เอกสารวิจัยส่วนบุคคล

เรื่อง

EFFECTIVE EMPLOYMENT OF UNMANNED AERIAL SYSTEMS
IN STRIKE ROLE

โดย

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CERTIFICATE

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ABSTRACT

RESEARCH TOPIC	EFFECTIVE EMPLOYMENT OF UNMANNED AERIAL SYSTEMS IN STRIKE ROLE
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This research paper explores the effective employment of Unmanned Aerial Systems (UAS) in military strike operations. It aims to identify key considerations for UAS utilization, assess their present capabilities and limitations, and propose a methodology for selecting suitable UAS platforms for specific missions.

Using qualitative and quantitative research methods, the paper conducts a comprehensive analysis of military documents, research articles, and online resources to identify factors influencing UAS employment in strike roles. Paired comparison analysis evaluates UAS strengths and weaknesses, while the Analytic Hierarchy Process (AHP) determines the most appropriate platform for different strike roles.

Findings highlight essential employment considerations, including combat availability, survivability, effectiveness, integration, and cost. Factors such as portability, flexibility in altitude, payload carriage, and data linking capabilities are identified as crucial. However, current UAS capabilities are inadequate in terms of combat survivability, effectiveness, and integration. Overcoming these limitations, with space and weight constraints, poses challenges. To address platform selection, an AHP graph comparison methodology is proposed. By comparing AHP graphs of UAS platforms with specific strike roles, the most suitable platform can be identified.

This research provides insights for military strategists and decision-makers. The identified considerations, limitations, and proposed methodology inform UAS deployment and optimization in strike operations. Further research is recommended to explore advancements in technology and innovative solutions that can enhance UAS capabilities for effective employment in strike roles

FOREWORD

It is with great pleasure and a sense of accomplishment that I present this research paper on the effective employment of Unmanned Aerial Systems (UAS) in strike roles. Throughout my journey in exploring this topic, I have come to appreciate the significance of UAS in modern warfare and the potential they hold in enhancing military capabilities.

This research paper represents the culmination of extensive efforts and countless hours dedicated to understanding the intricacies of UAS utilization in strike roles. By employing a combination of qualitative and quantitative research methodologies, I aimed to provide comprehensive insights and practical guidance for military strategists and decision-makers.

The findings of this research shed light on essential employment considerations, such as combat availability, survivability, effectiveness, integration, and cost. These considerations provide a comprehensive framework for assessing UAS capabilities and formulating strategies for their optimal deployment. Additionally, the research highlights the challenges faced in terms of combat survivability, effectiveness, and integration, calling for innovative solutions to overcome these limitations.

It is my sincerest hope that this research paper serves as a valuable resource for fellow researchers, military professionals, and all those involved in the advancement of UAS utilization in strike roles. I firmly believe that by continuing to explore technological advancements and innovative solutions, we can unlock the full potential of UAS and further enhance its effectiveness in modern warfare.

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Squadron Leader
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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTD.)

LIST OF TABLES

List of Figures

CHAPTER-1

INTRODUCTION

1. Importance and Origin of research

The Gulf wars are often credited by Air Power practitioners for shaping many of the modern Air Power tenets. Versatility, flexibility, and sensitivity to technology were the guiding principles to victory. These lessons have been assimilated by Air Forces across the world and reflected in their doctrines and capability upgrades. One of the technological advancements that gained popularity during the Gulf Wars was the use of Unmanned Aerial Systems (UAS). The impressive performance displayed by UAS in the Iraq and Afghanistan conflicts, where UAS were used in intelligence, surveillance, and reconnaissance (ISR) missions, target acquisition, and precision strikes paved way for UAS to become an integral part of modern warfare. The demand for the game changing technology was so high that the global spending on defence drones increased by 36 %.(Divis, 2018).

The ongoing war between Russia and Ukraine is unique; it involves two sides having similar weapon technologies and comparable levels of committed forces. Reports from the ongoing Russia-Ukraine war suggests that Russian Air Force has lost more than 60 aircraft in strike and close Air support role until November 2022. (Vakulyuk, 2022). This high attrition of fighter aircraft is a result of increasing battle fatigue, degraded Situational Awareness of the pilots coupled with very effective Air Defence systems protecting the surface elements. (Kaonga, 2022). The high attrition of aircraft has resulted in rapid proliferation of UAS. With the growing prevalence of Integrated Air Defence systems and risks posed to pilots, the use of UAS has become an attractive option to militaries.

Although unmanned aircraft systems were quickly acquired for urgent operational needs, the development of operational doctrine to guide their use did not keep up with the pace of technological advancements and tactical developments. (Axe, 2022). In other words, there was a lack of strategic planning in effectively and efficiently employing unmanned aircraft systems in various operational contexts. This lack of understanding on the effective employment considerations resulted in increasing vulnerabilities of UAS particularly in combat environments with multi range air defense systems and electronic warfare assets. (Borsari, 2022).

The research on effective employment considerations of Unmanned Aerial Systems (UAS) in strike roles can reduce the attrition rates of both UAS and traditional aircraft and increasing mission success rates. Furthermore, as UAS and Counter UAS (CUAS) technology advances, understanding true capabilities and limitations of UAS becomes increasingly important. Ultimately, the research on effective employment considerations of UAS in strike roles can have a significant impact on the success of military operations and the safety of personnel on the battlefield.

2. Research Objectives

The research objective is to identify effective employment considerations, understand the capabilities and limitations of UAS towards employment in strike roles and develop a methodology to identify suitable platform for various missions in strike role.

3. Research Questions

3.1 What are the effective UAS employment considerations?
3.2 Are UAS capable enough to handle strike roles?
3.3 How do we identify suitable UAS platform for a particular strike mission?

4. Scope of Research

The scope of the research will be restricted to UAS employment against or in support of land forces only. Miniature UAS systems not capable of carrying out strike missions are exempted from the scope of the research.

5. Research Methodology

A combination of Qualitative and Quantitative research methodologies has been utilized for the research. Initially, content analysis of military documents, research articles, articles in journals and online resources was carried out to understand the current UAS employment considerations and identify the factors effecting employment in strike role. Subsequently, paired comparison analysis was carried out to understand the capabilities and limitations of UAS and finally, Analytic Hierarchy Process (AHP) was used to identify the best UAS platform for specific strike roles.

6. Expected benefits

Potential benefits of the research to the Air Force are: -

6.1 Reduction in manned and unmanned aircraft attrition to enemy air defense systems.

6.2 Reduction in training and equipment costs involved in maintaining certain capabilities.

6.2 Developing capability to identify suitable platform for a specific role.

6.3 Developing capability to procure or design UAS platforms most suitable to the expected combat scenario.

6.4 Improve the overall mission success rates by providing realistic training environment and better understanding of own and adversary asset capabilities.

7. Definitions of terminology

7.1 UAS- Unmanned Aerial Systems: Aerial systems capable of flight and mission accomplishment without a human presence on board, for example, drone, Remotely Piloted Aircraft (RPA), Loitering munitions, etc.

7.2 CUAS- Counter Unmanned Aerial Systems: Systems designed to target the UAS systems by restricting or prohibiting UAS employment in a desired area. These systems could be either hard kill or soft kill variety. Examples are GPS spoofers /jammers, command link jammers, Directed Energy Weapons (DEW), etc.

7.3 Strike- Use of aircraft to deliver offensive firepower against a specific target, such as enemy troops, equipment, or infrastructure. Strikes can be conducted by a variety of aircraft, including fighter jets, bombers, and attack helicopters, and can involve a range of munitions, such as bombs, missiles, and rockets.

8. Conceptual framework

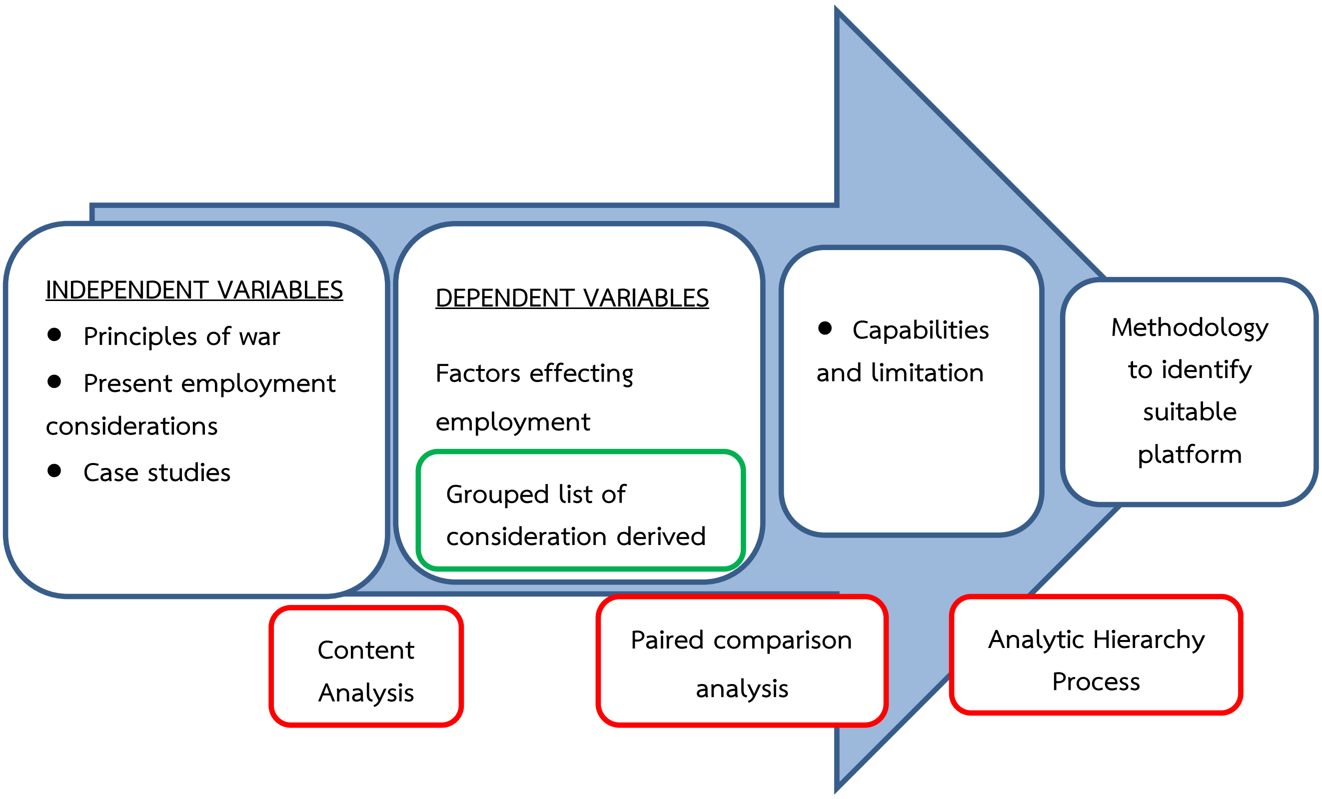


Figure 1-1 Conceptual Framework

CHAPTER-2

LITERATURE REVIEW

This literature review aims to examine the current state of UAS employment considerations in the strike role and identify the key elements that contribute to their effectiveness. The review will consider a range of sources, including academic literature, news articles and government reports to gain a comprehensive understanding of the field's current state and shortcomings. The review will examine various contributing factors for effective employment of UAS in strike role and the challenges associated with their employment.

1. Strike.

Some of the roles employing airpower to deliver offensive firepower are in Air Land operations and Conventional Air operations, the operations and their respective roles are explained below.

1.1 Air land Operations.

The Indian Air Force doctrine, defines Air Land operations as operations which involve all air operations in cooperation with own and friendly land forces to deter, contain, neutralise, or defeat the enemy's land forces. The doctrine further emphasizes that, Air land operations are not associated with a particular type of aircraft or weapon system. In practice a variety of airpower assets conduct counter land operations to deliver lethal and nonlethal effects against enemy land forces and infrastructure. Counter-land operations are divided into the following types: -

1.1.1 Air Interdiction (AI). Operations designed to destroy, neutralize or delay the enemy's reinforcements, supplies, or strategic military potential before it is effectively brought to bear in the battlefield. These operations isolate the enemy forces in the battle zone and restrict his freedom of maneuver. The effects of Air Interdiction are cumulative, and these operations must continue to degrade the war fighting capacity of the enemy's land forces.

1.1.2 Battlefield Air Strike (BAS). Air actions conducted against enemy targets in the close vicinity of own ground forces. These require not only joint planning but close coordination with the fire plan, disposition and movement of own forces, and Integrated Air Defense operations. BAS maybe time sensitive. Target acquisition, identification, enemy AD threat, jamming of communication, and the possibility of fratricide are some limitations in BAS environment.

1.2 Conventional Air Operations.

These operations consist of Strategic Bombing, Political Signaling and Psychological Operations. Among the above-mentioned roles Strategic Bombing only qualifies as offensive use. Strategic Bombing is designed to target the enemy's capability to fight or his will to resist.

To summarize, strike operations can be grouped into three major roles. Air Interdiction (AI), Battle field Air Strikes (BAS), and Strategic Bombing. Since, these operations are inherently risky; UAS can be employed in these operations to aid in risk mitigation.

2. Present UAS employment considerations

In order to understand the employment considerations of UAS, the documents titled: Strategic concept of employment for UAS in NATO and Joint doctrine publication 0-30.2 Unmanned Aerial Systems of the United Kingdom were referred. The classification of UAS is attached as Table A-1 in Appendix A.

To summarize the employment doctrines, it is important to understand that, many of the UAS employment considerations are similar to that of manned aerial assets employment considerations. The additional specific considerations for UAS are: -

2.1 Robust data link.

Unmanned Aerial Systems depend on a constant stream of communications to effectively finish each mission; any degradation of the link means mission failure and at times loss of the aerial asset. Thus, it is crucial to defend communications security, and more specifically bandwidth, from both unintentional friendly interference and hostile activity.

2.2 Flight planning considerations.

If very long remotely piloted aircraft missions occur during numerous unconfirmed and non-promulgated air planning cycles, such as the ATO, coordination problems may result. It is paramount that the central planning agency gives due attention to the lengthy operating timelines of UAS.

2.3 Emergency planning.

Planning for lost-link occurrences requires thorough contingency measures. It should outline what should be done in the event of broken sensor links, broken control links, and lost GPS-derived position, navigation, and timing signals that could be necessary for the aircraft to operate. Consideration should be given to recovery zones held by friendly forces so that delicate equipment or data can be collected after landing if there are no suitable diversion airfields available.

2.4 Battle/Air space coordination.

The Joint Force Commander will need to strictly regulate air battle space management to maximize each aircraft's freedom of operation in complex air scenarios due to the combination of friendly, hostile, and neutral aircraft, both manned and unmanned, as well as any mission limits in place.

2.5 Weather.

Weather at various geographically dispersed locations, including satellite ground stations, the launch and recovery element, enroute transit, and the operating area (including potential diversion airfields and or lost-link recovery areas) must be considered. Furthermore, space weather, including sun activity has to be considered as this affects high frequency, ultra-high frequency, and satellite communication links. Also, availability and precision of the global positioning system has to be considered in the tactical area.

2.6 Deployment pace.

With tactical UAS, the full capability i.e. pilots, sensor operators, image analyzers, and maintainer will deploy forward. There will be a smaller forward logistical footprint for strategic UAS, since only maintenance workers and a launch and recovery element will be present in the theater. The benefit of this is that it lightens the burden on in-theatre life support equipment, enabling quick deployment and redeployment.

The review of both the documents reveals many important employment considerations for UAS. The considerations were designed for UAS operation in free airspace. As the UAS systems start operating in the contested airspace, opposition from various other war fighting machinery is unavoidable. The considerations for combat survival, considerations for employment in counter UAS environment and synergetic utilization along with manned assets need due acknowledgement. As it can be seen in the current Russia – Ukraine war, when Ukraine started utilizing UAS systems without due consideration to the changing CUAS environment, Russian forces were able to take down huge number of UAS utilizing CUAS systems (Axe, 2022).

3. Combat Survivability

In the research by a Naval Postgraduate School (NPS) Master's student, Kine Seng Tham, changes in operating criteria like altitude, speed, improving the situation awareness of the operator, improving the payload performance and improving resistance of the data link to jamming were suggested in order to improve combat survivability of UAS. It is to be noted that a standard "one size fits all" solution to UAS combat survivability is not possible due to wide range of employment options requiring various sizes and capabilities. The combat survivability enhancements are as suggested.

3.1 Operating Altitude.

Operating at altitudes higher than the known threat's engagement capability improves chances of survival. During Desert Storm, Allied aircraft changed their tactics from low-altitude flights and strikes to medium-altitude (10,000 to 20,000 ft) so as to avoid enemy AAA (Perry, 1991). Increasing operating altitudes to 15,000 ft and above keeps the UAS clear of the threat envelope of most of the AAA and short-range SAM systems. The threat from long range SAM systems still persist, even after shifting operation to medium levels. Operating altitude at times would depend on the sensor type, range and cloud cover over the target area. Optical sensors require UAS to fly below cloud cover, increasing the vulnerability to AAA and SAM systems.

3.2 Operating Speed.

The analysis by a Naval Postgraduate School (NPS) Master's student, Kevin McMindes, suggested that a speed of at least 135 kts is required to ensure survivability and survivability will improve appreciably upto about 225 kts. McMindes simulated an UAS performing a reconnaissance mission over a target area defended by air defense units and infantry. The UAS was modeled with various stealth levels, sensor detection ranges, operating altitude, and speed. Although the quoted figures may only be applicable to scenarios studied in McMindes' analysis, his results show that high speeds for a UAS has a positive effect on survivability. However, in scenarios where UAS may counter the threat from fighter aircraft, it is advisable that UAS may drop speed and fly low accompanied by an optimum aspect change that can evade a Pulse Doppler radar thereby increasing the probability of survivability. The capability to operate at low speeds without stalling would also aid in improving UAS survivability.

3.3 Reduce Signature.

The Radar Cross Section (RCS) is one of the factors based on which the likeliness of UAS detection by surveillance radar depends. A lower RCS implies a lower probability of detection; conversely, a higher RCS implies a higher probability of detection. When the Ukrainian Air Force spokesman was asked why Russian Kamikaze drones flying along the Dnipro riverbed during the night could not be shot down, commented that the drones become less visible to the Radar while flying close to the ground (Romanenko, 2023). Hence, reducing Radar signature by using ground clutter or RCS reduction improves the probability of mission achievement for UAS. The RCS of UAS is independent of size, small UAS can have large RCS and large UAS can have small RCS. RCS of UAS depends on the physical geometry and exterior features of the UAS coupled with the electrical properties of the UAS surface. RCS reduction requires modifications in design from the blueprint stage itself. While new UAS can be designed keeping the reduced RCS requirements in mind the already available UAS's RCS can be reduced by utilizing Radar Absorbent Materials (RAM). Apart from Radar signatures; Visual, infrared and acoustic signatures can give away the position of UAS. Existing engines can be replaced with engines that produce less heat, propulsion systems using propellers can be replaced with blades that produce less noise, and camouflage patterns can be applied to the UA to reduce its contrast with the surroundings so as to reduce visual radiations. It is possible to reduce UAS signatures without making any structural modification, neither requiring more power nor space.

3.4 Improving Situational Awareness.

The situational awareness of an operator sitting in the GCS is limited by the sensor's field of view. Unlike a fighter aircraft, the UAS has limited to no warning systems onboard. If the UAS is being tracked by a radar/SAM system, the operator would not know. If the UAS is fired upon by hostile systems the operator would not know. The operator at present takes input from combined ground and air picture and builds his situational awareness. The moment the operator losses contact with the UAS is the moment the operator suspects enemy action in the area. As a result, without warning systems the UAS cannot carry out evasive maneuvers nor can it employ countermeasures. As the UAS are being increasingly employed in contested airspaces with SAM and aerial threat, General Atomics Aeronautical Systems, Inc. (GA-ASI) was forced to equip their B/MQ-9 Reaper Block-5 with a Radar Warning Receiver (RWR) (Eshel, 2017) to improve survivability. Improving the operator's situational awareness thus can improve combat survivability. Situational awareness can be improved by installing warning systems. The warning system can provide sufficient, timely, accurate, and prioritized information on relevant threats. Warning systems include Radar Warning Receiver (RWR) system, Missile Approach Warning Systems (MAWS), and Laser Warning Systems (LWS). The threat warning comparison is attached as Table A-2 in Appendix A.

3.5 Countering Incoming Threats.

During operational employment, UAS will face situations where they will be targeted by adversary's systems. In most of the situations, with enough warning, the UAS can employ evasive manoeuvres and exit the threat area. However, there will be instances in which, exiting from the threat envelope may not be feasible or mission criticality requires the UAS to continue operating in the same area. For such instances employing countermeasures like Chaff, flares, decoys, and EW jammers can significantly improve combat survivability. Employing weapon systems onboard UAS would be an extreme step, however, in Operation Iraqi Freedom, some Predators were armed with Stinger missiles. When a MIG-25 intercepted one of these Predators, both aircraft launched their missiles at each other. The fight ended with the Predator being killed when the MIG's missile found the Predator while the Predator's missile was diverted by the MIG's missile (Krane, 2003). Large UAS can be equipped with A/A Passive missiles together with countermeasures to improve combat survivability.

4. Counter Unmanned Aerial Systems

To combat the threat posed by using UAV systems in a harmful, threatening, or illegal manner, numerous technologies have been created. Several armed forces have previously implemented technology that can be used to locate, recognize, and interact with unmanned systems. These were mainly evolved from systems meant to defend against other aerial threats, such as piloted aircraft, guided missiles, and smaller munitions like direct and indirect fire projectiles. These frequently employ kinetic interceptors, like projectiles or missiles. Kinetic solutions like missiles are too expensive in comparison to the cost of a single UAS, utilization of missile systems like Iron Dome against UAS may be very effective but over an extended period, utilization becomes economically unfeasible. Some more recent innovations which are economically more viable against many UAS over extended periods of conflict are use of directed energy weapons and RF Jammers. (MBDA, 2021).

4.1 Directed Energy.

Joint Chiefs of Staff, Electronic Warfare, Joint Publication 3-13.1 (February 8, 2012), I-16 defines directed energy (DE) as an umbrella term covering technologies that produce concentrated electromagnetic energy and atomic or subatomic particles. A DE weapon is a system using DE primarily to incapacitate damage, disable or destroy enemy equipment, facilities and/or personnel. Directed-energy warfare is military action involving the use of DE weapons, devices and countermeasures to incapacitate, cause direct damage to or destroy adversary equipment, facilities and/or personnel or to determine, exploit, reduce or prevent hostile use of the electromagnetic spectrum through damage, destruction and disruption. It also includes actions taken to protect friendly equipment, facilities and personnel and retain friendly use of the electromagnetic spectrum. With the maturation of DE technology, weaponized DE systems are becoming more prolific and powerful, and a significant subset of the electronic warfare mission area. The graph of effective range versus power output of DE weapons is shown below.

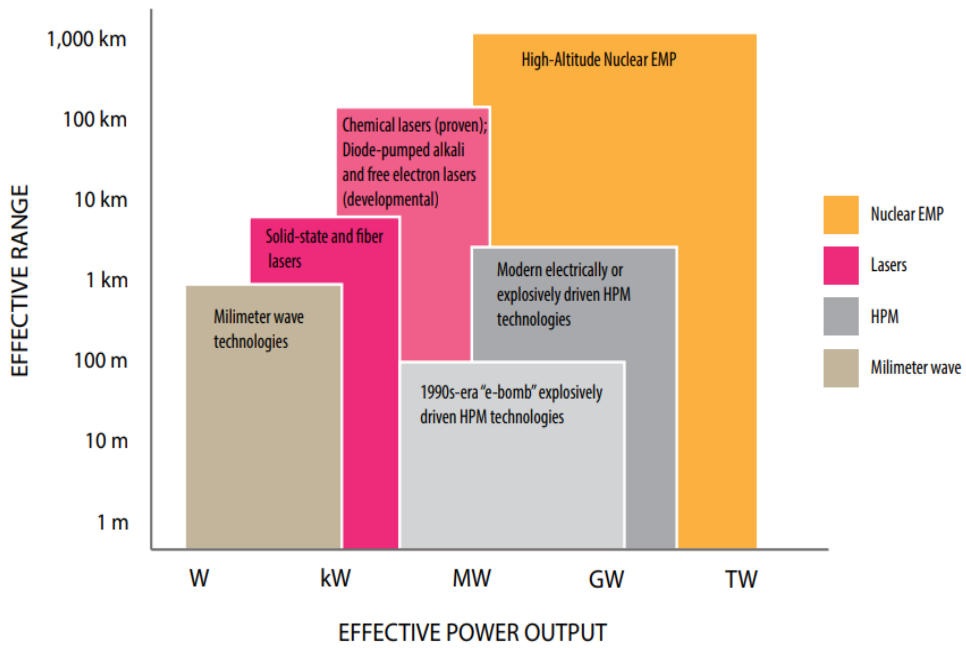


Figure 2-1 Directed Energy weapons effective range versus effective power output

To summarize, directed energy weapons are the future of Anti UAS. With low cost per shot and large magazine capacity DE weapons offer flexibility and resilience over increasing UAS attacks. UASs on the other hand require extensive hardware up gradations to build immunity against DE weapons. These hardware upgrades would increase the overall weight and flight characteristics of UAS. The only feasible method available for UAS to counter DE weapons is to avoid the airspace protected by DE weapons.

4.2 Radio Frequency Jammers.

The use of radio frequency (RF) jammers against unmanned aerial vehicles (UAVs) in combat scenarios can have both advantages and disadvantages. On one hand, RF jammers can disrupt the communication and navigation systems of enemy UAVs, making them difficult or impossible to control. This can provide a tactical advantage by reducing the threat posed by enemy drones, on the other hand, jamming signals can also interfere with friendly UAVs, communication systems, and other electronic devices, which can negatively impact the ability of military forces to communicate, navigate, and carry out their mission.

4.3 GPS jamming and spoofing.

GPS jamming refers to the intentional or unintentional blocking of GPS signals by transmitting high-powered radio signals at the same frequency as GPS signals. GPS spoofing, on the other hand, refers to the intentional manipulation of GPS signals to deceive GPS receivers into providing false information. However, issues of interference with friendly GPS-dependent systems land technical difficulties in countering UAS with redundant navigation systems and GPS receivers remain biggest challenges in employing these systems.

To summarize, Radio frequency jamming, GPS jamming and GPS spoofing have capability to nullify threat from UAS without a hard kill solution. However, the use of such systems in the Tactical Battlefield Area (TBA) is highly unlikely due to their effects on friendly systems. The jamming equipment is best suitable when own forces are not operating in the area. The UAS on the other hand, can include standby inertial navigation systems to cross reference their own position and take corrective actions when the data link gets intercepted or when GPS positioning becomes erratic. Automated terminal weapon guidance using passive modes like digital scene matching or contour reading can mitigate the problems of datalink and GPS jamming. The payload capacity of UAS being limited requires the war-planner to understand the operating environment of UAS and deploy suitable UAS accordingly.

5. Weaponeering and payload

The USAF AFDP-Weaponeering defines weaponeering as the process of determining the quantity of a specific type of kinetic or non-kinetic means required to create a desired effect on a given target. Weaponeering considers such things as the desired effects against the target (both direct weapons effects and indirect desired outcomes, including the second- and third-order effects), target vulnerability, delivery accuracy, damage criteria, and weapon reliability. UAS historically when employed in deliberate strike, were utilized to strike C2 centers, tanks, APCs, convoys, etc. The armament carried by UAS are small caliber but precise. For dynamic targeting the weaponeering by UAS has not always been optimal. For example, in 2001, when designated terrorist Mullah Omar was identified entering a building with his entourage waiting outside, the USAF F16 were ready to strike the building with 2000 Lbs. bombs however, a Predator carrying hellfire missiles was cleared to take on the target. The entourage vehicles were destroyed but Mullah Omar missed. (Woods,2015). The likely reason for missed opportunity could be mismatch between weapon and target.

Payload is defined as device or equipment carried by the UAS, which performs the mission assigned. The useful payload comprises all elements of the air vehicle that are not necessary for flight but are carried for the purpose of fulfilling specific mission objectives. The table showing payload and weapons of various UAS by class is attached as Table A-3 in Appendix A.

To summarize, UAS of class II are only capable of directing artillery fire and designating targets for other platforms. Class III UAS are capable of carrying out strike operations independently. UAS when used in deliberate targeting profile offer an effective weaponeering solution, however, when employed in dynamic targeting profile, may suffer from suboptimal weaponeering solutions owing to restricted type and caliber of weapons. As UAS offer a very good platform for dynamic targeting owing to their long range and high endurance, the weaponeering suboptimal effects can be mitigated to an extent by revisits.

6. Case study of the six-day war

The 1967 Six-Day War was one of the first conflicts in which air power proved crucial for a swift and resounding victory.

Background: Israel and Arab hostilities were at peak in the months preceding the conflict. Israeli shipping was barred from the Straits of Tiran by Egypt, which had also blockaded the Israeli port of Eilat and gathered troops and armored vehicles around the Sinai border. Simultaneously, the Arab world was upgrading their weaponry with cutting-edge military hardware developed in the Soviet Union, such as SAM-2 surface-to-air missiles and MiG-21 fighter jets. Israel keeping a close watch on this development felt threatened.

Airpower Strategy: Israel employed an airpower intensive plan that was initially focused on gaining air superiority and later launching precision strikes on adversary installations. The Israeli Air Force (IAF) utilized fighter aircraft like the Mirage III and the F-4 Phantom and had also developed SEAD/DEAD strategies to counter the SAM-2 missiles. The targets for IAF were Arab airfields, SAM sites, and military installations.

Execution: A preemptive strike on Egyptian airfields on June 5th ensured destruction the majority of the Egyptian air force on the ground. Without aerial interference, Israel was able to conduct more airstrikes against Arab airfields and military installations over the whole region. Additionally, the IAF conducted targeted attacks against SAM facilities, eliminating a large number of the missiles and enabling Israeli aircraft to fly with a fair amount of air superiority.

Impact: The IAF's airpower plan was quite effective and was crucial to obtaining a quick and convincing victory. By the end of the conflict, Israel had shot down more than 400 Arab aircraft while suffering only 26 personal losses. As a result of the IAF's success in eliminating the SAM threat, other air missions were possible.

Lessons learned: The Six-Day War illustrated the importance of airpower in contemporary combat and the efficacy of a carefully planned and executed air operation. As a result of the conflict, air defense systems significantly improved, and Arab nations started acquiring cutting-edge SAMs to fight Israeli air attacks in the future.

7. Case study of the Nagorno-Karabakh conflict of 2020

The conflict of Armenia and Azerbaijan has roots in decades of disagreements over the Nagorno-Karabakh area. The disagreement had previously escalated into several armed confrontations. In the most recent conflict in 2020, airpower was utilised to play a decisive role.

Background: The genesis of the conflict can be traced back to the 1980s when the largely Armenian-populated territory of Nagorno-Karabakh (which was inside Azerbaijan), started demanding independence from Azerbaijan. In the 1990s, the conflict erupted into a full-scale war with Armenia initially occupied Nagorno-Karabakh and its surrounding areas.

Airpower Strategy: Azerbaijan utilized Drones and precision-guided bombs acquired from Turkey and Israel against Armenia in this war. The Azerbaijan Air Force (AAF) intended to attack infrastructure, logistics, and military installations of Armenia.

Execution: In Nagorno-Karabakh and the adjacent areas, the AAF conducted a concentrated air campaign against the Armenian troops. The AAF employed both manned and unmanned aircraft for Surveillance, target acquisition and strike missions. The AAF also employed loitering weapons, popularly known as "suicide drones," which were created to locate and attack targets on their own. The targets were military assets, such as tanks, artillery, and command and control centers.

Impact: The victory of Azerbaijan can be contributed to a large extent to the concentrated aerial operations. The interference from the AAF had seriously hampered the ability of the Armenian military to conduct effective operations.

Lessons Learned: The Nagorno-Karabakh conflict highlighted the role of Unmanned Aerial Systems (UASs) in contemporary combat. Effective targeting and synergy between air and ground operations can be identified as ingredients to successful campaign.

CHAPTER-3

RESEARCH METHODOLOGY

The logical evolution of airpower is reducing the inherent risk to life, while maintaining affectivity in combat roles. In this context, the objective of the research is to analyze the capabilities of UAS towards employment in strike roles and derive effective employment considerations for UAS in the strike role. The research questions are, to find out what are the effective UAS employment considerations, whether UAS is capable to handle strike roles and How do we identify a suitable UAS platform for each strike role.

In order to analyze the capabilities of UAS towards employment in a strike role and derive effective employment considerations, it is paramount to understand the present UAS employment considerations and identify areas restraining UAS's effective employment in combat scenarios. Employment doctrines of various agencies like NATO and the United Kingdom were studied to understand the present employment considerations. In this chapter, the methodology of research types of data sources, documents, and data analysis methodologies are discussed.

1. Research Methodology

A combination of Qualitative and Quantitative research methodologies has been utilized for the research. Initially, content analysis of military documents, research articles, articles in journals, and online resources was carried out to understand the current UAS employment considerations and identify the factors affecting employment in the strike role. Subsequently, paired comparison analysis and Analytic Hierarchy Process (AHP) was utilized to derive effective employment considerations of UAS in strike roles and methodology to identify suitable strike UAS platform. This hybrid methodology aids in not only understanding the current situation better but also helps in developing a tool for military employment based on quantifiable employment considerations.

2. Sources for research

The sources utilized in the research consist of two types of documents. Primary documents are consisting of Indian Air Force doctrine, concepts of employment of UAS in NATO and United Kingdom and secondary documents are consisting of related research papers, conceptual articles in journals, news articles and trade/industry documents. Due diligence had been exercised to maintain balance in appreciating the capabilities and limitations vis-à-vis practical applicability.

3. Analysis tools

Three types of analysis tools were utilized.

3.1 Content analysis.

Based on the research questions, data for analysis is selected, data segregated into categories for analysis and set of rules for coding the data developed. The data coded as per the coding rules and thereafter analyzed.

3.2 Paired comparison analysis.

Analysis used to rate or rank between the options where evaluation criteria are subjective in nature. A paired comparison analysis can evaluate and identify areas of strength and weakness.

3.3 Analytic Hierarchy Process (AHP).

AHP offers a framework for connecting the requirements to the overall objectives. AHP provides the relative weights of each criterion and can help prioritize the collection of requirements. Later on, in the process, these weights help with the decision on which options to use. An AHP process template is shown in the below as Table 3-1. The steps involved in the process are as follows: -

3.3.1 Various considerations are listed in both horizontal and vertical orientation to form a matrix.

3.3.2 A horizontal pairwise comparison is done by assigning a positive integer.

3.3.3 When consideration A is compared with itself, it yields a value of '1'. When consideration A is compared with consideration B based on the intensity of importance of A over B, a value of the integer is arrived upon. Values of 1,3,5,7,9 were utilized for equal, moderate, strong, very strong and extreme importance respectively, while 2,4,6,8 used as intermediate values.

3.3.4 In the template when A is compared with B a value of '3' is assigned. Automatically, the value of horizontal consideration B compared with A becomes '1/3'. When A is compared with C, since C is relatively more important than A, '1/3' is assigned. Automatically, the value of horizontal consideration C compared with A becomes '3'. The process is repeated till all position's values are assigned. Post comparison the geometrical mean of the row is calculated and weightage among the requirements is decided. Geometrical Mean is the mean value signifying the central tendency of the set of numbers by finding the product of their values. The result is converted to a graphical representation for further analysis.

Table 3-1 AHP process template

	Consideration A	Consideration B	Consideration C	Consideration D	Weightage
Consideration A	1	3	1/3	1/5	0.668740305
Consideration B	1/3	1	1/3	1/5	0.386097395
Consideration C	3	3	1	5	2.590020064
Consideration D	5	5	1/5	1	1.495348781

4. Method of Analysis

To analyze the data, three methods of analysis were utilized.

4.1 Content analysis.

Content analysis of Indian Air Force doctrine, documents titled, Strategic concept of employment for UAS in NATO, Joint doctrine publication on Unmanned Aerial Systems of the United Kingdom, documents consisting of related research papers, conceptual articles in journals, news articles and trade/industry documents was carried out to derive the considerations affecting the the employment of UAS in strike role and a grouped list of considerations prepared.

4.2 Paired comparison analysis.

Utilizing the derived considerations, paired comparison analysis between strike aircraft and UAS was carried out to derive the capabilities and limitations of UAS in employment for strike roles. The considerations were listed and each of them was compared with UAS and strike aircraft, the group of considerations where UAS outperformed or matched strike aircraft were the capabilities and the vice-versa were the limitations.

4.3 Analytic Hierarchy Process (AHP).

Based on considerations derived earlier, Analytic Hierarchy Process (AHP) analysis was carried out to identify the weightage of each employment consideration in a particular strike role separately (BAS, AI, and Strategic Bombing). Later, AHP was again carried out to identify employment capabilities weightage of three types of UAS systems (Shaheed, TB-,2 and MQ-9). Finally, a comparison of the results was carried out. Post the three-step analysis of the data, a methodology would be derived which would take into consideration all the effective employment considerations and can assist the planner in effective employment of UAS in AI or BAS or Strategic strike role on case to case basis

CHAPTER-4

RESEARCH ANALYSIS

In this chapter, a comprehensive analysis of the data collected during the study will be presented. The analysis tools and statistical methods used to analyze the data shall be discussed and relationship between various variables examined.

1. Identifying factors affecting employment in strike role

Various employment doctrines on UAS, case studies on the 6-day war and the Nagorno-Karabakh conflict, highlight multiple variables, which are necessary for the effective employment of UAS in strike role. These variables are generally based on the ideas from the founding principles of Air Power. Hence, the elements in the principles of Air Power were considered as Independent variables.

The core principles of Air Power with respect to the context of UAS employment in a strike role are Concentration of Force, Cooperation, Offensive action, Surprise, Security, Maneuver, Economy of effort, Survivability, and Unity of command. The core principles can be further grouped into factors of availability/applicability in combat zone, combat survivability, combat effectiveness, combat integration, procurement and affordability.

The independent variables were further analyzed in context of the doctrines, case studies and combat experiences to draw out the dependent variables. The Independent variables grouped together with the respective dependent variables and their cumulative contributions to the overall employment are as follows: -

1.1 Combat Availability.

This grouping involves all such capabilities that aid in operations remaining adaptable and independent of any dependency. These include portability, sustainability, flexibility, and ease of operations. Portability ensures that the equipment can be quickly moved, launched, and recovered from various locations without relying on large fixed air base support. Sustainability ensures capability to operate with minimal requirement of spares, repairs and maintenance facilities. Flexibility means capability to switch between roles as per the changing combat scenario. Finally, ease of operations refers to capability to carry out operations with the least amount of administrative, maintenance and logistic support. Together these capabilities are critical in ensuring operations are agile, adaptable and effective.

1.2 Combat survivability.

This grouping involves all such capabilities that aid in improving the survival chances of the aerial asset in a hostile environment. It includes capabilities to operate with varying altitudes and speeds, allowing the aerial platform to quickly vacate a threat area. Maintaining low detection is critical in avoiding detection by hostile forces and reducing the risk of a possible attack. Situational awareness of the combat environment not only provides intelligence to stay away from threat zones but also aids in making decisions based on calculated risks. Finally, the capability to address the threats arising in the hostile area, whether through defensive measures like the use of countermeasures dispensation systems or through offensive measures like air-to-air missile launch is essential to improve the survival chances of the aerial platform.

1.3 Combat effectiveness.

This grouping involves all the capabilities that aid in projecting combat force with precision. It includes capabilities to operate with a large radius of action (range) with a large amount of endurance. Additionally, the capability to carry a large amount and variety of armaments and sensors which aid in the detection, identification, and destruction of targets is vital for the shock and awe effect. Finally, the capability to operate in high electronic interference environments and environments with counter platform systems like Surface to Air Missiles, Directed Energy Weapons, etc. which is crucial in delivering strikes with precision and reliability.

1.4 Combat integration.

This grouping involves all the capabilities that aid in seamless operations between elements of the entire war machinery. These capabilities would aid in improving the overall battlefield transparency and avoid instances of friendly fire and improve coordination between various elements. These include capabilities to identify either procedurally or electronically (IFF), and capabilities to transfer and accept data

1.5 Affordability.

This grouping involves the financial aspect of costs involved in procurement, training of operations and maintenance manpower and cost of operating the platform. This grouping aids in a nation’s overall capability to sustain tempo of operations over a specified period of time.

2. Capabilities and limitations of UAS

A Grouped list of all the dependent variables which affect the employment of aerial assets in strike role is prepared. Paired comparison analysis between strike aircraft and UAS was carried out against the said considerations. The aim of the analysis is to find out Whether UAS can take on strike roles. Identify the capabilities and limitations of UAS when compared to the traditional strike aircraft. The capabilities were referenced for comparison and the platform with higher capability was given a "✓" mark. In the end, an average weightage multiplied by a factorial of 5 (to round off the results) of each consideration was transposed to a graph, the table is attached in Appendix B as Table B-1 and graph as Figure B-1. The rationale utilized in the comparison in discussed below.

2.1 Combat availability.

UAS have designs that can operate independently of large airfield infrastructure, UAS also have the capability to be transported, launched and recovered from areas very close to conflict zones. However, UAS at present does not have enough flexibility to switch into roles different from those planned. The UAS scored three x "✓" in favor and Strike aircraft scored one x "✓". The results when transposed on to a graph (Figure B-1) show UAS better suitable in this domain than strike aircrafts. Combat availability is a capability of UAS.

2.2 Combat Survivability.

Most of the strike aircraft enjoy advantage of flexibility in operating altitude and speed when compared to UAS systems. Strike aircraft also have well developed situational awareness improvement aids and threat countering capabilities. However, UAS owing to their relatively smaller size and design are less detectable than a strike aircraft. The UAS scored one x "✓" in favor and Strike aircraft scored four x "✓". The results when transposed on to a graph (Figure B-1) show strike aircraft surpassing UAS in this domain. Combat survivability is a limitation of UAS.

2.3 Combat Effectiveness.

Strike aircraft can carry navigation redundancy equipment like inertial navigation systems and additional geo positioning sensors, capability to carry large amount of armament loads gives a huge advantage to strike aircraft over UAS. However, UAS have capability to operate over large ranges with very high endurance. The UAS scored two x "✓" in favor and Strike aircraft scored five x "✓". The results when transposed on to a graph (Figure B-1) show strike aircraft's superior capabilities in comparison with UAS in this domain. Combat effectiveness is a limitation of UAS.

2.4 Combat Integration.

Presently UAS are not well integrated with other elements of war to the required extent. The UAS scored zero x "✓" in favor and Strike aircraft scored two x "✓". The results when transposed on to a graph (Figure B-1) show strike aircraft surpassing UAS in this domain. Combat integration is a major limitation of UAS.

2.5 Affordability.

The overall cost of procurement, training of operations and maintenance manpower and cost of operating the platform is relatively low for UAS. The time required for training manpower for operating an UAS is also considerable low when compared to that of training of pilots. The UAS scored three x "✓" in favor and Strike aircraft scored zero x "✓". The results when transposed on to a graph (Figure B-1) show UAS have advantage over strike aircraft in this domain of affordability.

3. Identifying a suitable platform for the strike role

Strike roles involve Air Interdiction, Battlefield Air Strike, and Strategic Bombing missions. The weightage of the individual considerations which affect UAS employment in strike roles varies as per mission requirements in various strike roles. For example, the weightage to mission survivability is different for a Battlefield Air Strike from that of an Air Interdiction or Strategic Bombing role. Hence a statistical tool was necessary to compare these considerations with one other and derive their inter weightages to identify a suitable platform for each of the three strike roles.

In the course of the research, evaluations for various considerations in the AHP matrix were fed based on case studies, literature reviews, and combat experiences. The AHP matrix for various strike roles is attached as Table C-1 in Appendix C. The resultant graph of AHP is shown in Figure C-1. The rationale behind the evaluation is as follows.

3.1 Battlefield Air Strike.

In BAS role, combat effectiveness is vital for the mission's overall success. The survival and progress of the surface forces is heavily dependent on the mission's success. The importance of effective target engagement is a key decision point in the further progress of battle in that area. However, the degree of calculated risks taken in a BAS role is very high, as the role requires excessive exposure to threats. BAS role also requires operating close to enemy surface forces and own land forces; Hence a high degree of integration is required. Lack of integrations means fratricide in a BAS environment. When the above-said arguments were considered in the AHP evaluations, the resultant graph of BAS (shown in Figure C-1) shows heavy weightage on Combat effectiveness and Combat integration than that of combat survivability and combat availability.

3.2 Air Interdiction.

In AI role, combat survivability and combat effectiveness play an important role in achieving the objectives. The success or failure of an AI mission decides the future course of battle. However, between combat effectiveness and combat survivability, combat effectiveness outweighs combat survivability as AI missions are undertaken taking into consideration the risks and gains. As intelligence about enemy integrated mobile AD system is seldom complete, AI role inherently is attached with a degree of asset attrition. Once an aerial platform reaches target area it becomes a priority that effective target engagement be done. If target is not engaged effectively and a revisit is required, it means addition avoidable risk and attrition. When the above said arguments were considered in the AHP evaluations, the resultant graph of AI (shown in figure-4) shows heavy weightage on Combat effectiveness and Combat survivability than that of combat availability and combat integration.

3.3 Strategic bombing.

In strategic bombing role combat survivability and combat effectiveness play a vital role in overall mission success as the platform is expected to transit deep into enemy airspace and deliver strategic load. The platform requires a capability to identify threats and take evasive/counter actions to mitigate the risks. Combat Integration is a pre-requisite for strategic bombing in order to coordinate attacks, provide support deep inside enemy territory and recover the platform safely. When the above said arguments were considered in the AHP evaluations, the resultant graph of Strategic bombing (shown in Figure C-1) shows heavy weightage on Combat integration, combat effectiveness and Combat survivability than that of combat availability. The results observed are as per the graph in Figure C-1.

AHP for three varieties of UAS has been carried out. The operationally proven UAS varieties that are being currently extensively utilized in the Russia – Ukraine war were selected for the AHP analysis. These UAS systems are the MQ-9 Reaper, Bayraktar TB-2 and Shahed (Turkish drone). Shahed drone is a highly portable UAS with capability to engage targets with reasonable accuracy. However, Shahed is highly susceptible to electronic attacks. The Bayraktar TB-2 on the other hand is a MALE UCAV system capable of operating with satellite communication inputs. TB-2 lacks in proper integration with other war machinery. Finally, the MQ-9 Reaper is a hunter-killer UAV designed for long-endurance, high-altitude missions. The Reaper is highly integrated on datalink with all other systems. However, the dependency on runway strips limits the combat availability domain for Reaper. Using the above mentioned and open source data, AHP analysis of these three drones were carried out. The AHP matrix is attached as Table D-1 in Appendix D, the resultant graph is shown as Figure D-1.

CHAPTER-5

SUMMARY OF RESEARCH RESULTS, DISCUSSION AND RECOMMENDATIONS

In this chapter, a comprehensive analysis of the research findings and the implications of the research are discussed. The chapter also considers the wider context of the research, and highlights the contributions of the study to the sphere of military combat asset procurement and effective employment. The recommendations presented in this chapter are based on the insights gained from the research,

1. Summary of research results

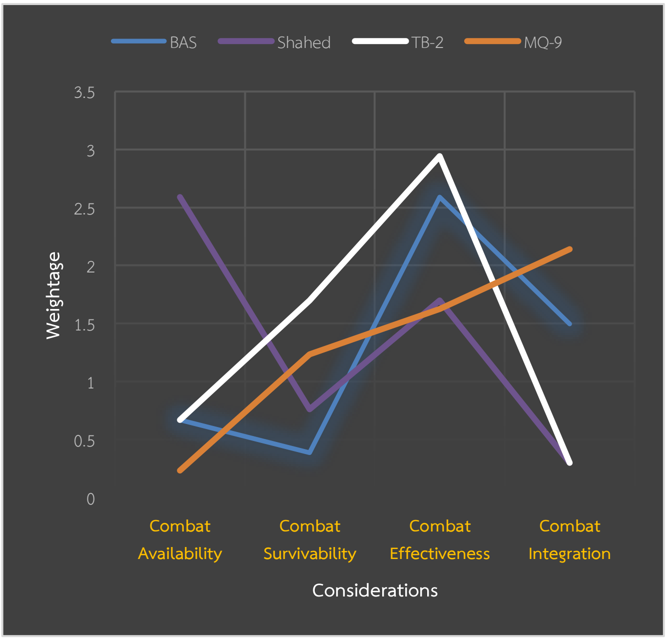
1.1 The first question of the research was to find out what the effective UAS employment considerations were. During the course of research, the effective employment considerations for UAS were identified and can be classified into considerations which affect combat availability, combat survivability, combat effectiveness, combat integrability and finally cost. The individual considerations are shown in the table below.

Table 5-1 Effective employment considerations for UAS in strike roles

Combat Availability	Combat Survivability	Combat Effectiveness	Combat Integration
Portability	Altitude flexibility	Inertial Nav sys	IFF
Sustainability	Speed flexibility	RF protection	Data link
Flexibility	Reduced Detectability	Payload-Sensor	**Affordability**
Ease of operations	Improved Situational Assessment	Payload-Weapon	Procurement cost
	Threat counter ability	Quantity of weapons	Training cost
		Endurance	Operating cost
		Effective Range	

1.2 The second research question was, “Are UAS capable enough to handle strike roles?” At present, UAS are not capable of carrying out strike roles effectively. When compared to strike aircraft, UAS lack in areas of combat survivability, combat effectiveness and combat integration. However, UAS being relatively cheap to procure, train and operate, they can contribute with more numeric strength towards improving their shortcomings in the combat effectiveness domain. UAS's weakness in combat survivability domain, in a dense anti-UAS environment will result in large-scale attrition of UAS in combat, especially against electronic attacks and Directed Energy weapons (DEW). In order to prevail against anti-UAS systems, UAS will require self-protection suites. As the space and load-carrying capability available in a UAS are limited, equipping UAS with self-protection suites whilst maintaining combat effectiveness is a challenge.

1.3 The final research question was, how to identify a suitable UAS platform for a particular strike role. An AHP graph comparison methodology is suggested to identify a suitable UAS. In the AHP graph comparison methodology, the AHP graphs of all varieties of UAS platforms are compared against the AHP graph of a particular strike role. The best shape match among the platforms in the comparison is the best available UAS platform for a particular strike role. The AHP comparison graph for BAS role is shown below as Figure 5-1, the comparison graph for AI and strategic strike role are attached in Appendix E as Figure E-1 and E-2 respectively.



Amongst the UAS platforms, the best suitable platform for BAS role appears to be TB-2.

Figure 5-1 AHP comparison graph for BAS role

2. Discussion

2.1 Importance of the research.

From the research, it can be ascertained that haphazard employment of UAS in strike role is not an alternative to reduce strike aircraft attrition. With counter UAS technologies integrating into the battlefield the attrition levels of UAS is also raising. To effectively employ UAS in strike role there is a requirement to first understand the underlaying employment considerations and then analyze capabilities and limitations. The results of the research identify the effective employment considerations in a strike role, identify the capabilities and limitations of UAS in strike role and suggest a methodology to identify most suitable platform for a particular role. The research identifies a methodology, that can empower the Commander and his staff to convert the previously objective considerations and analytical weightages of various domains of asset employment in combat to a comprehensive statistical model. Such conversion can reduce the decision fatigue on the Commander and provide an employment guidance.

2.2 Relation with other studies.

In the research by a Naval Postgraduate School (NPS) Master's student, Kine Seng Tham and the analysis by a Naval Postgraduate School (NPS) Master's student, Kevin McMindes, solutions to enhance combat survivability were explored. This research takes a step further by exploring the relationship between all other employment domains and suggests a methodology to identify the relationship amongst these domains. However, all three researches identify the shortcomings of present UAS employment models which is resulting in increased UAS attrition in an anti UAS environment.

2.3 Limitations of the research findings.

The research data evaluations fed in the AHP analysis were based on literature review, case studies and combat experiences. These evaluations depend on Commander's directives, reserve asset strength, adversary defenses, theatre of operation amongst many other such factors. The evaluations need to be adjusted for each theatre periodically and then the results can be utilized in planning the deployment and employment of UAS.

3. Recommendations

The recommendations of the research can be broadly divided into development/procurement, and deployment aspects. These aspects together affect both the operational and strategic domains involved in the employment of aerial assets.

3.1 Development/Procurement Aspects.

The feedback about various UAS platforms' shortcomings experienced in the theatre can be utilized towards the upgradations of already available assets and/or during the procurement of new platforms.

3.1.1 UAS platforms are highly optimized, they have limited load-carrying capability and space to accommodate the capability or survivability enhancements. In order to equip any capability a trade-off in some other domain would be a necessity. In order to analytically arrive at a balance among these domains AHP analysis of each consideration against one another is recommended. The AHP analysis can yield the weightage of each domain over the other for a particular scenario and aid in equipping a UAS platform with the most suitable configuration.

3.1.2 The AHP analysis results of own and adversary assets can be utilized for creating a realistic training environment. Such a realistic environment can be utilized for developing counter-strategies and tactics.

3.1.3 The AHP analysis results of own and adversary assets can also be modeled into the war gaming software. The domains considered in the AHP analysis give a realistic basis for attrition prediction.

3.2 Deployment Aspects

In the course of the research, evaluations for various considerations in the AHP matrix were fed based on case studies, literature review, and combat experiences. The evaluations will vary based on the operations environment from country to country, theatre to theatre. The research only shows an ideal statistical approach and methodology to identify suitable UAS platform. However, in the actual scenario, the evaluations fed in the AHP matrix for various strike roles are to be assessed by the Joint Force Commander and his staff based on the commander's directives on attrition, effectiveness, force commitment levels, etc. Similarly, the evaluations for various UAS platforms are to be assessed by the field commander and his staff as per the combat environment in the operational theater. Based on the AHP comparison results suitable UAS platforms may be deployed in a particular theatre.

3.2.1 As the combat environment dynamic, changes in enemy dispositions and strategies greatly affect own employment philosophies. Based on the AHP comparison graphs for each role, the field commander and his staff become aware of the exact domains in which a particular UAS platform has shortcomings in comparison to the requirements set by the Commander's directives. The knowledge about such shortcomings can be utilized to mitigate the risks to UAS in the theatre by the synergetic employment of other resources in support to these UAS platforms.

3.2.2 The AHP analysis on various aerial assets of the adversary may be carried out and the results made part of adversary intelligence estimates. This knowledge can be utilized to exploit adversary assets' shortcomings and development of suitable Course Of Actions (COAs) in a theatre. For example, if the AHP analysis identifies the enemy's assets lacking in the Combat Integration domain, this knowledge can be leveraged to boost own ISR and counter-strike operations.

3.3 Recommendations for future research.

3.3.1 The research and its methodology of AHP graph comparison can also be extrapolated to various other roles and air assets like effective employment of helicopters in strike role, effective employment of UAS in Offensive counter air roles, etc. The methodology will help in planning deployments in line with the Commander's directives and mission objectives.

3.3.2 In the development of an ideal UAS suitable for a particular role, space for additional equipment and load-carrying capability pose severe restrictions in developing a one stop solution. The AHP analysis of each individual dependent variable, for example AHP analysis of Combat effectiveness with its independent variables namely Inertial Navigation systems redundancy, Radio Frequency protection circuits, Sensor -payload carriage, weapon-payload carriage, quantity of weapons, Endurance, and Effective Range, will yield the weightage of each dependent variable. This weightage can be utilized in developing apt UAS designs for specific roles.

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APPENDIX

Appendix A – UAS taxonomy and capabilities

Table A-1 NATO class, common taxonomy of UAS

Maximum Takeoff weight	NATO class	Common Taxonomy	Normal Operating Altitude	Normal Mission Radius
<200g	Class I <150 Kg	Nano	Upto 200 ft AGL	5 Km (LOS)
200g-20 Kg		Micro< 2Kg	Upto 200 ft AGL	5 Km (LOS)
		Mini 2-20 Kg	Upto 3K ft AGL	25 Km (LOS)
20 -150 Kg		Small> 20 Kg	Upto 5K ft AGL	50 Km (LOS)
>150 Kg	Class II 150-600 Kg	Tactical> 150 Kg	Upto 10,000 ft AGL	200 Km (LOS)
>600 Kg	Class III >600 Kg	HALE and Strike	Upto 65,000 ft AGL	Unlimited (BLOS)
>600 Kg	Class III >600 Kg	MALE	Upto 45,000 ft AGL	Unlimited (BLOS)

Table A-2 Comparison of threat warning systems

RWR	MAWS	LWS
Passive	Passive/ active	Passive
Detects RF threats only.	Detects any incoming threat that emits exhaust plume (other aircraft, etc.), but is not able to detect AAA.	Detects only threats that use the laser as guidance.
Medium to long lead-time between detecting RF threat and threat firing at UAS.	Short to medium lead time between detecting threat and threat reaching UAS.	Short to medium lead time between detecting laser guided threat and threat firing at UAS
Combat survivability can be enhanced even without installing countermeasures	Combat survivability can only be enhanced if countermeasures are installed.	Combat survivability can only be enhanced if countermeasures are installed.

Table A-3 Payload and weapons of various UAS by class

NATO class	Common Taxonomy	Normal Operating Payload	Weapons carried
Class I <150 Kg	Nano	Fixed EO/IR	NIL
	Micro< 2Kg		
	Mini 2-20 Kg		
	Small> 20 Kg		
Class II 150-600 Kg	Tactical> 150 Kg	Sensor ball with EO/IR and an LRF/D	Kamakazi-warhead of 40-50 Kg
Class III >600 Kg	HALE and Strike	Sensor ball with EO/IR, radars, lasers, SAR, communications relay, SIGInT, EA	LGB,JDAM, Hellfire missiles, Stinger, AAM
Class III >600 Kg	MALE		

Appendix B Paired comparison analysis

Table B-1 Paired comparison analysis

Considerations	Strike Aircraft	Unmanned Aerial Systems
Combat Availability		
Portability		✓
Sustainability	✓	✓
Flexibility	✓	
Ease of operations		✓
Combat Survivability		
Altitude flexibility	✓	
Speed flexibility	✓	
Reduced Detectability		✓
Improved Situational Assessment	✓	
Threat counter ability	✓	
Combat Effectiveness		
Inertial Nav sys	✓	
RF protection		
Payload-Sensor	✓	
Payload-Weapon	✓	
Quantity of weapons	✓	
Endurance		✓
Effective Range		✓
Combat Integration		
IFF	✓	
Data link	✓	
Cost		
Procurement		✓
Training		✓
Operating		✓

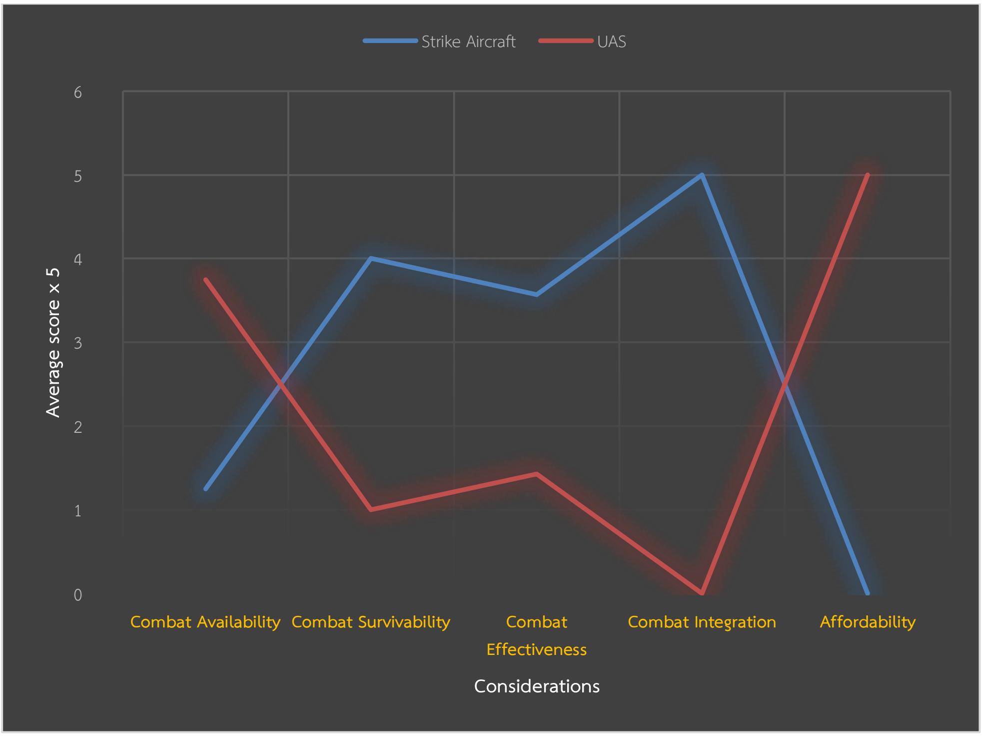


Figure B-1 Paired comparison analysis graph

Appendix C AHP matrix and graph of various strike roles

Table C-1 AHP matrix of various strike roles

Close Air support	Combat Availability	Combat survivability	Combat Effectiveness	Combat Integration	Weightage
Combat Availability	1	3	1/3	1/5	0.668740305
Combat Survivability	1/3	1	1/3	1/5	0.386097395
Combat Effectiveness	3	3	1	5	2.590020064
Combat Integration	5	5	1/5	1	1.495348781

Air Interdiction	Combat Availability	Combat survivability	Combat Effectiveness	Combat Integration	Weightage
Combat Availability	1	1/5	1/3	1/3	0.386097395
Combat Survivability	5	1	1/5	3	1.316074013
Combat Effectiveness	3	5	1	3	2.590020064
Combat Integration	3	1/3	1/3	1	0.759835686

Strategic strike	Combat Availability	Combat survivability	Combat Effectiveness	Combat Integration	Weightage
Combat Availability	1	1/7	1/7	1/5	0.252760077
Combat Survivability	7	1	1/3	1	1.235930917
Combat Effectiveness	7	3	1	1/5	1.626576562
Combat Integration	5	1	3	1	1.967989671

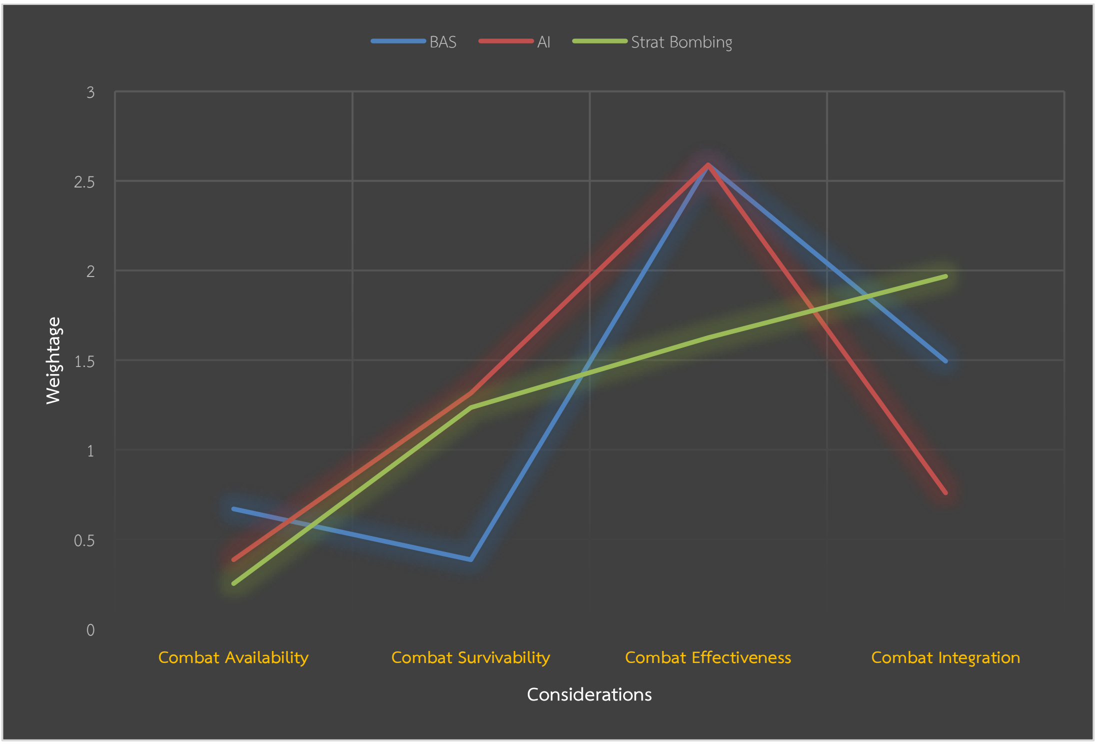


Figure C-1 AHP graph of various strike missions

Appendix D AHP matrix and graph of various strike roles

Table D-1 AHP matrix of UAS in various strike roles

IRANIAN SHAHED	Combat Availability	Combat survivability	Combat Effectiveness	Combat Integration	Weightage
Combat Availability	1	3	3	5	2.590020064
Combat Survivability	1/3	1	1/5	5	0.759835686
Combat Effectiveness	1/3	5	1	5	1.699044245
Combat Integration	1/5	1/5	1/5	1	0.299069756

BYRAKTAR TB-2	Combat Availability	Combat survivability	Combat Effectiveness	Combat Integration	Weightage
Combat Availability	1	1/5	1/5	5	0.668740305
Combat Survivability	5	1	1/3	5	1.699044245
Combat Effectiveness	5	3	1	5	2.942830956
Combat Integration	1/5	1/5	1/5	1	0.299069756

MQ-9 REAPER	Combat Availability	Combat survivability	Combat Effectiveness	Combat Integration	Weightage
Combat Availability	1	1/7	1/7	1/7	0.23236808
Combat Survivability	7	1	1/3	1	1.235930917
Combat Effectiveness	7	3	1	1/5	1.626576562
Combat Integration	7	1	3	1	2.140695143

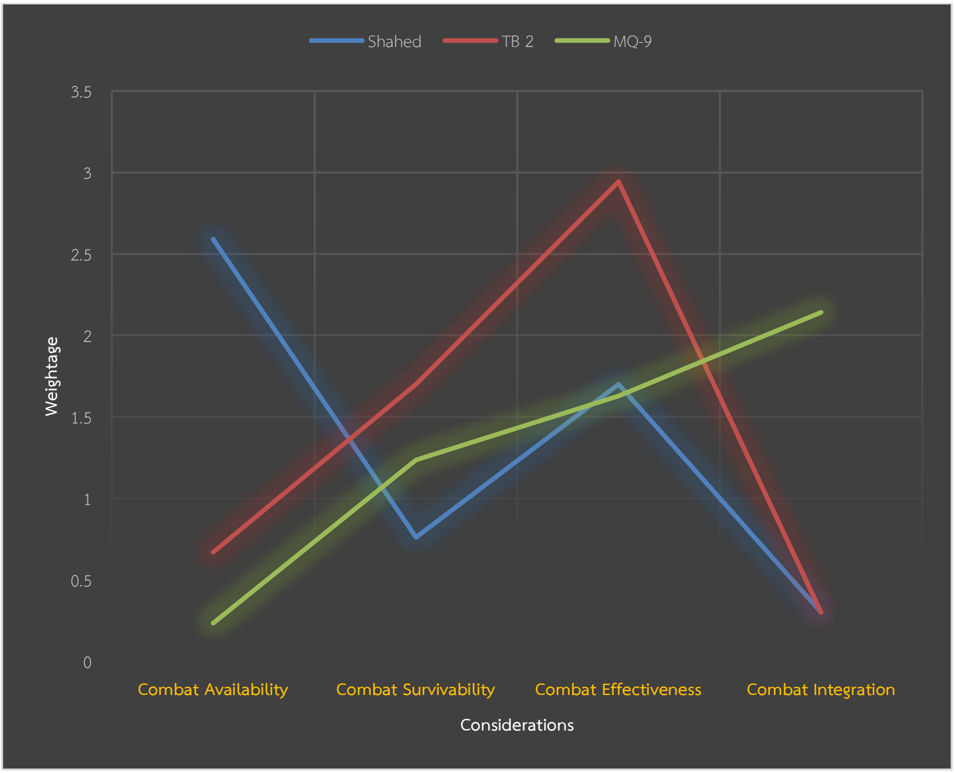
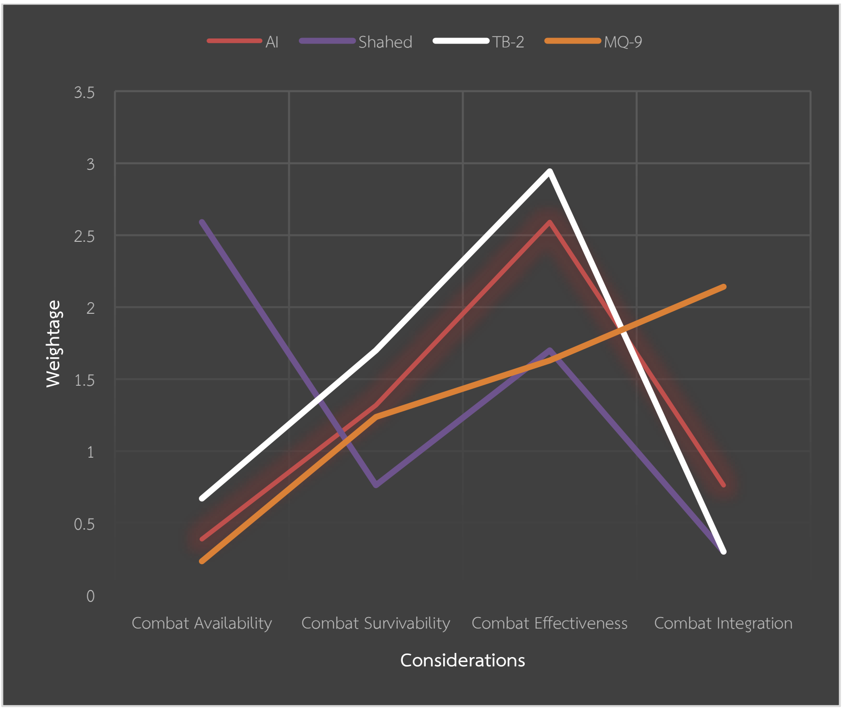


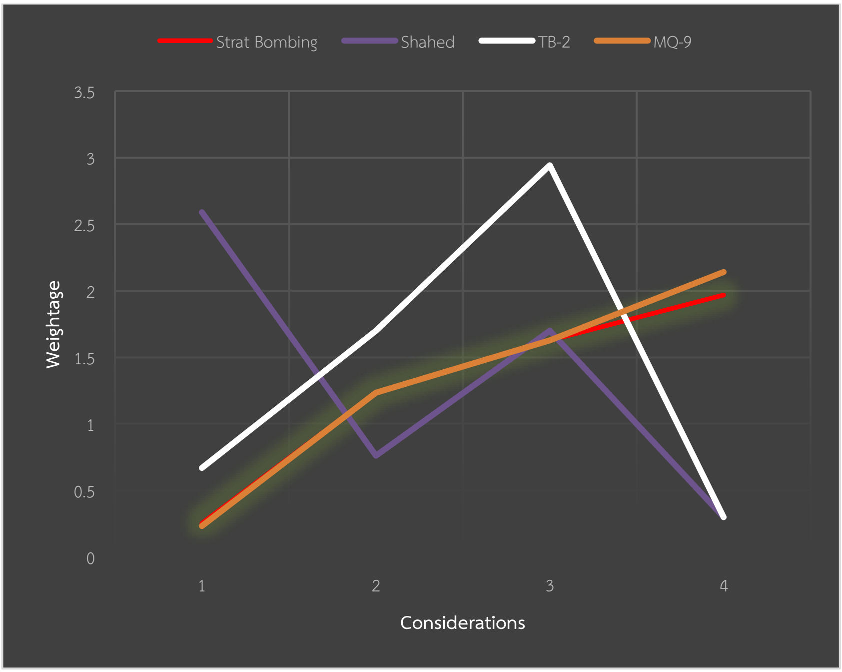
Figure D-2 AHP graph of UAS in various strike missions

Appendix E AHP comparison graph for AI and strategic bombing role



Amongst the UAS platforms, the best suitable platform for AI role appears to be TB-2.

Figure E-1 AHP comparison graph for AI role



Amongst the UAS platforms, the best suitable platform for Strategic Bombing role appears to be MQ-9 Reaper.

Figure E-2 AHP comparison graph for Strategic bombing role

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