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Study on the Effectiveness of Commercial Drones in Military Education

Abstract. *Within various societal fields, technological developments are more evident than ever, and in this regard, drones have an increasingly critical role. Specific to the military field, drone technology is continuously adapting, being currently characterised by an accentuated versatility considering the extremely wide spectrum of tasks and missions to which they are subjected. Given the decisive contribution of drones in various conflicts and the need to exploit the experiences from ongoing military operations, this study seeks to determine the effectiveness of small commercial drones (SCDs) in military education, more precisely in military training and tactical exercises. To confirm the formulated hypotheses, the collected data were analysed using correlation and regression analysis. The obtained results highlight an essential contribution of commercial drones to the operational*

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performance in military exercises, with a greater effectiveness for tactical operation at the expense of the sensor ability and vehicle ability. Also, the results indicate a greater effectiveness for combat forces compared to combat support forces.

Keywords: *military education, operational performance, commercial drone, drone effectiveness, tactical exercise, correlation and regression analysis.*

JEL Classification: O33, I23, H56, C83.

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1. Introduction

The proliferation of commercial drones, also found under the name of ***u**nmanned **a**erial **s**ystems* (UAS) or ***u**nmanned **a**erial **v**ehicles* (UAVs) in military applications, represents a significant shift in modern warfare and training methods. Originally developed for the civilian market, these drones were quickly adopted for military purposes due to their versatility, advanced technological capabilities, and cost-effectiveness (Boyle, 2025). Commercial drones offer a wide range of capabilities that are highly useful in tactical military exercises, including ***i**ntelligence, **s**urveillance, **t**arget **a**cquisition, **r**econnaissance* (ISTAR), and ***b**attle **d**amage **a**ssessment* (BDA). Their capability to ensure real-time data and high-resolution imagery has made them an indispensable tool in both operational and training contexts. This trend underscores a broader evolution in military strategy, where the integration of advanced technology is the key to maintaining operational superiority. The conflict in Ukraine has significantly accelerated the adoption and innovation of using commercial drones in military scenarios and provides a relevant case study to examine their effectiveness.

The need to incorporate commercial drones into military education and training programs stems from several critical factors. First and foremost, commercial drones are significantly less expensive compared to their military counterparts. This cost-effectiveness allows for wider deployment and more extensive training exercises without placing an undue burden on the defence budget (Singer, 2009). In addition, rapid technological advances in the commercial drone sector have led to significant improvements in capabilities such as autonomous navigation, high-resolution imaging, and real-time data transmission. These technological improvements are critical to creating realistic and effective training scenarios.

The versatility of commercial drones also plays an important role. They can be used in a variety of environments, from dense urban landscapes to remote and difficult terrain, providing a comprehensive training experience (Hambling, 2015). This adaptability ensures that military personnel can train in different scenarios, preparing them for a wide range of operational conditions. In addition, the use of drones in training reduces the risk to human life during reconnaissance and surveillance missions. By using drones, military forces can gather important information and conduct exercises with less risk of injury or loss of life.

The effectiveness of commercial drones in military exercises is closely linked to technological advances. Innovations in machine learning, ***a**rtificial **i**ntelligence* (AI), and autonomous systems have essentially improved the capabilities of drones, making them more reliable and efficient (Kumar and Michael, 2012). However, challenges such as cyber security threats, ***e**lectronic **w**arfare* (EW) countermeasures, and regulatory restrictions represent significant obstacles to their deployment and operational performance (Yaacoub et al., 2020).

The current conflict in Ukraine has underscored the strategic importance of drones and highlighted their role in modern warfare. Both parties to the conflict have used commercial drones extensively for surveillance, joint targeting, and intelligence gathering. This real-world application provides valuable insight into how drones can be effectively integrated into military education and training, demonstrating that they can change the dynamics on the battlefield.

Despite the importance of commercial drones in military applications, there is a notable research gap regarding their operational performance in tactical military exercises. Most of the current literature focuses on the technical specifications and potential applications of these drones rather than their practical utility in military education and training (Sauser, 2025). This gap is significant in that it limits our understanding of the performance of commercial drones in real-world military exercises, which is critical to their effective integration and utilisation.

Empirical research on the practical use and effectiveness of commercial drones in military training remains limited. Without solid data, their optimisation and full potential cannot be realised. Although the war in Ukraine offers valuable real-world insights into their use in high-intensity conflict, academic analysis is lacking. This highlights the urgent need for studies focused on the operational performance of commercial drones in military training, based on real conflict data.

The study aims to examine the effectiveness of ***s**mall **c**ommercial **d**rones* (SCDs) in tactical military exercises, with a primary focus on their operational performance, reliability, and overall impact on training outcomes. By examining the use, performance, and utility of commercial drones in training scenarios, the study will provide critical insights and recommendations for their integration into military education and training programs. To address the scope of the study, the following ***r**esearch **o**bjectives* (RObj) have been formulated:

RObj1 – determining the attributes and indicators specific to SCDs' effectiveness essential for the operational performance of military training forces;

RObj2 – analysing and description of the relationship between SCDs' effectiveness and operational performance within tactical military exercises;

RObj3 – conducting a comprehensive assessment of the SCDs' effectiveness in tactical military exercises and by forces types, especially for *combat* (CBT) and *combat support* (CS);

RObj4 – providing critical recommendations for the integration and optimisation of SCDs' into military education and training programs.

To achieve the objectives above, the hypotheses shown in Table 1 were formulated. There are two main hypotheses (H_1, H_2) and six secondary hypotheses (H_{11} - H_{23}).

Table 1. Main and secondary hypotheses

Main hypotheses	Secondary hypotheses
H_1 - at tactical level, the operational performance in military exercises largely depends on the SCDs' effectiveness.	H_{11} - sensor ability significantly influences the operational performance within tactical military exercises;
	H_{12} - vehicle ability significantly influences the operational performance within tactical military exercises;
	H_{13} - tactical ability significantly influences the operational performance within tactical military exercises.
H_2 - the score of SCDs' effectiveness achieved for CBT personnel influences the operational performance in tactical military exercises more than that of CS personnel.	H_{21} - the sensor ability score obtained for CBT personnel influences the operational performance in tactical military exercises more than that of CS personnel;
	H_{22} - the vehicle ability score obtained for CBT personnel influences the operational performance in tactical military exercises more than that of CS personnel;
	H_{23} - the tactical ability score obtained for CBT personnel influences the operational performance in tactical military exercises more than that of CS personnel.

Source: Authors' own creation.

Hypotheses H_{11} - H_{13} are formulated to examine the individual dimensions underlying the main hypothesis (H1), while serving as analytical components rather than standalone substantive hypotheses. Hypotheses H_{21} - H_{23} address outcome-related differences across force types and are tested separately.

2. Literature review

This section explores the contributions of commercial drone technology in the educational field, both civilian and military.

In this regard, the usage of commercial drones has been proposed to support socially the educational activities in classrooms. Understood as a composition of robot and social interface (social form, social functionality, social context), social drones have proved to be highly tutoring in managing the educational audiences (grouping, role-playing, asking and answering questions), doing supportive activities (cleaning whiteboard, transferring items), providing supervision during examinations, gaining students' focus, providing different theoretical contents, etc. To the end, the commercial social drones are useful for students to determine them to react in a particular way and to think at different scenarios, using various interacting modalities, most of them being nonverbal in fashion (Johal et al., 2022).

Another scientific perspective has explored the contributions of commercial drones in collaborative educational activities with the main focus on *science, technology, engineering, and mathematics* (STEM) disciplines. Using the analytical context of the *substantiation, augmentation, modification, and redefinition* (SAMR) conceptual model, the findings are centred on the last two (modification, redefinition), mainly used to adjust key learning outcomes and to stimulate transdisciplinary experiences. Furthermore, it has been emphasised the necessity to improve education and training of students by exploiting commercial drone-based technology to stimulate students' focus and cognitive outcomes (Jiang et al., 2024).

In the same manner, it has also been investigated how commercial robotic technology is integrated and exploited in the educational processes of the target audiences. The analysis is based on identifying the most important commercial drone technology's contributions to STEM education, virtual reality, and physical education, including the progress of adjusting tailored curriculum including: teachers' knowledge, drone's type, students' knowledge, safety and reflexion. Besides numerous advantages offered by drone technology for educational purposes, there are also important factors on which they depend, of which the most important is the educator's level of training in adjusting the educational act in dealing with various audiences (Pergantis and Drigas, 2024).

Moreover, the exploitation of commercial drone-based technology in STEM disciplines has been also analysed from the perspective of their effectiveness on learning, using active methodologies. The main conclusion has found that there is a positive correlation between commercial drone-based technology and STEM learning, facilitating the understanding, construction, and interpretation of specific contents. Additionally, the pedagogical technology through commercial drones and *problem-based learning* (PBL), highly improved students' effectiveness during workshops related to decision-making scenarios (Yepes et al., 2022).

On the other hand, for the military education, commercial drones are indispensable for military training and tactical exercises. Commercial drones not only support the target audiences operating in the field during different hypothetical scenarios, but might completely replace them in complex, dangerous, and highly demanding operational areas that challenge large-scale live training forces. Moreover, the exploitation of commercial drones during military exercises is connected to better reconnaissance, increased convenience, enhanced safety, increased flexibility, or accuracy in fulfilling designated missions and tasks (Sadiku et al., 2024). Due to the fact that commercial drones seem to be quite effective and efficient for the military education and training, there is a critical need to adjust specific academic curricula, especially in practicing *command, control, communication, computers, information* (C4I) during tactical hypothetical scenarios. Even if the issue of the efficiency of commercial drones in military education is no longer addressed, the question that still persists can be summed up as to how effective they are compared to military ones (Barros et al., 2024).

Additionally, some specialised studies also identify the impact of SCDs on military tactics and strategies, and the fact that they are much cheaper has led to their widespread use by opponents for reconnaissance, surveillance, and precise engagements (Kunertova, 2023a). They have been identified as the perfect option for military training forces with limited resources and a real threat to future soldiers who will face new generations of small and stealthy drone scouts (Kunertova, 2023b). The positive aspects, such as accessibility, availability, real time data, portability, ease of operation, reduced risk, and boost of the morale of training forces, come with limitations regarding reduced battery autonomy, vulnerability to adverse weather conditions, and data security (Bojor and Grigore, 2024).

SCDs are used for complex mapping of the tactical exercises using urban terrain. Urban planning is improved with the help of commercial drone sensors that can collect highly accurate coordinates (Noor et al., 2018). The access of training forces to urban terrain is based on real-time support with images and information taken from the sky. Commercial drones cover the so-called "airlittoral" (Bremer and Grieco, 2021), whose superiority cannot be achieved by high altitude long endurance (HALE) or medium altitude long endurance (MALE) drones (Chamola et al., 2020).

Although the academic community has predominantly addressed the role of large drones, or the role of drones in civilian social domains, research has underestimated the impact and effects of SCDs on warfare and military education. In Ukraine, large drones continue to provide strategic victories in certain contexts, but, overall, they seem to be replaced by SCDs due to their multiple advantages (accessibility, mobility, easy operation, low costs).

3. Data and research methodology

Data were collected during the ***F**ield **T**raining **E**xercise* (FTX) "CADET 2024", held at "**N**icolae **B**ălcescu" **L**and **F**orces **A**cademy (NB-LFA), and attended by students from CBT, CS, and ***c**ombat **s**ervice **s**upport* (CSS) forces (FTX, 2024). The reason of using SCDs during CADET_24 was to demonstrate their overall effectiveness in military training, as well as their high contribution for optimising the operational performance during simulated tactical tasks as offensive, defensive, stability, and enabling, in general, and during movement to contact, attack, and exploitation, in particular.

The sample was composed of 212 respondents, representing third-year students of the NB-LFA. During the exercise, the respondents used either directly or indirectly information products provided by SCDs. The 212 respondents were distributed among the following military branches: 109 CBT respondents (51.4%), 77 CS respondents (36.3%), and 26 CSS respondents (12.3%). Of these, 161 were male (75.9%), while 51 were female (24.1%).

Data collection was carried out through the indirect survey based on the online questionnaire. Two questionnaires were developed: ***d**rone **e**ffectiveness **q**uestionnaire* (DEQ) and ***o**perational **p**erformance **q**uestionnaire* (OPQ). Each was designed in 3 sections, with a total number of 45 items.

DEQ was designed in accordance with research conducted on identifying SCDs' critical attributes for enhancing effectiveness in various operational environments. By exploiting the existing conceptual models, the attributes of SCDs' effectiveness, such as sensor ability, vehicle ability, and tactical operation were converted into DEQ items. Furthermore, each attribute was treated based on tested factors, such as: sensor ability – imagery quality, classification probability, classification range, susceptibility to weather; vehicle ability – air speed, altitude;

tactical operation - operational range, endurance (Hyunkyung et al., 2016). In order to ensure a balanced perspective on the investigated subject, positive (at least 12 items) and negative (2 items) items were formulated for each attribute.

OPQ was designed in conjunction with the needs of NB-LFA for military training and tactical military exercises. Considering the offensive nature of the CADET_24 tactical exercise, there were identified the essential activities specific to each primary offensive task on the basis of working groups in which subject matter experts (SMEs) in the field of military operations and training took part. OPQ items were developed for the first three primary offensive tasks, as follows: movement to contact, attack, and exploitation (Army Doctrine Publications [ADP], 2019). As in the case of DEQ, the OPQ also included both positive (at least 12 items) and negative items (2 items for each attribute).

Variables, Attributes, Indicators and Dimensions

The study looks at the independent variable of drone effectiveness and the dependent variable which is the operational performance within tactical military exercises. The definition of each variable as well as their specific attributes and indicators is highlighted in Table 2.

Table 2. Defining variables, attributes, indicators

Variables	Attributes	Indicators
Drone effectiveness – the capability of commercial UAV to support military training forces during tactical military exercises.	*Sensor ability* – used to “measure how much the sensor’s resolution of UAV effects to the UAV’s mission achievements” (Hyunkyung et al., 2016).	Imagery quality – given by “fidelity, perception and aesthetics” (Wang, 2023);
		Classification probability – “probability the UAV can classify a target correctly” (MacCalman et al., 2015);
		Classification range – “distance the UAV can classify something as a threat, friendly, or neutral” (MacCalman et al., 2015);
		Susceptibility to weather – determined by rain, icing, wind speed, wind direction, fog clouds, etc.
	Vehicle ability – used to “measure how much the aircraft’s performance effects to the UAV’s mission achievements” (Hyunkyung et al., 2016).	Air speed – the flight speed of the UAV;
		Altitude – “height above the UAV starting point” (Pritzl et al., 2023);
	Tactical operation – used to “measure how much operational tactics like routing effects to the UAV’s mission achievements” (Hyunkyung et al., 2016).	Operation range – “distance between the control station and the aircraft” (Maddalon et al., 2013);
		Endurance – “total amount of time an aircraft can stay in flight” (Wilson et al., 2020)
Operational performance in military tactical exercises – the ability of military training forces to	*Movement to contact* – “type of offensive operation designed to develop the situation and	Checking communications, equipment and materials; Conducting coordinated and synchronised movements;

Variables	Attributes	Indicators
perform missions and tasks during offensive tactical military exercises.	to establish or regain contact” (ADP, 2019);	Performing vertical and horizontal information flow; Identifying red forces *battle positions* (BPs) and their vulnerabilities; Avoiding exposure to red forces’ heavy fire; Coordinating with *field artillery* (FA) and *rotary wing* (RW) coverage fire; Achieving designated points and *phase lines* (PLs).
	Attack – “type of offensive operation that destroys or defeats enemy forces, seizes and secures terrain, or both” (ADP, 2019);	Starting the attack in accordance with higher echelon time; Getting through minefields; Achieving superiority in critical key points; Securing immediate mission PLs; Destroying regular and irregular elements; Repelling red forces’ *counterattack* (CATK); Synchronising various offensive forms of maneuver; Introducing air assault forces; Conducting shaping operations using CBT and CS forces; Achieving mutual support during combat operations; Avoiding fratricide; Ensuring continuous communications (radio, data).
	Exploitation – “type of offensive operation that usually follows a successful attack and is designed to disorganise the enemy in depth” (ADP, 2019).	Introducing second echelon to exploit opportunities; Disrupting red forces in their depth; Setting necessary conditions to conduct decisive operation; Destroying red forces’ center of gravity (COG) through decisive operation; Avoiding collateral damage; Securing flanks, intervals, and PLs; Fixing and blocking red forces in urban areas.

Source: Authors’ own creation.

Data collection and quantification in numerical values were achieved by applying the Likert scale (1 – totally not applicable to 5 – totally applicable). The dimensions of each variable, attribute, and indicator are shown in Table 3.

Table 3. Dimensions of variables, attributes and indicators

Variables	Attributes	Indicators
Drone effectiveness: 45 items (39 positive, 6 negative); min = 45, average = 135, max = 225.	Sensor ability: 16 items (14 positive, 2 negative); min = 16, average = 48, max = 80.	Imagery quality: 5 items; min = 5, average = 15, max = 25;
		Classification probability: 4 items; min = 4, average = 12, max = 20;
		Classification range: 4 items; min = 4, average = 12, max = 20;

Variables	Attributes	Indicators
		Susceptibility to weather: 3 items; min = 3, average = 9, max = 15.
	Vehicle ability: 14 items (12 positive, 2 negative); min = 14, average = 42, max = 70.	Air speed: 7 items; min = 7, average = 21, max = 35;
		Altitude: 7 items; min = 7, average = 21, max = 35.
	Tactical operation: 15 items (13 positive, 2 negative); min = 15, average = 45, max = 75.	Operation range: 8 items; min = 8, average = 24, max = 40;
		Endurance: 7 items; min = 7, average = 21, max = 35.
Operational performance in military tactical exercises: 45 items (39 positive, 6 negative); min = 45, average = 135, max = 225.	Movement to contact: 14 items (12 positive, 2 negative);	min = 14, average = 42, max = 70;
	Attack: 16 items (14 positive, 2 negative);	min = 16, average = 48, max = 80;
	Exploitation: 15 items (13 positive, 2 negative).	min = 15, average = 45, max = 75.

Source: FTX “CADET 2024”. Authors’ processing.

Testing DEQ and OPQ

A battery of tests was performed before testing the research hypotheses. First, the summary statistics of DEQ and OPQ questionnaires is shown in Table 4.

Table 4. Summary statistics

Questionnaire	Attribute	Obs.	Mean	Std. dev.	Min.	Max.
DEQ	sensor_ab	212	63.722	8.565	29	80
	vehicle_ab	212	53.778	7.061	26	70
	tact_op	212	59.033	8.101	29	75
	de_tot	212	176.533	21.487	85	225
OPQ	mov_contact	212	55.901	6.899	27	70
	attack_t	212	64.377	7.434	30	80
	exploit_t	212	58.476	7.423	27	75
	op_tot	212	178.755	20.668	84	225

Source: FTX “CADET 2024”. Authors’ processing.

In Table 4, DEQ includes 45 items (i.e., questions with ranking from 1 to 5), and refers to drone effectiveness. DEQ is divided into 3 sections, namely: sensor_ab which represents the sensor ability questions (e.g., 16 items); vehicle_ab which represents vehicle ability questions (e.g., 14 items); and tact_op which represents tactical operation questions (e.g., 15 items); de_tot refers to drone effectiveness as total points which summarises all 45 items pertaining to DEQ.

OPQ refers to operational performance and is also divided in three sections, namely: *mov_contact* which represents the movement to contact including 14 items; *attack_t* which represents the attack ability of military forces with 16 items and *exploit_t* which represents the exploitation section with 15 items; op_tot represents the total points which summarises all 45 items pertaining to OPQ.

The analysis of Table 4 shows that mean values for each attribute and variable are significantly higher than the average measurement intervals (Table 3), indicating respondents mostly answered “largely applicable.” Standard deviations reveal that attribute scores are relatively concentrated around the mean, while variables show greater variability. Minimum responses reflect “hardly applicable,” and maximum responses indicate “totally applicable” across all attributes and variables.

The Cronbach’s alpha (α) test was used to assess the internal consistency of questions within each sub-section. Alpha values range from 0 to 1, where:

- Below 0.7 indicates low consistency and potential unreliability,
- Between 0.7 and 0.9 indicates acceptable consistency, and
- Above 0.9 suggests high consistency, possibly indicating redundancy if >0.95.

Table 5 presents the Cronbach’s alpha results for the first section of drone effectiveness, sensor ability, and its sub-sections.

Table 5. Internal consistency assessment within sensor ability section

Indicators	Imagery quality	Classification probability	Classification range	Weather	Overall
Average interitem covariance	0.2925	0.3385	0.4079	0.1785	0.2680
Number of items in the scale	5	4	4	3	16
Scale reliability coefficient	0.7473	0.7938	0.8311	0.3564	0.8863

Source: FTX “CADET 2024”. Authors’ processing.

The results presented in Table 5 show an acceptable internal consistency, which varies between 0.74 and 0.83, with the exception of susceptibility to weather conditions (0.35). The main explanation for this rather low internal consistency is due to the small number of items (i.e., only three questions). Also, this can be justified by the respondents’ assessment of the subject questions, considering them not so relevant since they had favourable weather conditions during CADET_24 and, consequently, not affecting the possibilities of the SCDs’. The overall Cronbach’s alpha (α) test, for sensor ability is 0.88 which is very close to 0.9, demonstrating a high internal consistency of the items included for this section of DEQ. Table 6 shows the results of the internal consistency test for the vehicle ability section.

Table 6. Internal consistency assessment within vehicle ability section

Indicators	Air speed	Altitude	Overall
Average interitem covariance	0.2363	0.2173	0.2377
Number of items in the scale	7	7	14
Scale reliability coefficient	0.6830	0.6717	0.8171

Source: FTX “CADET 2024”. Authors’ processing.

According to results from Table 6, it was found that the overall internal consistency is 0.81, while the internal consistency for each sub-section, namely air speed and altitude are somewhat low in terms of scale reliability, failing to exceed the acceptable internal consistency threshold. The scores can be justified by some questions that were too generic and did not capture the essence, since the SCDs’ were handled in conditions of increased safety, considering the juvenile experience of the operators (altitudes below 200 m, speeds below 20 km/h), well under its average capabilities. Table 7 presents the internal consistency of the items for the third sub-section of drone effectiveness, namely tactical operation. The results provide a satisfactory acceptable internal consistency for each sub-section, ranging between 0.74 and 0.76, with an overall internal consistency of 0.86 which is close to high consistency threshold.

Table 7. Internal consistency assessment within tactical operation section

Indicators	Operation range	Endurance	Overall
Average interitem covariance	0.2280	0.3133	0.2800
Number of items in the scale	8	7	15
Scale reliability coefficient	0.7438	0.7673	0.8690

Source: FTX “CADET 2024”. Authors’ processing.

Table 8 illustrates the internal consistency for the second questionnaire (OPQ) and its three subsections: movement to contact, attack, and exploitation. The internal consistency for each sub-section was found acceptable, while the overall Cronbach’s alpha (α) for operational performance exceeds the 0.9 threshold, pointing towards high internal consistency. It is important to mention that the overall internal consistency of 0.94 does not exceed the 0.95 threshold, which indicates that the items included in the second questionnaire do not rephrase each other.

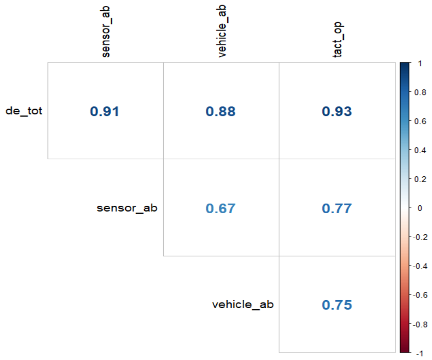
Table 8. Internal consistency assessment within OPQ

Indicators	Movement to contact	Attack	Exploitation	Overall
Average interitem covariance	0.1933	0.2126	0.2348	0.2207
Number of items in the scale	14	16	15	45
Scale reliability coefficient	0.8004	0.8682	0.8408	0.9409

Source: FTX “CADET 2024”. Authors’ processing.

Prior to hypothesis testing, the normality of the main composite variables (drone effectiveness and operational performance) was examined using the Kolmogorov–Smirnov test with parameters adjusted to the sample mean and standard deviation. Although minor deviations from perfect normality were observed – expected given the Likert-based nature of the data and the presence of ties – the sample size (N = 212) ensures the robustness of parametric statistical methods. Consequently, correlation analysis, t-tests, and OLS regression were considered appropriate.

In terms of questionnaire score investigation, the correlations between the overall score obtained and the main sections are also presented. Figure 1 emphasises the correlations between *drone effectiveness* (*de_tot*) and *sensor ability* (*sensor_ab*), *vehicle ability* (*vehicle_ab*), and *tactical operation* (*tact_op*) and shows strong positive correlations between the overall drone effectiveness score and its three sub-components, confirming the coherence of the defined attributes and the relevance of the related questions.



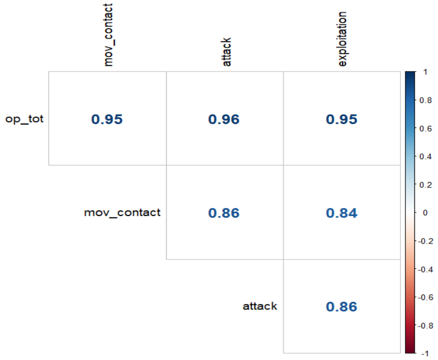


Figure 1. Drone effectiveness correlations

Figure 2. Operational performance correlations

Source: FTX "CADET 2024". Authors' processing.

Figure 2 presents correlations for operational performance (OPQ) and its three phases: movement to contact (mov_contact), attack (attack_t), and exploitation (exploit_t). The positive correlations indicate the appropriateness of the attributes and the questionnaire's consistency.

To examine the link between drone effectiveness and operational performance, the Spearman rank correlation was used, yielding a coefficient of 0.758, statistically significant at the 5% level, demonstrating a strong positive monotonic relationship between the two variables. As shown in Table 9, the analysis of variance (ANOVA) was also performed, with the operational performance being the dependent variable and drone effectiveness the independent one.

Table 9. ANOVA results

de_tot	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
	86.45	14.72	6.01	0.0001	57.35	115.54	***
R-squared	0.791		**Number of obs.**			212	
F-test	7.789		**Prob > F**			0.000	
Akaike crit. (AIC)	1709.335		**Bayesian crit. (BIC)**			1944.296	

$* p<0.1$, $** p<0.05$, $*** p<0.01$

Source: FTX "CADET 2024". Authors' processing.

The Analysis of Variance (ANOVA) was used to assess whether the observed differences in a continuous variable (e.g., operational performance) are due to the effects of another independent variable (e.g., drone effectiveness). The value of the R-squared coefficient shows that 79.1% of the variation in operational performance is explained by the differences between the drone effectiveness groups.

To verify the main and secondary hypotheses (Table 1), correlation and OLS regression analyses were used. Correlation analysis assessed the statistical association between variables, while regression analysis modelled the influence of drone effectiveness on operational performance.

To test the main hypothesis, OLS regression was applied with operational performance (op_tot) as the dependent variable and drone effectiveness (de_tot) as the independent variable. Secondary hypotheses examined the impact of sensor ability, vehicle ability, and tactical operation on performance, also using OLS regressions (Table 10).

Table 10. Regression equation & Main and secondary hypotheses

Hypothesis	Regression Model	
H_1	$op\_tot = \beta_0 + \beta_1(de\_tot) + \epsilon$	**(1)**
H_{11}	$op\_tot = \beta_0 + \beta_1(sensor\_ab) + \epsilon$	**(2)**
H_{12}	$op\_tot = \beta_0 + \beta_1(vehicle\_ab) + \epsilon$	**(3)**
H_{13}	$op\_tot = \beta_0 + \beta_1(tact\_op) + \epsilon$	**(4)**
H_2	$op\_tot_{mil\_type} = \beta_0 + \beta_1(de\_tot_{mil\_type}) + \epsilon$	**(5)**
H_{21}	$op\_tot_{mil\_type} = \beta_0 + \beta_1(sensor\_ab_{mil\_type}) + \epsilon$	**(6)**
H_{22}	$op\_tot_{mil\_type} = \beta_0 + \beta_1(vehicle\_ab_{mil\_type}) + \epsilon$	**(7)**
H_{23}	$op\_tot_{mil\_type} = \beta_0 + \beta_1(tact\_op_{mil\_type}) + \epsilon$	**(8)**
Variabile	*op_tot - the total score of operational performance of training forces* *de_tot – score of drone effectiveness* *sensor_ab - sensor ability* *vehicle_ab - vehicle ability* *tact_op - tactical operation*	

Note: The subscript *mil_type* refers to the category of military personnel involved in tactical exercises, namely CBT and CS personnel.

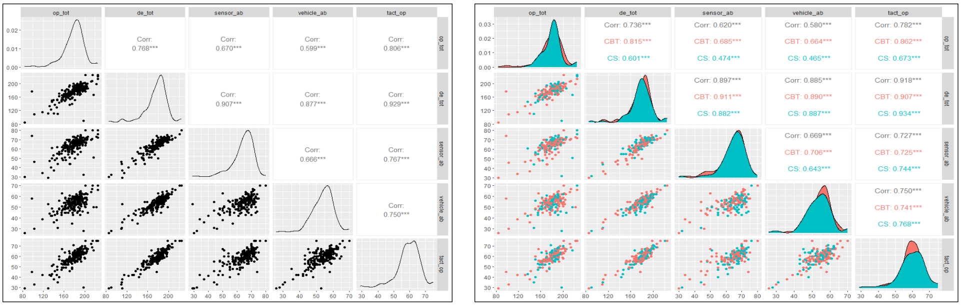
Source: Authors' processing.

4. Results

Data analysis was carried out using STATA 17 and R 4.1.3 software.

The Kolmogorov–Smirnov test applied to the main composite variables revealed only limited departures from normality, which are expected given the Likert-based construction of the indices; given the sample size (N = 212), parametric regression and correlation analyses remain appropriate. Preliminary mean-comparison tests between combat (CBT) and combat support (CS) personnel indicate no statistically significant differences in the average drone effectiveness or operational performance scores. These results suggest broadly comparable mean perceptions across force types and motivate the use of regression analysis to examine whether the *impact* of drone effectiveness on operational performance differs between CBT and CS personnel.

Figure 3 shows the main hypothesis testing as the well as secondary hypotheses, using correlation. As shown in Figure 3, a strong positive correlation between an overall score of drone effectiveness and operational performance of 0.768 was found. In terms of secondary hypotheses testing (H_{11} - H_{13}), positive correlations are determined: 0.670 between sensor ability and operational performance, 0.599 between vehicle ability and operational performance, and 0.806 between tactical operation and operational performance.



H_1 & H_{11} - H_{13} **H_2 & H_{21} - H_{23}**

Figure 3. Correlation analysis

Source: FTX “CADET 2024”. Authors’ processing.

The results obtained validate both the main hypothesis (H_1) and the secondary hypotheses (H_{11} - H_{13}). Table 11 reports the regression results used to test the main hypothesis (H_1) and its associated dimensional hypotheses (H_{11}–H_{13}), using the regression equations Eq. 1 – 4

Table 11. Regression results: H_1 & H_{11} - H_{13}

op_tot	**H_1**	**H_{11}**	**H_{12}**	**H_{13}**
de_tot	0.738***			
sensor_ab		1.616***		
vehicle_ab			1.753***	
tact_op				2.056***
Constant	48.413***	75.789***	84.490***	57.389***
N	212	212	212	212
R^2	0.589	0.448	0.359	0.649

*Note: * $p<0.05$, ** $p<0.01$, *** $p<0.001$. All models include a constant term; coefficients reported are OLS estimates. Standard errors are omitted for brevity.*

Source: FTX “CADET 2024”. Authors’ processing.

Table 11 presents the overall positive impact of the total score for drone effectiveness on operational performance, showing that a 1-unit increase in drone effectiveness leads to a 0.738-unit increase in operational performance. Regarding the testing of the secondary hypotheses (H_{11}–H_{13}), similar results were obtained, with all three analysed variables having a positive impact on operational performance in tactical exercises. A 1-unit increase in sensor ability results in a 1.616-unit increase in operational performance, a 1-unit increase in vehicle ability leads to a 1.753-unit increase, and a 1-unit increase in tactical operations results in a 2.056-unit increase in operational performance.

As shown in Figure 3, the second main hypothesis (H_2) and secondary hypotheses (H_{21}–H_{23}) were tested through correlation analysis between overall drone effectiveness and operational performance, focusing on CBT and CS personnel. The results show a stronger correlation for CBT personnel (0.835) compared to CS (0.601), supporting H_2. Similarly, for H_{21}–H_{23}, CBT personnel reported higher correlations across sensor, vehicle, and tactical operation attributes, further validating the secondary hypotheses.

Table 12 shows the results for H_2 main hypothesis testing, where the main objective is to investigate whether the scores obtained are different between the CBT and CS military personnel which was involved in CADET_24 tactical exercise.

Table 12. Regression results: H_2 & H_{21} - H_{23}

	H_2		H_{21}		H_{22}		H_{23}	
	op_tot CBT	*op_tot CS*	*op_tot CBT*	*op_tot CS*	*op_tot CBT*	*op_tot CS*	*op_tot CBT*	*op_tot CS*
de_tot	0.872***	0.486***						
sensor_ab			1.753***	1.055***				
vehicle_ab					2.178***	1.077***		
tact_op							2.539***	1.379***
N	109	77	109	77	109	77	109	77
R^2	0.664	0.361	0.469	0.225	0.44	0.216	0.743	0.454

Note: * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Source: FTX "CADET 2024". Authors' processing.

The Eq. 5 was performed for the second main hypothesis (H_2) and also Eq. 6 - 8 for each component of drone effectiveness, such as: sensor ability, vehicle ability, and tactical operation. There is a clear difference between CBT and CS military personnel in terms of overall score granted for drone effectiveness and its impact on the operational performance. The scores obtained from CBT personnel imply that there is a higher impact of drone effectiveness on operational performance of 0.872 versus the scores obtained from CS military personnel of only 0.486. When testing secondary hypotheses (H_{21} - H_{23}), the results show a similar trend where the scores of CBT military personnel regarding the impact of sensor ability on operational performance has a higher effect, compared with scores obtained from CS military personnel (i.e., 1.753 coefficient for CBT versus 1.055 coefficient for CS personnel).

The same results were obtained for H_{22} and H_{23} secondary hypotheses, where vehicle ability and tactical operation scores obtained from CBT personnel have a higher positive impact on operational performance within military exercises as compared to the scores from CS military personnel.

5. Discussions

The results validate the main hypotheses (H_1, H_2) and the secondary hypotheses (H_{11} – H_{13}, H_{21} – H_{23}).

The scores for testing H_1 and H_{13} (0.768, 0.806) indicate strong positive correlations, while for testing H_{11} and H_{13} the values of 0.67 and 0.599 indicate moderate positive correlations. The highest correlation value of 0.806 was obtained for the tactical operation and this can be justified by the greater sensitivity of the operational performance for this attribute, since it was perceived as directly contributing to the fulfilment of the objectives and the accomplishment of the tasks within the CADET_24 tactical exercise. Moreover, other justifications consist of the easy integration of the tactical operation of the SCDs within all phases of the exercise, as well as by the need to cover a relatively small operation area (2 km^2) which did not question the effectiveness of the two indicators – operation range and endurance. Contrastingly, the lowest value of the correlation coefficient was obtained for the vehicle ability (0.599), and this can be explained by the fact that its specific indicators, such as altitude and air speed, although they represent fundamental characteristics of the drone, are not the most important indicators for determining operational performance. Also, operating the SCDs at about the same altitude and speed (altitudes below 200 m, speeds below 20 km/h) represented another factor that significantly influenced the score obtained for the correlation coefficient.

The scores for testing H_2 and $H_{21} – H_{23}$ indicate moderate and strong positive correlations for CBT personnel, while for CS personnel correlations are weak and moderate. Analysing the scores obtained for validating H_2 hypothesis (CBT - 0.835, CS - 0.601), some of the justifications are given by:

- immediate impact of SCDs’ support on the security of the CBT personnel, considering the greater exposure of this category compared to CS, the former being emplaced in the first echelon and being the one that neutralises/destroys the enemy by directly engaging them, while the CS fulfils its missions from the second echelon, outside of a direct contact with the enemy forces;
- during CADET_24 exercise, the request for drone support was much more pronounced for the CBT missions on all phases of the offensive operation (movement to contact, attack, and exploitation) compared to the CS, where most of the requests took place only for the field artillery structures for providing indirect planned and on call fire;
- dynamic nature of the CBT missions which required a quick and adaptable response, different from CS where the missions had a more passive nature;
- motivational and psychological impact generated by the presence of drones for the CBT staff, different from the CS where the exposure to risk was not so obvious.

Significant differences in correlation coefficients were observed for each drone effectiveness attribute: sensor ability (0.259), vehicle ability (0.204), and tactical operation (0.197), all favouring CBT personnel. These differences are explained by the greater operational impact of specific indicators – such as imagery quality, classification accuracy, range, air speed, and endurance – on CBT missions, which demanded more frequent and timely critical information. Additionally, CBT units often had drone operators embedded at the platoon level, enabling real-time access to combat data. In contrast, CS personnel relied on post-processed intelligence products, which were not always timely or contextually relevant.

6. Conclusions

The results highlight the significant role of SCDs in enhancing military education and tactical exercises. The strong correlation with tactical operation (0.806) shows a clear dependence of training forces on drone attributes, particularly operational range and endurance – key elements for improving cadet training. While drones benefit all force types, they are especially effective for front-line units, such as CBT forces in the first echelon.

Based on these findings, the following recommendations are made to optimise academic and training programs through commercial drone integration:

- **Academic curriculum**: Incorporate SCD use into relevant courses, with objectives aimed at developing both individual (e.g., UAV operation, PID, POL) and collective skills (e.g., platoon-level maneuvers like gaining contact, attacking objectives, and counterattacking). ISR is best suited for individual skill training.
- **Training programs and exercises**: Prioritise drone support for CBT units; allocate to others (echelon 2, CS, CSS) based on availability and mission importance. Use platforms with strong range/endurance and moderate performance in other areas. Integrate drones in all exercise types (offensive, defensive, stability, enabling) for reconnaissance and key actions.

Despite validating all hypotheses, the study has limitations: inexperienced operators, limited operator availability, small operational areas, low-altitude/low-speed daytime flights, and data limited to CBT and CS respondents.

Future research should include comparative, quantitative studies examining the effectiveness of commercial versus military drones across various tactical tasks in military exercises.

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