi (2016), MALE UAV operator must meet the standard of Basic UAS Qualification (BUQ) Level 4 to comply with the regulation detailed in NATO's STANAG 4760. The BUQ, a standard from the U.S. Department of Defense, serves as guidance for Joint Unmanned Aircraft Systems minimum training standards (CJCS, 2011). BUQ Level 4 qualification requires knowledge and skill to operate UAV under Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) in all airspace. The regulator wants the operator to meet or exceed the standard from civilian aviation, such as an equivalent to the private pilot license requirement to fly under VFR and the instrument rating requirement to fly under IFR.

MALE UAVs are operated by various categories of personnel, and thus, safety concerns arise due to the differing standards imposed on military MALE UAV pilots and civilian contractors in the United States (Townsend, 2020). All civilian contractors operating MALE UAVs must have a civilian commercial pilot license with a minimum of 250 recorded flight hours. By contrast, in the military, the operators can vary by rank (officer vs. enlisted), by education (undergraduate degree vs. high school diploma), by occupational specialty (pilot rated vs. non-pilot rated), and—most important for this study—the number of hours of manned flight training. As a result, inconsistencies exist between the training standards for MALE UAV operators. Townsend (2020) also reveals variations in the minimum manned aircraft training requirements for MALE UAV operators. The minimum level of training required for manned aircraft experience can range from 40 to 250 hours, or even no hours at all. Therefore, Townsend (2020) argues that the training requirement for manned aircraft experience prior to MALE UAV training must be standardized. In the short term, Townsend (2020) suggests that MALE UAV operators have completed 40 hours of manned aircraft flight training prior to their UAV-specific operator training. In the long term, Townsend (2020) the author emphasizes that the MALE UAV operator should complete up to 250 hours in manned aircraft flight training. However, it is still unknown for the Indonesian Navy related which additional training should be provided for its MALE UAV operator. Moreover, it also unknown what would be the consequences of each additional training options to the training outcome.

C. U.S. ARMY AND AIR FORCE: MQ1-C GRAY EAGLE AND MQ1-B PREDATOR CASE STUDIES

The development of technology related to MALE UAVs, the increasing demand for MALE UAV in military operations, and the shortage of MALE UAV operators in the military have led to discussions about whether to include manned aircraft flight training for these operators (Harrison, 2021). In this section, I discuss the case study of two MALE UAV platforms—MQ-1C Gray Eagle and MQ-1B Predator—from the perspective of human resources management. While the two UAVs are similar (in platform design, size, altitude capability, and flight endurance), they are operated by different branches of the U.S. Armed Forces.

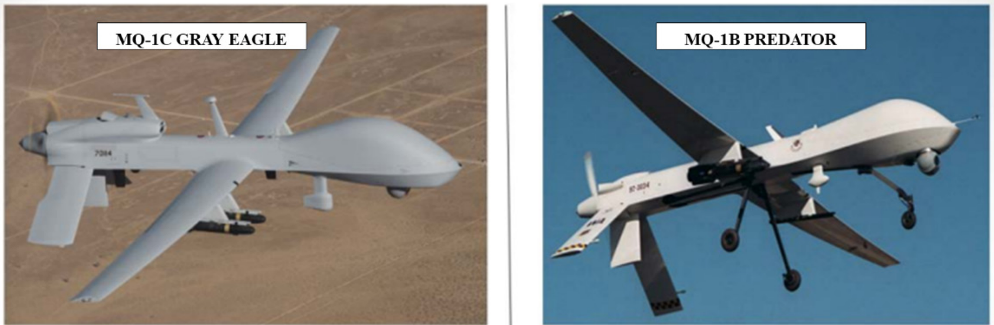
Many military researchers have been focused on the change in the personnel requirements for MALE UAV operators. For example, Norton (2016) discusses the need to secure economic efficiency in military operations by creating a MALE UAV operator team optimally composed of a rated pilot officer, non-rated pilot enlisted, Department of Defense civilian, and civilian contractor. On the other hand, some studies only focus on the contrast between commissioned officers vs. warrant officers (Coonrad, 2012) and officers vs. enlisted personnel as MALE UAV operators (James, 2016). Despite their different areas of focus, all three researchers share similar critiques of the current practice of requiring a MALE UAV operator to be an officer and rated pilot.

The requirements for the operators of the MQ-1C Gray Eagle and the MQ-1B Predator vary to meet the needs and vision of their respective organizations. First, the U.S. Air Force divides the job into Remote Pilot and Sensor Operator, while the U.S. Army divides the job into Air Vehicle Operator and Sensor Operator. Second, the Remote Pilot for an MQ1-B Predator must be an officer who has passed the initial flight screening in a DA-20 Katana Manned Aircraft (Church, 2011), but the Sensor Operator is an enlisted service member who does not need manned aircraft training. Meanwhile, the Air Vehicle Operator and Sensor Operator for the MQ1-B Gray Eagle are both enlisted service members without prior manned aircraft training. Third, the career specialty code for both the Air Vehicle Operator and Sensor Operator of the MQ1-C Gray Eagle is 15 W. By comparison, there are two career specialty codes for MQ1-B Predator operators; for the Remote Pilot, it is 18X, and for its Sensor Operator, it is 1UO. In short, the Remote Pilot of the MQ1-B Predator is comparable to the MQ1-C Gray Eagle Air Vehicle Operator. Table 1 provides a comparison of the qualifications and classifications for U.S. Army and U.S. Air Force MALE UAV operators.

Table 1. MALE UAV Operator Comparison. Source: James (2016).

PLATFORM	MQ1-B PREDATOR		MQ1-C GRAY EAGLE	
TASK	REMOTE PILOT	SENSOR OPERATOR	AIR VEHICLE OPERATOR	SENSOR OPERATOR
RANK	Officer	Enlisted	Enlisted	Enlisted
Manned Aircraft Flying Training	Yes	No	No	No
Undergraduate Degree	Yes	No	No	No
Military Occupational Specialties	18X	1UO	15W	15W

In this thesis, I focus on the difference in the manned aircraft flight experience requirement for MALE UAV operators in the U.S. military. While operators of the U.S. Army's MQ-1C Gray Eagle do not need to have prior manned aircraft flight experience, the Remote Pilots for MQ-1B Predators in the U.S. Air Force do. Figure 2 present images of the MQ1-C Gray Eagle and MQ-1B Predator platforms and their respective specifications. It is clear that both MALE UAVs have similar physical characteristics.



Wing Span	55/56 ft
Max GTW	2550/3600 lbs
Range With Relay	125km LOS/1200 km SATCOM
Max Airspeed	120/130 knots (A/O)
Altitude	25000/29000 ft
Endurance	22/18 hours
Weapon	Up to 2/4 Hellfire Missiles
Launch Recovery	3000/3200 ft @ 9k ft DA (A/O)

Wing Span	55 ft
Max GTW	2250 lbs
Range With Relay	125km LOS/1200 km SATCOM
Max Airspeed	70 knots
Altitude	26000 ft
Endurance	24 hours
Weapon	Up to 2/4 Hellfire Missiles
Launch Recovery	3000/3200 ft @ 9k ft DA (A/O)

Figure 2. U.S. Army Gray Eagle vs. U.S. Air Force Predator. Source: James (2016).

The U.S. Army and the U.S. Air Force have different perspectives on incorporating manned aircraft flight training in MALE UAV operator training. These differences arise from variations in training requirements, airspace considerations, regulatory compliance, and operator classification, as well as time and financial constraints (Matwick, 2017). These disparities reflect the unique needs and operational contexts of each military branch.

The U.S. Army's approach to training MALE UAV operators, particularly for the MQ1C Gray Eagle, is characterized by a focus on the extensive automation features contained within the system (Norton, 2016). These features, including automatic takeoff, landing, and navigation, minimize the need for conventional controls and prioritize efficiency. Furthermore, the training system for the MQ1-C Gray Eagle's operation is supported by a high technology simulator that can virtually represent actual flight for training purposes (General Atomic, 2023). As a result of the highly automated and high-technology simulator, operators of the MQ1-C Gray Eagle may not require prior manned aircraft flying experience (CJCS, 2011).

In contrast, the U.S. Air Force's MQ1B Reaper utilizes a different operational approach and control system. While the Reaper also incorporates automation features, it retains manual takeoff and landing modes and employs controls similar to those found in traditional manned aircraft, such as throttle, rudder, and stick controls (Coonrad, 2012). Consequently, the U.S. Air Force's training program for UAV operators includes 40 hours of flight screening in manned aircraft, recognizing the potential benefits of manned aircraft flying experience for effective operation of the MQ1-B Predator.

The U.S. Air Force's decision to provide manned aircraft flight training for MALE UAV operators was supported by a study conducted by Schreiber et al. (2002). In their study, they offer insight into the acquisition of essential skills for operating a MALE UAV. The study's findings suggested that accumulated flight experience of approximately 150–200 hours on a manned aircraft with handling attributes like those of the MQ1-B Predator is sufficient for a MALE UAV operator to attain the requisite proficiencies. Yet, a study by Harrison (2021) showed that this method was inadequate to prepare operators to cope with the swift expansion of MQ-1 combat operations and to meet the subsequent surge in demand for MALE UAV operators. As a result, in 2010, the Air Force altered its approach by establishing a distinct career path for remotely piloted aircraft (RPA) pilots designated by the Air Force Specialty Code 18X, along with a separate training trajectory tailored for these pilots. One of the driving factors behind this shift was cost reduction. According to certain approximations, the expenses associated with the RPA pilot training pipeline were notably lower—approximately 95 percent less per pilot—compared to the conventional training employed for crewed aircraft.

Meanwhile, the U.S. Army's reliance on automation and simplified controls raises the possibility that advanced automation technology can obviate the need for manned aircraft experience in certain MALE UAV operations. Conversely, the Air Force's emphasis on manned aircraft flying experience indicates confidence in the applicability of aviation skills and knowledge to MALE UAV operations. I use these two different approaches as a source for the Indonesian Navy to learn further about training requirements and qualifications for MALE UAV operators.

It is crucial for the Indonesian Navy to continually review and modify its training programs to align with the evolving requirements of MALE UAV operations and advances in technology. When considering the necessity of manned aircraft flight experience for MALE UAV operators, the Navy should carefully assess factors such as the level of automation, control systems, and operational context.

Furthermore, these differences in training strategies underscore the importance of tailoring training programs to suit the unique needs and capabilities of specific MALE UAV platforms. By drawing on the experiences and insights gained from both the U.S. Army and U.S. Air Force, the Indonesian Navy can develop a coherent and effective training program for MALE UAV operators that aligns with the Navy's operational objectives and resources.

III. METHODOLOGY

This chapter presents the Cost-Benefit Analysis (CBA) framework I use to compare the net benefits of different policy alternatives. The CBA framework entails quantifying and monetizing impacts and outputs to the greatest extent possible so that they can be compared and contrasted (Boardman, 2011). CBA is an especially useful tool for *ex-ante* analyses, which pertain to projects that have not yet been implemented. Thus, this thesis implements a step-by-step *ex-ante* analysis in the following sections of this chapter.

A. COURSES OF ACTION CONSIDERED

The first step is to outline the proposed Courses of Action (or COAs). This step involves identifying and defining a range of policy alternatives that could address the problem at hand—how to train UAV operators in the Indonesian Navy. Each alternative represents a distinct course of action that will be evaluated in terms of its associated costs and benefits.

- COA 1 is 0 hours of manned aircraft flight training in addition to MALE UAV-specific training, adapted from the U.S. Army's training for MQ1-C Gray Eagle which does not require manned aircraft flight training for operators. This COA is set as the baseline for the other COAs.

- COA 2 is additional training consisting of a minimum of 40 hours of manned aircraft flight training, adapted from the U.S. Air Force strategy for MQ1-B Predator training since 2012 up to now. For this alternative, MALE UAV operators conduct manned aircraft training equivalent to the requirement for a Federal Aviation Administration (FAA) licensed private pilot, which is an accumulated 40 hours of flight record.

- COA 3 is additional training consisting of a minimum of 250 hours manned aircraft flight training, adapted from the U.S. Air Force strategy for MQ1-B Predator training from 1996 to 2012. For this alternative, MALE UAV operators first complete 250 hours accumulated flight in manned aircraft training, which is equivalent to the requirement for an FAA licensed commercial pilot with instrument rating.

Assuming the Indonesian Navy procures the MQ1-C Gray Eagle, one reasonable follow-on training after each COA would be to have a similar training curriculum as the U.S. Army, which includes two months of the Military Occupational Specialties 15W common core course and five months of a Gray Eagle-specific course (Matwick, 2017). During the 15W common core course, students complete four modules: A, B, C, and D. Module A consists of all knowledge learned in the U.S. Federal FAA private pilot's ground school, including concepts such as aerodynamics, civilian aviation regulation, management of risk, mission flight planning, safety of flight, and flight navigation. Module A therefore enables students to pass the FAA's Private Pilot Knowledge Test. Students then continue to module B which consists of Unmanned Scouting operations, a tactic of Intelligence, Surveillance and Reconnaissance using aerial assets. Next, students go to module C, which focuses on Army Aviation regulations. The module describes how to conduct aerial operations in combat based on the U.S. Army's rules and regulations. As the last common course, students complete module D, which consists of gunnery training. Following the 15 W common core course, a Gray Eagle-specific course introduces students to instrument flight rules, a system overview of the Gray Eagle, its mission systems, simulator flight training, weapons training, flight line operations, a capstone exercise, and administrative training.

Upon the completion of the Gray Eagle course, students will be able to pass the FAA Instrument Check Ride Test (King, 2015). Thus, the U.S. Army training has provided the student with fundamental knowledge equal to private pilot knowledge and instrument rating knowledge. However, this knowledge is never applied with practical training in manned aircraft. Instead, students practice their aeronautical knowledge on MALE UAVs.

To assess the several options of manned aircraft training as additional training prior to 15W common core course and the Gray Eagle curriculum, I set three courses of action. Each COA is designed to capture a corresponding training model used by the U.S. Army, which is 0 hours of manned aircraft training; U.S. Air Force prior to 2012, which is 250 hours of manned aircraft training; and U.S. Air Force after 2012, which is 40 hours of manned aircraft training.

The additional requirement of 40 hours of manned aircraft flight training provides students with the FAA private pilot curriculum. According to FAA 14 CFR Part 61, a private pilot certificate holder must be at least 17 years old and be able to read, speak, write, and understand the English language. Students are required to have 40 hours of total time flight training with single engine aircraft. Of those 40 hours, students must complete 20 hours of dual instruction, three hours of instrument instruction, ten hours of solo flight time, three hours of night flying, three hours cross country, and five hours of solo cross-country flight. The cross-country requirement is based on one flight of a 100 nm distance. Solo cross country must be one flight of 150 nm with three stops. Take off and landing at night must be ten full-stop landings. Take off and landing at a control tower must be three take-off/full-stop landings. Sixty days prior to their flight tests, students must have three hours with an instructor (Townsend, 2020).

The additional requirement of 250 hours of manned aircraft flight training provides students with the FAA commercial pilot curriculum with instrument rating. According to FAA 14 CFR Part 61, commercial pilot students must be at least 18 years old and able to read, speak, write, and understand the English language. Students must have logbook endorsement from an authorized instructor, pass the required knowledge test, pass the required practical test, and hold at least a private pilot certificate. Students are also required to demonstrate aeronautical knowledge about applicable areas that pertain to the aircraft category. The minimum aeronautical experience is 250 hours. Of those 250 hours, students must have experience as a pilot in command (PIC) for 100 hours, cross country as PIC for 50 hours, ten hours of instrument training time, ten hours of solo flight time, and five hours of night flying with at least ten take-offs and landings (Townsend, 2020).

B. IDENTIFY INPUT

The second step is identifying the inputs that are required to implement any of the COAs. These inputs consist of the cost component and other components that affect the training. The cost component is associated with out-of-pocket money paid by the

Indonesian Navy to provide additional manned aircraft training. For example, the Indonesian Navy Aviation Center could hire a private flying school or spend extra money for additional fuel at in-house school training using the existing facility. Also incurred in the process are opportunity costs. The opportunity cost is estimated as the total compensation of personnel who are taking the additional training for the training's duration.

C. IDENTIFY OUTPUT

The third step of the analysis involves the identification of the various outputs that would ensue from the implementation of each COA. These outputs encompass a range of benefits and other consequential elements resulting from the training process. Among the identified outputs, I specifically delve into the evaluation of benefits arising from different factors, including the quality of operators, the degree of recruitment challenges, the attrition rate during training, the post-first contract retention rate, and the rate of production acceleration.

Regarding operator quality, a multifaceted approach is adopted. I utilize historical mishap rate data sourced from the U.S. Armed Forces as a surrogate measure to estimate the potential reduction in mishap occurrences achievable through the selection of a particular COA. However, it is imperative to emphasize that operator quality engenders a spectrum of outputs, each contributing to the overall effectiveness of the training process.

Furthermore, while the mishap rate stands as a quantifiable representation of one negative outcome, it is essential to acknowledge that the operator's performance in mission execution and other critical aspects equally constitute significant outputs. Unfortunately, quantifying these outputs proves to be challenging due to the absence of publicly available data from the U.S. Armed Forces that pertains to the broader impact of various training policies on manpower-related aspects.

D. QUANTIFY AND COMPARE

In the fourth phase of analysis, the task involves the quantification and comparative assessment of the array of costs and benefits linked to each COA. Within this evaluation, my focus remains directed solely on the quantifiable and monetizable benefits and costs. To be precise, I calculate the net benefits by gauging the disparity between the cumulative monetized benefits and the aggregate monetized costs for each COA.

Specifically, I calculate the aggregate benefits associated with each policy alternative by deducting the total costs from the overall benefits that have been monetized and quantified. This systematic approach allows for a precise quantification of the comprehensive desirability quotient for each alternative.

The items that will not be quantified are the recruitment difficulty level, the attrition issue, the retention issue, and the production rate. However, I can draw useful conclusions regardless of those missing metrics. I do not quantify and monetize all inputs and outputs because some of them are hard to quantify and monetize. For example, while it is known that by not requiring UAV operator candidates to have manned aircraft flight training, the U.S. Army likely captures a wider pool of candidates, it remains unknown whether the Indonesian Navy would gain any monetary benefit from having a wider pool of candidates. Next, even though it has been proven by the U.S. Air Force that a higher attrition rate occurs during the manned aircraft flight training phase, it remains unknown how much money the Indonesian Navy could lose in this phase because the attrition rate does not yet exist. Next, it is also known that the U.S. Air Force provides a generous flying hour bonus and attrition bonus for MALE UAV operators as a retention incentive because their capability is valuable in the civilian sector. It is difficult, however, to predict what monetary incentive, if any, the Indonesian Navy should offer its operators because the civilian aviation sector in Indonesia is not operating any MALE UAVs yet. Finally, it is also hard to quantify the production rate for the Indonesian Navy because the organization is basically not retaining any revenue from its UAV operation. Thus, it is unclear whether a more rapid production rate would be converted into a higher benefit or not.

Another factor for consideration is the transferable skill gained from 40 hours of flying, which is still unknown. Therefore, it is hard to quantify how additional flight experience benefits MALE UAV operation. Also, it is unclear whether the 40 hours of manned aircraft flight training is enough to confer adequate airmanship, situational awareness, aerodynamics if the operator is no longer onboard the cockpit. It is also unclear whether adding the manned aircraft flight training of 250 hours could provide operators with better transferable skills for MALE UAV operation.

There will also be some uncertainty related to the how many mishaps will actually happen compared to the prediction. The actual mishap could be worse or less severe than predicted. Moreover, another aspect such as the difficulties of recruitment, the risk of attrition from the training, the challenges related to retention, and the effectiveness of the training policy must be accounted for not only before but during and after the purchase of the MALE UAV, because the analysis will be more accurate using actual data from the Indonesian Navy.

E. MAKE A POLICY RECOMMENDATION

The concluding phase involves formulating a policy recommendation. The COA with the most substantial net benefit will be selected as the recommended approach, despite certain inputs and outputs not being quantified. This choice is justified by the necessity for the Indonesian Navy to initiate actions aimed at collecting tangible data. In this recommendation process, I also integrate additional qualitative considerations. These include evaluating the level of difficulty in recruitment, risks of and from attrition, and challenges related to retention. This broader analysis aims to preemptively identify any potential obstacles associated with the chosen COA.

By applying CBA *ex ante* analysis, the Indonesian Navy can gain insights into the economic viability and potential benefits of integrating manned aircraft training into MALE UAV operator training. This analysis can support evidence-based decision making and resource allocation to determine whether to add mandatory manned aircraft flight training to the MALE UAV operator training while considering the financial implications for the organization.

IV. RESULTS

This chapter provides the result of the CBA. The inputs of training, the output of the training, and the quantifiable metrics are analyzed in the following sections.

A. THE INPUTS TO TRAINING

In this thesis, I want to provide recommendations on whether to require additional training—specifically, manned aircraft flight training—for MALE UAV operators in the Indonesian Navy. However, the current flight training facility for the Indonesian Navy is allocated for training of manned aircraft pilots only. Adding the training of MALE UAV operators to those training facilities could disrupt the current training process. Meanwhile, building a new training facility to accommodate additional training for MALE UAV operators would entail purchasing new aircraft, hiring more trainers, and expanding the fuel budget. Thus, I would recommend the Indonesian Navy replicate the U.S. Air Force MALE UAV operator training model which contracts with the private sector for the manned aircraft training phase.

The cost of adopting this model could be calculated based on the price of flight training packages in civilian flight schools in Indonesia. Therefore, I conducted a search of the manned aircraft flight training packages from several flying schools in Indonesia to get information about the cost and duration of their training programs. One of the flying schools most recommended by several Indonesian aviation websites is the Aero Flyer School (Medcomid, 2023). Their 40 hours manned aircraft flight training is based on the private pilot license curriculum (Martono et al., 2021). The cost of this four-month training program is $ 19,627 per student. The program for 250 hours of manned aircraft flight training is based on the private pilot license, commercial pilot license, and instrument rating curricula (Martono et al., 2021). The cost is $ 50,188 per student, and it takes place over 14 months.

Assuming the Indonesian Navy needs 30 MALE UAV operators, the total cost for the 40-hour option is $588,810, and the total cost for the 250-hour option is $1,505,640. Further, there is also an opportunity cost incurred for the process. The opportunity cost is defined as the loss of work output due to additional training. This opportunity cost is calculated as the per-month total compensation for the Officer-1 level of Indonesian Navy (World Salaries, 2023). Table 2 shows the calculated cost for each COA.

Table 2. Cost Analysis of Additional Training for MALE UAV Operators in the Indonesian Navy. Source: Medcomid (2023).

	Additional training alternatives in manned aircraft flight training prior to MALE UAV training		
	COA 1	COA 2	COA 3
Cost per student	$ 0	$ 19,627	$ 50,188
Cost for 30 students	$ 0	$ 588,810	$1,505,640
Time	0 months	4 months	14 months
Opportunity cost per student (calculated as $416 per month)	$ 0	$1,664	$5,824
Opportunity cost for 30 students	$0	$ 49,920	$174,720
Total cost for 30 students	$0	$638,730	$1,680,360

Table 2 comprehensively presents the cost analysis for each COA if the training for MALE UAV operators requires additional (prior) training in flying manned aircraft. Interestingly, the opportunity cost associated with this training approach is relatively low compared to the training costs themselves. This can be attributed to the modest compensation levels in Indonesia. However, when exploring this concept within high-income countries like the United States, the ratio of opportunity cost to training costs can yield a contrasting perspective, potentially highlighting the more substantial financial implications of such an approach.

B. THE OUTPUTS OF TRAINING

There are several output aspects as a consequence of each COA. The observable aspect is the benefit. For example, COA 1 could increase operational readiness with shorter periods of training, while COA 3 might need a higher retention bonus to make sure the trained service member does not leave the military after his or her first contract expires. Moreover, from the military perspective, escalation in the regional area that demands the presence of MALE UAV operators could be reasonable argument to expedite the training process, setting COA 1 as top priority. While the benefit of each COA may be more than only reduced mishaps, those other benefits are hard to quantify. Moreover, the integration of MALE UAVs into the Indonesian airspace is a novel development requiring much attention to safety as a priority. Thus, my thesis narrows its focus to a discussion of the benefit of reduced mishaps according to each COA.

The benefit of each COA is calculated based on the potential for reduced mishap if a particular COA is chosen. For this thesis, I use the predicted number of Class A mishaps associated with each COA. Such a mishap is an accident which incurs a loss of $20,000,000 or more.

To predict the Class A mishap rate for COA 1, I use the data from the U.S. Army Combat Readiness Center for fiscal years 2018–2022 (USACRC, 2022). This data represents the mishap rate of the MQ1-C Gray Eagle, for which operators have no hours of manned aircraft flight training. Assuming the Indonesian Navy adopts this policy, the predicted Class A mishap rate for MALE UAVs will be close to the average of the data. Table 3 shows the predicted Class A mishap rate for COA 1, COA 2, and COA 3, respectively.

Table 3. Mishap Rate of Each COA. Adapted from USAFSC (2022) and USACRC (2022).

Fiscal Year	COA 1	COA 2	COA 3
FY 2008	X	X	4.53
FY 20099	X	X	4.2
FY 2010	X	X	4.26
FY 2011	X	X	5.91
FY 2012	X	X	4.31
FY 2013	X	4.53	X
FY 2014	X	4.2	X
FY 2015	X	4.26	X
FY 2016	X	5.91	X
FY 2017	X	4.31	X
FY 2018	3.51	X	X
FY 2019	8.77	X	X
FY 2020	4.82	X	X
FY 2021	11.42	X	X
FY 2022	10.32	X	X
AVERAGE	7.49	4.6	5.27

To predict the mishap rate for COA 2, I use the data from the U.S. Air Force Safety Center from fiscal years 2013–2017 (U.S. Air Force Safety Center, 2022). This data represents the mishap rate of the MQ1-B Predator, for which operators have 39 hours of manned aircraft flight training. Assuming the Indonesian Navy adopts the additional requirement of 40 hours of manned aircraft flight training for its MALE UAV operators, the predicted Class A mishap rate for MALE UAVs will be close to the average of the data shown in the COA 2 column of Table 3.

I realize that the MQ1-B Predator and the MQ1-C Gray Eagle are different MALE UAVs; however, I believe that the estimates for COA 2 and COA 3 could be applicable to the MQ1-C Gray Eagle. This is because both share the same MALE UAV classification, work at the same altitude range, have similar endurance, and therefore have similar flying characteristics. The only significant difference is the training of their operators, with only the MQ1-B Predator requiring manned aircraft flight training. Furthermore, the MQ1-C Gray Eagle is also a variant derived from the MQ1-B Predator and built by the same manufacturer, which is General Atomic. This MQ1 family has reached more than 5 million hours of flight (UAS Vision, 2023), and thus, its failure rate has reached the steady state (Petritoli et al., 2018). Therefore, any mishap that happens is driven by human error rather than equipment failure (Koch, 2021). One significant human factor that contributes to mishaps is training (Jaussi & Hoffmann, 2018; Tvaryanas et al., 2006).

To predict the mishap rate for COA 3, I use data from the U.S. Air Force Safety Center from fiscal years 2008–2012 (U.S. Air Force Safety Center, 2022). This data represents the mishap rate of the MQ1-B Predator, for which operators must have at least 250 hours of manned aircraft flight training. Assuming the Indonesian Navy adopts the additional requirement of 250 hours of manned aircraft flight training for its operators, the predicted Class A mishap rate for MALE UAVs will be close to the average of the data shown in the COA3 column of Table 3.

After calculating the predicted mishap rate, I assign a monetary value to each COA. The potential mishap rate is acquired by multiplying the Class A mishap rate by the value of $20,000,000. Without the additional requirement of manned aircraft flight training for MALE UAV operators, the loss of material is predicted to cost $14,980,000. With a reduction in the predicted Class A mishap rate, COA 2 yields a $5,780,000 margin compared to COA 1. Meanwhile, COA 3 yields a $4,440,000 margin compared to COA 1. Table 4 shows the benefit analysis for each COA.

Table 4. Benefit Analysis.

	Additional training alternatives in manned aircraft flight training prior to UAV training		
	COA 1	COA 2	COA 3
Predicted Class A mishap rate for 100,000 hours, with additional training	7.49	4.6	5.27
Potential loss from Class A mishap, with additional training	$14,980,000	$9,200,000	$10,540,000
Benefit from implementation of additional training	$0	$5,780,000	$4,440,000

C. COMPARISON OF QUANTIFIED COSTS AND BENEFITS

The net benefit is acquired by subtracting the total quantified costs from the total quantified benefits, as presented in Table 5.

Table 5. Comparison of Quantified Costs and Benefits.

	COA 2 – COA 1	COA 3 – COA 1
Cost	$638,730	$1,680,360
Benefit	$5,780,000	$4,440,000
Benefit-Cost	$5,141,270	$2,759,640

The net benefit from COA 2 is bigger than the net benefit of COA 1, and net benefit of COA 2 is bigger than the net benefit of COA 3; therefore, COA 2 is the recommended policy option based on these quantified costs and benefits alone. Based on the analysis, the Indonesian Navy should choose COA 2, which requires 40 hours of manned aircraft flight training for operators prior to their MALE UAV training.

In line with the finding that COA 2 is more cost effective in terms of reduced mishap rate, there are several considerations related to choosing this option. For instance, COA 1 is the cheapest and has the shortest duration; however, it has the biggest predicted mishap rate. In a wartime situation when demand for MALE UAV operators is high and urgent, COA 1 could be a viable solution. Using this option, more operators could be produced and at a faster pace for the lowest cost compared to the other COAs. The U.S. Army proved this in operations in Iraq and Afghanistan in 2012. In contrast, when the production of operators is not so urgent, COA 3 is seemed the optimal choice from the U.S. Air Force perspective. They wanted to isolate the errors originating from the equipment, because in 1996, the MALE UAV was still in its development phase. However, this option became a hindrance to providing enough MALE UAV operators in 2012 when the U.S. Air Force deployed to Iraq and Afghanistan. Therefore, the U.S. Congress wanted to evaluate the gap between those two training models. As a result, the U.S. Air Force created a new curriculum in 2012, which looked similar to COA 2. The summary of inputs and outputs of each COA is exhibited on Table 6.

Table 6. Summary of Inputs and Outputs of Each COA.

CATEGORY	COA 1	COA 2	COA 3
INPUT			
TRAINING COST	$0	$588,810	$1,505,640
OPPORTUNITY COST	$0	$ 49,920	$174,720
TOTAL COST	$0	$638,730	$1,680,360
OUTPUT			
REDUCED MISHAP RATE	$ 0	$5,780,000	$4,440,000
RECRUITMENT	EASY	MEDIUM	HARD
TRAINING ATTRITION	LOW	MEDIUM	HIGH
RETENTION RATE	HIGH	HIGH	LOW
PRODUCTION RATE	FAST	MEDIUM	SLOW

If a conflict in the regional area rapidly increases, the Indonesian Navy could also take step similar to COA 3 in the short term by assigning current Navy pilots to serve as MALE UAV operators. After that, the Indonesian Navy can simultaneously prepare newly recruited personnel to be trained according to COA 1 and COA 2. Having three categories of operators and studying their job performance, the Indonesian Navy can then conduct an evaluation of whether to switch permanently into COA 2, switch permanently to COA 1, or remain permanently with COA 3, based on their own actual data.

In short, if there are no budget and time constraints, safety should be the top priority in the option selected. Other factors such as challenges related to recruitment, attrition, and retention would follow as secondary priorities. Only if safety is proven to be the same for each COA can the Indonesian Navy then choose the COA that best satisfies the secondary criteria, ensuring the easiest recruitment, lowest attrition rate during training, the highest retention rate, and the fastest production rate.

V. CONCLUSION AND RECOMMENDATIONS

A. FINDING OF THIS RESEARCH

This research sought to answer two research questions. First, what are the tradeoffs between incorporating or not incorporating manned aircraft flight training into MALE UAV operator training? Second, which additional training, if any, is best for the Indonesian Navy? This thesis's analysis demonstrated that the tradeoff is the financial cost and time spent on manned aircraft flight training in return for a sufficient number of well-qualified operators. Requiring manned aircraft flight training, especially a minimum of 250 hours of this additional training, costs the most in terms of money and time and achieves a certain level of safety. However, this option also creates a shortage of manpower. In short, it achieves quality at the sacrifice of quantity. Reducing the amount of manned aircraft flight training to 40 hours is effective for tackling the operator shortage while also increasing the safety level of MALE UAV operation. Even so, this option could still potentially lead to manpower shortfall if the demand for operators were rising exponentially. Thus, the policy requiring no hours of manned aircraft flight training could eliminate a manpower shortfall by ramping up production of MALE UAV operators. This option, however, leads to a higher mishap rate.

The analysis also showed that the best policy option is for the Indonesian Navy to require 40 hours of manned aircraft flight training prior to MALE UAV operator training. This decision could strike the desired balance between an acceptable level of safety as a proxy for operator quality and the required number of MALE UAV operators. Therefore, the additional cost and time is justifiable.

As discussed in this thesis, the U.S. Armed Forces have leveraged adaptability in responding to the rise of MALE UAVs in military operation. Since the emergence of the MQ-1 B Predator in 1996, data shows that rated military aviators can do nothing to minimize the number of mishaps because errors are mainly due to equipment failures rather than human error. In that era, the U.S. Air Force only allowed someone from a fighter or a bomber pilot background to be a MALE UAV operator. With the rise of automation and equipment errors entering the steady state phase, mishaps have become the result of human factors. Meanwhile, as the demand for MALE UAVs in military operations increased exponentially, there was a growing manpower shortfall. MALE UAV operators simply were not being trained fast enough to keep up with the demand. Therefore, in 2012, the U.S. Air Force revised its requirements, allowing entry-level recruits to become MALE UAV operators with only 39 hours of manned aircraft flight training and follow-on MALE UAV training.

In contrast, the U.S. Army responded to the advances in automation technology such as automatic take-off, point-and-click navigation, and automatic landing by setting a very minimum requirement for MALE UAV operators. This policy has had a huge advantage in terms of personnel and training costs compared to the U.S. Air Force policy. However, the Army's operators may be missing some airmanship skills as a consequence of never having flown a manned aircraft. Therefore, the mishap rate for the U.S. Army's MALE UAV is higher. In other words, any savings of time and money realized from the shorter and less comprehensive training are eroded by of the high dollar value coming from the mishaps that occurred.

Reviewing the different approaches to MALE UAV operator training in the U.S. Armed Forces, and the three different training models analyzed in this thesis, I have tried to employ the CBA framework as a guide for the Indonesian Navy in making its policy decisions. Nevertheless, it is still difficult to calculate the total net benefits of these policies because several factors, such as recruitment, attrition, and retention issues, are difficult to quantify and monetize. As shown by literature review in Chapter II, based on the experience of the U.S. Armed Forces, each COA has unique characteristics in the tradeoffs between the quality and quantity of MALE UAV operators. For example, COA 3 has been proven by the U.S. Air Force during the transition phase of MALE UAVs entering military service. Producing a MALE UAV operator with COA 3 takes too much time and costs too much money; therefore, it creates manpower shortfall. By switching to COA 2, the U.S. Air Force effectively addressed those problems. On the other hand, the U.S. Army, which opted for a shorter training period and lower budget, proved that manned aircraft flight training is not always necessary for MALE UAV operators, even though this policy decision led to the highest mishap rate of the three COAs. Based on these findings, I can make short-term recommendations to be executed soon. For the longer term, I recommend studying the correlation between operator proficiency and the duration of manned aircraft flight training needed. Those two recommendations would be sufficient for establishing a policy to produce enough MALE UAV operators in the Indonesian Navy.

B. SHORT-TERM RECOMMENDATION

To speed up the acquisition of MALE UAV operators, I recommend the Indonesian Navy adopt COA 2. The Indonesian Navy Aviation Squadron should assign Small UAV ScanEagle operators to go to 40 hours of manned aircraft flight training and then proceed to MALE UAV operator training. As shown in Chapter II, the experience of operating of Small UAVs is one of the requirements for MALE UAV operators (Qi et al., 2018). Thus, the ScanEagle operator already fits this recommended requirement. However, this group of people has never flown a manned aircraft, so they need such additional training to meet the follow-on requirements. This decision, however, should only be a temporary policy to respond to the surge in demand for MALE UAV operators.

Unfortunately, because the historical data for each COA in this study comes from different periods, the comparison of COAs may not be entirely accurate or robust. For example, the COA 3 data is based on fiscal years 2008–2012. Meanwhile, COA 2 data is based on fiscal years 2013–2017, and COA 3 data is based on fiscal years 2018–2022. It would be better to have real data that runs on the same timeframe. For example, the Indonesian Navy could utilize its own mishap rate for five consecutive fiscal years with the three categories of operators. As the next section explains, a long–term policy is needed and should be able to tackle this issue.

C. LONG-TERM RECOMMENDATION

This thesis is a preliminary study and should be followed by another stage of research. Currently, the Indonesian Navy does not have any MALE UAV operators; so, it is impossible to get any data on their performance. Using the historical data from the U.S. Armed Forces is not a perfect match for the Indonesian Navy setting in the long term. After the Indonesian government purchases the MALE UAV, I recommend the Indonesian Navy conduct trials to measure the efficacy of manned aircraft flight training for MALE UAV operator performance.

My recommendation is for the Indonesian Navy to replicate a study on the proficiency of the Surface Warfare Officer community. This study was done by Cunha and Dearth (2019) to measure the correlation between proficiency and different trainings. The study's method could be also applied to measure MALE UAV operator proficiency.

The cleanest way to measure the efficacy of different training approaches would be to use a randomized controlled trial, which entails randomly assigning student operators to take the training associated with the various COAs I outlined previously. The benefits of randomization are that it helps minimize selection bias and ensures that the groups being compared are as similar as possible at the start of the study. This allows for a more accurate assessment of the training approaches' effects on operator performance, as any differences observed can be attributed to the training itself rather than pre-existing differences between the groups. Additionally, randomization enhances the generalizability of the study's findings to a broader population, as the randomly assigned groups are likely to be representative of the larger population of operators. This rigorous approach contributes to the robustness and validity of the study's conclusions.

Nevertheless, the feasibility of implementing a randomized controlled trial in this context warrants careful consideration. Carrying out such a trial requires significant resources in terms of personnel, time, and funding. The research team would need to include experts in the field of UAV operations, training methodologies, and research design. They would be responsible for designing the study, implementing the randomization process, overseeing the training interventions, collecting data, and analyzing the results.

The timeframe for conducting a randomized controlled trial can vary depending on the complexity of the study design, the number of participants involved, and the duration of the training interventions. It may involve several months or even years to gather comprehensive and meaningful data, especially if long-term effects of the training approaches are of interest.

Efforts would also need to be directed towards ensuring ethical considerations, participant recruitment, and obtaining informed consent. The availability of suitable training facilities, resources, and cooperation from the student operators and their respective institutions would play a crucial role in the feasibility of the trial.

In terms of financial investment, conducting a randomized controlled trial demands budget allocations for research personnel, participant compensation, data collection tools, equipment, data analysis software, and potentially compensating for any disruptions caused to normal training schedules.

For such a trial, I recommend the grouping of test subjects as follows: a control group of operators who do not take any hours of manned aircraft flight training, a second group of operators who record 40 hours of in-cockpit flight, and a third group of operators who record 250 hours of manned aircraft flight training.

Further, I propose structuring the test subjects into distinct treatment arms to systematically investigate the effects of different training approaches. These treatment arms encompass:

- Control Group (0 Hours of Manned Aircraft Flight Training): This group of operators will not undergo any manned aircraft flight training. Their performance will serve as a baseline against which the effects of the other training approaches can be measured.

- Treatment Group A (40 Hours of In-Cockpit Flight): The second group of operators will engage in 40 hours of in-cockpit flight training. This training will provide them with hands-on experience within the aircraft, familiarizing them with operational aspects and potential challenges that arise during flight.

- Treatment Group B (250 Hours of Manned Aircraft Training): The third group will undergo an extensive 250 hours of manned aircraft flight training. This immersive training regimen aims to cultivate advanced piloting skills, comprehensive situational awareness, and proficiency in managing complex aerial scenarios.

Each treatment arm embodies a distinct level of exposure to manned aircraft training, enabling a nuanced evaluation of the impact of training intensity on operator performance. The progression from no training to varying degrees of hands-on experience seeks to illuminate the correlations between training depth and operator proficiency, yielding insights crucial for formulating effective training paradigms.

The data necessary to study the impacts of these different training approaches will be collected in three ways. First, students will complete a survey to collect data on their self-reported proficiency as UAV operators. Recommended survey questions for such a future study are provided in Appendix A.

The rationale behind the survey questions and their significance are carefully aligned with the study's objectives. The initial question seeks to establish a foundational understanding of participants' previous experience in piloting manned aircraft. This serves as a critical baseline against which the efficacy of distinct training approaches can be evaluated, allowing for a comparative analysis of their impact.

The subsequent inquiry—comprising the second and third questions—focuses on gathering data pertaining to participants' certifications and ratings. This insightful data sheds light on their broader aviation background and qualifications, enriching the contextual understanding of their profiles.

A crucial aspect, encapsulated in the fourth question, pertains to participants' current knowledge levels. This provides valuable insight into their grasp of essential aviation concepts and operational procedures, serving as a crucial variable in the evaluation of training effectiveness.

Moving to questions five and six, the survey delves into participants' comfort levels concerning specific automated flight operations. These responses offer a tangible indication of the training approaches' influence on enhancing confidence in navigating advanced automation systems.

Moreover, the seventh question probes participants' capacity to identify sensor flight failures, thereby underscoring the degree to which training cultivates situational awareness, a pivotal attribute in MALE UAV operations.

The final question explores participants' perceived competence in executing emergency procedures, affording insights into their preparedness for unforeseen circumstances—a pivotal facet in safety-conscious training.

The holistic design of these survey questions collectively serves to evaluate a multifaceted spectrum of participant attributes, ranging from their aviation background to their comfort with automation and emergency management. The culmination of participant responses ultimately facilitates a comprehensive appraisal of the training approaches' efficacy in enhancing operator knowledge and performance. This meticulously curated dataset constitutes a valuable resource in generating insightful conclusions that guide the study's findings.

The second data collection method involves a written proficiency test, aimed at assessing the skill level of participants. The proficiency checklist, presented in Appendix B, outlines a comprehensive set of tasks required of MALE UAV operators. These tasks span various operational categories, such as mission preparation, communication, aircraft operations, air operation, before-flight procedures, contact maneuvers, instrument procedures, navigation, and emergency responses.

The checklist's recommendations stem from the BUQ Level 4 as per CJCSI 3255.01 CH1, dated October 31, 2011. The tasks encompass a wide spectrum of competencies, including knowledge of aviation weather, aircraft performance, communication planning, navigation procedures, recognizing and responding to emergency conditions, as well as post-flight checks and safety protocols.

The detailed nature of the checklist ensures a comprehensive evaluation of operator proficiency across diverse operational scenarios. It encompasses aspects like aircraft control, navigation, communication, emergency handling, and more. The utilization of such a structured checklist is pivotal in capturing a holistic representation of operator capabilities, ultimately contributing to a comprehensive understanding of the training approaches' effectiveness.

The third set of data comes from students being evaluated by a senior subject matter expert in a MALE UAV simulator. For example, the tester runs some scenarios such as basic take-off, landing, enroute, mission, degraded equipment, and emergency scenario, as shown in Appendix C. The performance of each student is recorded and quantified. Then, the result of training could be analyzed as an indicator of outcome training, which is operator quality.

Using these datasets, the future researcher can compare the various metrics of operator knowledge and performance in order to make a more holistic recommendation concerning the optimal training model for MALE UAV operators in the Indonesian Navy. This approach ensures that the comparison between different training approaches is unbiased and that any observed differences can be confidently attributed to the training interventions rather than inherent variations among the groups. This methodological rigor enhances the validity and reliability of the study's findings, bolstering the foundation upon which the final recommendation is based.

APPENDIX A. SURVEY QUESTIONS FOR FOLLOW-ON STUDY

Fill in the box that closely applies:

1. How many hours have you been flying on manned aircraft?

☐0 hours ☐40 hours ☐250 hours

2. What is your current certification?

☐Small UAV Remote Pilot ☐Private Pilot ☐Commercial Pilot

3. What is your current rating?

☐Single Engine ☐Instrument Rating ☐Multi Engine

4. What is your current knowledge level?

☐Small UAV Remote Pilot Knowledge ☐Private Pilot Knowledge ☐Commercial Pilot Knowledge ☐Instrument Rating Knowledge

5. I feel comfortable operating the automatic take-off/ landing to its fullest extent in congested air traffic?

☐ Yes ☐ No

6. I feel comfortable operating the point and click navigation to its fullest extent in congested air traffic?

☐ Yes ☐ No

7. I feel confident to spot an issue with sensor flight failure?

☐ Yes ☐ No

8. I feel confident executing emergency procedure?

☐ Yes ☐ No

9. I feel comfortable recognizing a stall?

☐ Yes ☐ No

10. I feel confident recovering the UAV from a stall?

☐ Yes ☐ No

11. Do you feel confident when making a radio call to an Air Traffic Controller?

☐ Yes ☐ No

APPENDIX B. PROFICIENCY CHECKLIST BASED ON BUQ LEVEL 4 PER CJCSI 3255.01 CH1 31 OCTOBER 2011

Tasks required for MALE UAV operators are acquired from Basic Unmanned Qualification (BUQ) Level 4 (CJCS, 2011).

1. MISSION PREPARATION
    a. Aviation Weather
    b. Aircraft Performance Data and Limitations
    c. Crew Resource Management and Communications
    d. Publication
    e. Emergency Equipment/ In Flight Emergency Procedures
    f. Departure and Arrival Planning
    g. Flight Checklists and Use
    h. Computerized Flight Planning Systems
    i. Charts-Sectional, Tactical, and Global
    j. Mission Route Selection & Analysis
    k. International Civil Aviation Organization (ICAO)/ Flight Information Publications Procedures
    l. Global flight operation knowledge
2. COMMUNICATION
    a. Communication Planning and Management
    b. Data Links
    c. Knowledge of Airborne Communications System
    d. Satellite Communications (SATCOM)
3. AIRCRAFT OPERATIONS
    a. Weather Hazard
    b. Basic Manual Navigation
    c. General Flight Rules
    d. Low Level Flying
    e. Fuel Planning
    f. Aircraft Systems and Directives
    g. Integrated Navigation Systems
    h. Emergency Procedures
    i. Aviation Principles
    j. Manual Flight Control Skills
    k. Time & Course Control
    l. Air Tasking Order (ATO)
    m. Radio Aid Navigation

n. Radar Navigation/Fixing
o. Basic Instrument Flight
p. Basic Instrument Flight Procedures
q. Global Navigation Procedures

4. AIR OPERATION
    a. Search and Rescue (SAR)
5. BEFORE FLIGHT CATEGORY
    a. VFR mission planning
    b. Exterior inspection checks
    c. Weather data for mission planning
    d. Verbal communication/ radio procedures
    e. Map preparation for use during flight
    f. GPS position checks
    g. Route planning to destination & alternates
    h. Pre-flight clearances
    i. En route altitudes as required
    j. Ground Control Station (GCS) instrument checks
    k. Pre-flight checks
    l. Before launch/takeoff checks
    m. Maintenance logs
    n. Compute takeoff and landing data
    o. Clearance to taxi
    p. Local VFR flight clearance
    q. Clearance for takeoff
    r. Ground speed
    s. Taxiing to runway
    t. Filing DD 175/ICAO 1801 (Flight Plan)
    u. Taxiing into takeoff position
    v. Interior inspection check
    w. Line up checks, Engine start checks
    x. Before taxi check
    y. Operation of navigation systems
    z. Basic Instrument Flight Rules (IFR) mission planning
    aa. Operation of Air Traffic Surveillance Equipment (Identification, Friend or Foe (IFF)/Selective Identification Feature (SIF)/Traffic Collision Avoidance System (TCAS)/Sense and Avoid Sensors)
6. CONTACT CATEGORY
    a. Recognize departure and recovery procedures
    b. Controlling Rate of Descent
    c. Appropriate climb airspeed

d. Use of local area map for orientation
e. Establishing and maintaining altitude
f. Applicable in-flight checks
g. Turns, climbs, descents, as required
h. Approach to field checks
i. Level off/routine checks
j. Basic aero maneuvers
k. Basic area orientation
l. Before descent checks
m. Current wind conditions
n. Automatic approach & landing
o. Approach to landing/recovery
p. Go-around/wave-off on final approach turn
q. Landing/recovery and applicable rollout procedures
r. Airspeed change, straight-and-level as required
s. Go-around/missed approach checks
t. Go-around from final approach/flare
u. Post landing checks & procedures
v. GCS safety procedures
w. Flight line and air discipline
x. Normal traffic pattern
y. Final approach procedures
z. Traffic pattern deconfliction
aa. Launch/Takeoff, initial climb & associated checks
bb. Clearing airspace in direction of turn
cc. Maneuvering withing assigned airspace
dd. Aircraft configuration : Pre-landing checks
ee. Airmanship. judgment, & decision-making in aircraft (CS-situational awareness.
ff. Stalls and recovery procedures
gg. Altitude/attitude control throughout flight
hh. Appropriate climb per manuals
ii. Requesting and receiving landing clearance
jj. Basic departure procedures
kk. Local breakout procedures
ll. Levelling off from climb
mm. Closed pattern
nn. Normal overhead patterns

7. INSTRUMENT CATEGORY
    a. Partial panel instrument flight

b. Aircraft maneuvers under instrument conditions
c. Recognition of improper nose low condition
d. Course, rate, and angle of intercept
e. Recognition and recovery from unusual attitudes under instrument conditions
f. Operation of aircraft instruments and navigation equipment
g. Hazardous/adverse weather conditions in flight
h. Weather phenomena which affect flight
i. Establishing and maintaining constant altitude, airspeed, and heading during instrument flight
j. Auto/instrument takeoff, climb, & departure procedures
k. Departing a holding pattern
l. Instrument cross check
m. Procedure turns
n. Intercepting a heading at a predetermined angle
o. Transitioning from Minimum Descent Altitude (MDA) to runway
p. Establishing and maintaining appropriate heading
q. ATC/approach control clearances
r. Determination of lead point
s. Standard instrument approach plate procedures
t. Course interception
u. Procedure turn airspace
v. IFR navigation
w. En route descents
x. Fix-to-fix navigation
y. Appropriate landing configuration
z. Maintaining selected course with wind correction
aa. Descent gradients
bb. Knowledge of establishing arc
cc. Instrument Meteorological Conditions (IMC) penetration
dd. Arc interception
ee. ATC clearances and procedures
ff. Arc maintenance
gg. Radial interception from arc
hh. Remaining within cleared airspace
ii. Holding/loitering
jj. Controlling Rate of descent
kk. Understanding holding instruction
ll. Instrument approach procedures
mm. Holding pattern entry

nn. Radar patterns
oo. Maintaining position within holding pattern airspace following Ground Controlled Approach (GCA) controller's direction
pp. Wind analysis in holding pattern airspace
qq. Turning to directed headings
rr. Maintaining directed altitudes
ss. Glide slope control
tt. Maintaining proper airspace
uu. Course control
vv. Establishing proper holding configuration
ww. Transitioning from instruments to visual references
xx. Precision radar approach
yy. Visual Descent Point (VDP)
zz. Non-precision radar approach
aaa. Circling approach procedures
bbb. Gyro-out instrument pattern
ccc. Missed approach procedures
ddd. Half-standard rate turns on final
eee. ATC missed approach clearances
fff. Gyro-out precision radar approach
ggg. Missed approach checks
hhh. Correction to aircraft heading
iii. Transitioning from glide path to runway
jjj. In-flight IFR clearance

8. NAVIGATION CATEGORY
    a. Visual navigation
    b. Correlation of aircraft position with map
    c. Map reading
    d. Calculation of actual fuel assumption
    e. Using visual landmarks in flight planning
    f. In-flight navigation planning
    g. Calculation/ compensation for in flight winds
    h. Time and fuel management
    i. Calculation of new Estimated Time of Arrival (ETA)
    j. Lost communication/Command and Control (C2) link procedures
    k. Position reporting
    l. Usage of Pilot to Metro Service (PMSV) and Air Traffic Information Service (ATIS), and Pilot Report (PIREP)
    m. In-flight clearances
    n. Interpretation of radio weather condition report

o. Dead reckoning navigation
p. Navigation diversions based on weather reports
q. Actual and planned rate of fuel consumption
r. Comparing actual and planned groundspeeds
s. Unfamiliar field departure procedures
t. Low level navigation
u. Unfamiliar field visual and basic instrument approach procedures

9. EMERGENCY CATEGORY
   a. Emergency conditions
   b. Analyzing current situation, including systems for possible emergency
   c. Aircraft control during emergency conditions
   d. Recognition of applicable emergency procedures
   e. Communication/declaration of an emergency (if required)
   f. Recognition and proper response to unplanned lost C2 link events
   g. Land as soon as conditions permit
   h. Unusual attitudes and recovery techniques
10. AFTER FLIGHT CATEGORY
   a. After landing checks
   b. Completion of flight time logs
   c. Engine shutdown checks
   d. Completion of maintenance logs
   e. All safety procedures for securing aircraft
   f. Post landing procedures
   g. Taxiing clear of runway
   h. Closing a flight plan with ATC
   i. Taxiing to parking

APPENDIX C. SIMULATOR SCENARIO FOR FUTURE STUDY

- Mission Planning: student conducts mission planning task based on request from the operation order.
- Pre-flight procedure: student performs pre- flight procedures and makes a go or no-go decision.
- Take off: student performs take-off procedure under several circumstances such as normal conditions, cross wind condition, no wind condition, or abort take-off scenario.
- Enroute: student conducts departure from base into mission area safely while communicating with air traffic controller.
- Mission: student achieves mission successfully.
- Landing: student performs landing procedure under several circumstances such as normal conditions, cross wind condition, no wind condition, wave off, turn around, or heavy fuel load condition.
- Degraded equipment: student maintains the flight during one or more equipment failures such as GPS failure, lost uplink, lost downlink, lost video, or stuck throttle.
- Emergency scenario: student must be able to aviate, navigate, and communicate during adverse situations such as engine shutdown, lost link, carburetor icing, etc.
- Hand over: student conducts hand over from current operating GCS to receiving control GCS or vice versa.

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