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Integration of Robotics in Warfare

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Abstract: Modern day combat has transformed with the integration of Unmanned Ground Vehicles (UGVs) in small unit operations. To show how UGVs have changed operations and positively impacted U.S. military missions, the Infantry Warrior Simulations (IWARS) is used to develop scenarios involving infantry squads and robots. A base model involving an infantry squad gives the initial data (number of kills, shots fired, mission time). Using the base model, the infantry squad then integrates a UGV that can act as a forward observer and even dispose of IEDs. Currently the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) is designing capabilities for a robotic mule to deploy a small IED robot to conduct reconnaissance. To model TARDEC's mission, the IWARS model replicates a real-world scenario and determines the effects of modern-day tactics. An analysis between the two models shows the significance of using UGVs in combat and gives proper analysis into modern warfare.

Keywords: Unmanned Ground Vehicles, IWARS, IED, TARDEC

1. Introduction

This study into Unmanned Ground Vehicle (UGV) integration shows the effect on casualties in modern ground combat using the Infantry Warrior Simulation (IWARS) package. In a tactical scenario, an infantry team moves to cover when they receive contact and returns fire to provide cover for a sapper or EOD personnel to move in and breach a minefield. This places soldiers in close proximity to aggressors, making soldiers vulnerable and putting them at high risk. Robots were integrated into the scenario to identify the impact on friendly and enemy casualties along with the number of shots fired, which indicates the amount of collateral damage. To further explain the process of creating the simulations and collecting data, this paper will explain the two IWARS simulations and the necessary assumptions that were made to make the scenarios mimic combat.

Since the main goal of UGV integration is to reduce the number of casualties, the simulations focus on average deaths for friendly, enemy, and civilian forces. Each model changes human factors, such as moving and reacting to contact, which was gathered from real world data. The base model assumes a basic speed and reaction time due to wariness from carrying loads upward of 100-pounds. In the robot scenario, the robots offset some of this load, allowing actors to react and move quicker. Additionally, a robot replaces the sapper, performing the breach quicker and safer. The two scenarios are then compared to one another using collected data over multiple runs, which leads into an analysis of robot integration.

2. Problem Articulation

One way the U.S. Army has been attempting to reduce the number of casualties is integrating UGVs into infantry squads. The first solution was an IED robot that has been implemented for nearly two decades. The device, most commonly a small, tracked robot named either the TALON or MITR, is remotely controlled, can disarm improvise explosive devices (IEDs), and provide reconnaissance. The IED robot is typically small enough for a single soldier to lift off a vehicle and can receive radio signals between 500 and 800 meters with line of sight (*TALON Tracked Military Robot,* 2019). The robot keeps the soldier a safe distance away but cannot travel long distances without running into technical issues. In order to transport the IED robot, along with other equipment, the U.S. Army is conducting a competition for creating a robotic mule: an autonomous vehicle that can carry equipment, personnel, and specifically the IED robot. The Tank and Automotive Research, Development, and Engineer Center (TARDEC) is developing a mule called the Squad Multipurpose Equipment Transport (SMET) that can either be remotely controlled or tethered to an individual soldier to mimic movement (Lopez, 2018). With these two robotic devices, the goal is to limit or remove human involvement on reconnaissance missions and use these devices to the advantage of the U.S. Army by increasing soldier survivability. However, neither TARDEC nor the Army has designed a deployment and retraction device that allows the IED robot to depart the SMET and return without having a soldier physically picking up the IED robot.

Recognizing the failure in integration, TARDEC requested a United States Military Academy research team to create a remote-controlled ramp that a soldier can operate using the same controller for the SMET. The device being built integrates the SMET with the MITR so that all human interaction can occur a terrain feature away. Without the ramp, a soldier must place themselves in a comprising position to offload the robot for reconnaissance or bomb disposal. The full details of this project can be found at "Unmanned Ground Vehicle Deployment System" (Hung & Price, 2019). Based on this capstone project, the simulation collects data and indicates that soldier survivability increases with the integration of a robotic mule, ramp, and IED removal device. The study captures the survivability by simulating two combat scenarios in IWARS and comparing the results.

Figure 1. IWARS base model

3. Initial Model

3.1 Overview

In this first simulation, the goal is to recreate a real-world mission to gather baseline data without any robot integration (See Figure 1). The model begins with two infantry teams (consisting of 4 personnel each) moving from south to north in an urban environment modeled as the McKenna Training Site in Fort Benning. Together the teams form a squad that remain in-sync to accomplish a specific mission. Their mission is to destroy known enemy combatants who are holding civilian hostages in buildings on the north side of the city. The alpha team leads a sapper into the site and automatically returns fire and takes cover when the enemy makes contact. The alpha team lays suppressive fire to the enemy combatants allowing the sapper to move toward the minefield to dispose of the threat ordnance. Once the minefield is breached, the alpha team enters the building and engages the enemy combatants on the second floor. Simultaneously, the bravo team moves through the east side of the village and waits for word from the sapper that the minefield is breached. Once the message is received, the bravo team maneuvers into the adjacent building and destroys the remaining two enemy combatants. In a perfect scenario, the sapper is able to breach the minefield and the soldiers destroy the enemy combatants. If the sapper is incapacitated before the minefield is breached, alpha team will perform the breach and continue the mission.

Table 1. Comparison of values between Base and Altered Models

Variable	Base Model Value	Altered Model Value
Speed of Human Agent	1.1 m/s	1.6 m/s
Speed of Robot	n/a	2.7 m/s
Breach Time	20 s	18 s
Correct Force	26	15
Force Call Probability	0.5 (Blue on Blue), 0.2 (Blue on Red/Green)	0.9 (Blue on Blue), 0.8 (Blue on Red/Green)

3.2 Estimation and Assumptions

In order to make the model simulate reality, it was necessary to make assumptions regarding human physiological factors which can be shown as the variables in Table 1. The speed of a soldiers conducting a three-hour ruck march while carrying 45 pounds is expected to be 1.78 m/s (Kewley & Mittal, 2019). Using this data and operating under the assumption that soldiers in combat carry upwards of 100 pounds, an additional 55 pounds would make the soldier 60 percent slower (Pandolf, 1976). This created the assumption that friendly forces travel at a speed of 1.1 m/s.

Since the soldiers are expected to carry large loads, the model also looked at the changes in reaction time. IWARS uses the ACQUIRE-TTPM algorithm for target acquisition, which is fully explained in the IWARS Methodology Guide (2014). Reaction times and accuracy can be adjusted by changing the Correct Force and Force Call probability in the IWARS database. To account for the weariness and fatigue caused by the weight of a ruck and the overall exhaustion from conducting a mission, the Correct Force unit was increased from 18 to 26, making it more difficult to differentiate between friendly and enemy forces. The Force Call probability was changed from 1, meaning that the friendly force is always correct on determining the status of an individual, to either 0.5 or 0.2, making it more difficult for a soldier to react. The assumption was that without a reconnaissance robot and increased fatigue, soldiers would be correct in half of the scenarios meaning that it would be even more difficult to differentiate between a civilian and enemy actor.

After altering the simulation to realistic physiological factors, the study then looked at breach time. To keep the scenario run-time to a minimum, the breach time was set to 20 seconds, which is approximately the time for an experienced sapper to deploy the Antipersonnel Obstacle Breaching System (Holgate, 1992). In the overall grand scheme of the model, 20 seconds is a small fraction of the model run time of 5 minutes. The breach time truly did not matter when looking solely at the base model, only when being compared to the altered model. As long as the altered model is in relation to the base model breach time, the data is valid and allows for further analysis.

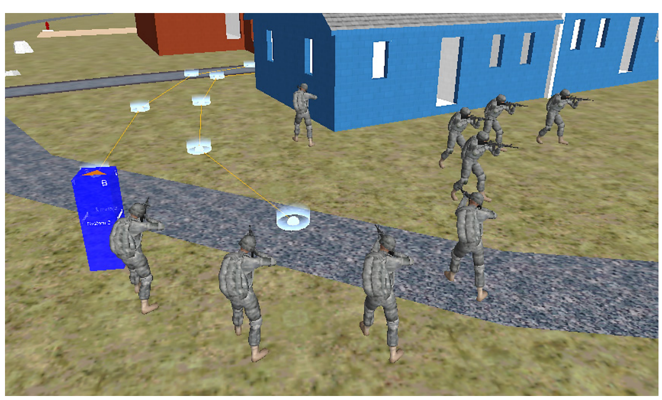

Figure 2. Friendly forces with the agent acting as the IED robot

4. Altered Model

4.1 Overview

To simulate the integration of robotic devices into combat, the simulation uses an unnamed agent to act as the IED robot. In IWARS an unnamed agent allows the user to manipulate every aspect of the agent because it does not mimic a specific individual or device. The robot moves to the minefield and disarms the bomb. Once the minefield is breached, the model simulates a user communicating a message to alpha and bravo teams to move forward (See Figure 3). The model reduces the risk of putting soldiers out in the open by allowing the teams to move directly onto the objective as well as removing the sapper from line of sight. The sapper remains a terrain feature away (on the south end of the McKenna training site) and simulates the IED robot controller disarming the bomb and conducting reconnaissance at a safe distance. IWARS has not integrated unmanned ground vehicles in the program, so it was necessary to use an unnamed agent and give it qualities to mimic a robot, as well as making physiological assumptions to model the implementation of the robotic mule.

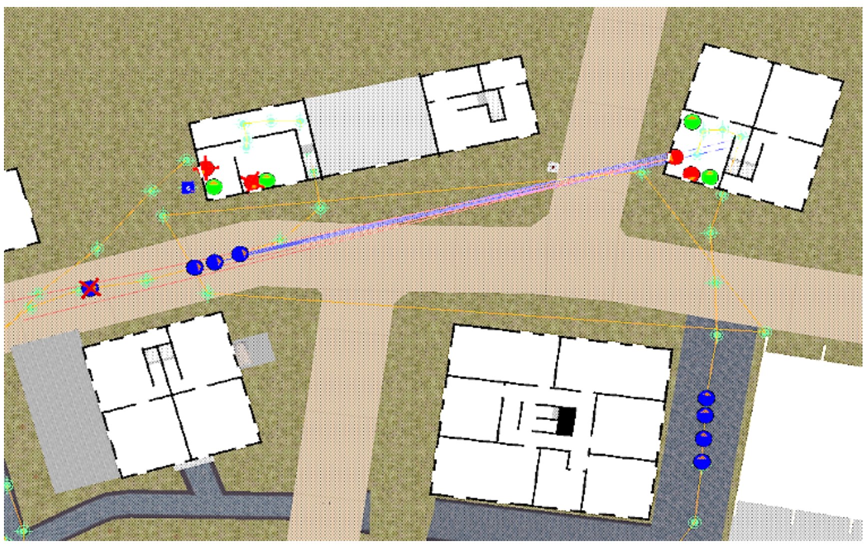

Figure 3. The robot has breached the minefield allowing the teams to maneuver into the buildings

4.2 Estimation and Assumptions

Since this study advances beyond the scope of IWARS, the simulation requires the use of an "Other System" in the Database and to make necessary changes to make the behavior and durability similar to an IED robot. An IED robot is designed to be durable, and failures with IEDs typically involve "improper design" and "improper (human) operation" (Nguyen-Huu & Titus, 2009). An IED robot is fairly robust with its ruggedness and computer monitoring but is not exempt from failure. To account for the low probability of failure, the model assumes an incapacitation probability of 2 percent. This means the probability of the IED robot becoming incapacitated is very unlikely. It was also necessary to increase the speed of the robot. The TALON, which is widely used in combat, travels at a maximum speed of 6 mph, or approximately 2.7 m/s (*TALON: Medium-Sized Tactical Robot,* 2019). This pre-determined specification gives us the simulation speed for the robot, which is significantly quicker than the sapper from the base model. The robot can move quicker than the sapper and still provide reconnaissance to the units in the rear. To simulate the robot sending a transmission to the robot operator to communicate with infantry teams, the agent acting as the robot sends a message to the teams and directs them to move forward. The third aspect of the robot is the breach time. Due to human factors, such as nervousness and fatigue, it was assumed that the breach time would be better but marginally less than the sapper. To account for this marginal difference, the robot's breach time is 20% better than the sapper time.

To capture the integration of the robotic mule (SMET) in the altered model, the model changes the physiological factors. There is no way to create the mule in IWARS and emplace equipment on a device, so it was necessary to alter human factors to mimic the decrease in load. If the soldiers are placing rucks, communication devices, and other equipment on the SMET, the model assumes that the soldiers will move quicker, react faster, and react more accurately. The fatigue and decreased speed experienced in the first model should be mitigated in the altered model by implementing the SMET. The model these changes, the speed of individual soldiers increased from 1.1 m/s to 1.6 m/s. This number was determined by assuming that removing the 100-pound ruck will increase the speed by nearly 70% since there is minimal restriction due to weight. The next assumption is that the Correct Force decreases by over 50%, meaning it is over two times easier to accurately determine the type of agent. Along the same lines, the Force Call probability increased to 0.9 for friendly forces detecting other friendly agents, and 0.8 for detecting civilian or enemy forces. These assumptions come from ease of determining your own forces due to uniform and protocol and an increase in awareness from the lack of fatigue. The comparison of variables between the two models is found below in Table 1.

5. Analysis

IWARS has an additional program named BRASS that collects data from a series of random runs and organizes the information to determine casualty rates and number of shots fired. The simulations are replicated 50 times running for five minutes each. Fifty runs were found to be sufficient for a 20% desired relative precision and a 95% confidence interval, based on Equation 1.

The analysis quantifies soldier lethality and survivability by determining how many red and blue deaths occurred respectively. The base model contains a total of nine blue personnel, including the sapper agent that is controlling the robot. In the altered model an additional agent is added to simulate the IED robot to make the total number ten. The base and altered models both contain four enemy and four civilian agents. The average number of Blue KIA is 5.86 in the base model, which decreased in the altered model to 4.16 with a standard deviation of 1.53 and 1.20 respectively (See Figure 4). This data shows the decrease in number of friendly casualties with the implementation of robotics in a tactical scenario, and less than half of the agents dying on average. With respect to the number of enemy casualties, the average is 3.72 with a standard deviation of 0.64 for the base model and 3.92 casualties with a standard deviation of 0.27. This indicates that there are substantially more missions where all the red forces are killed. These numbers show on average the increase of the number of enemy force casualties (See Figure 4).

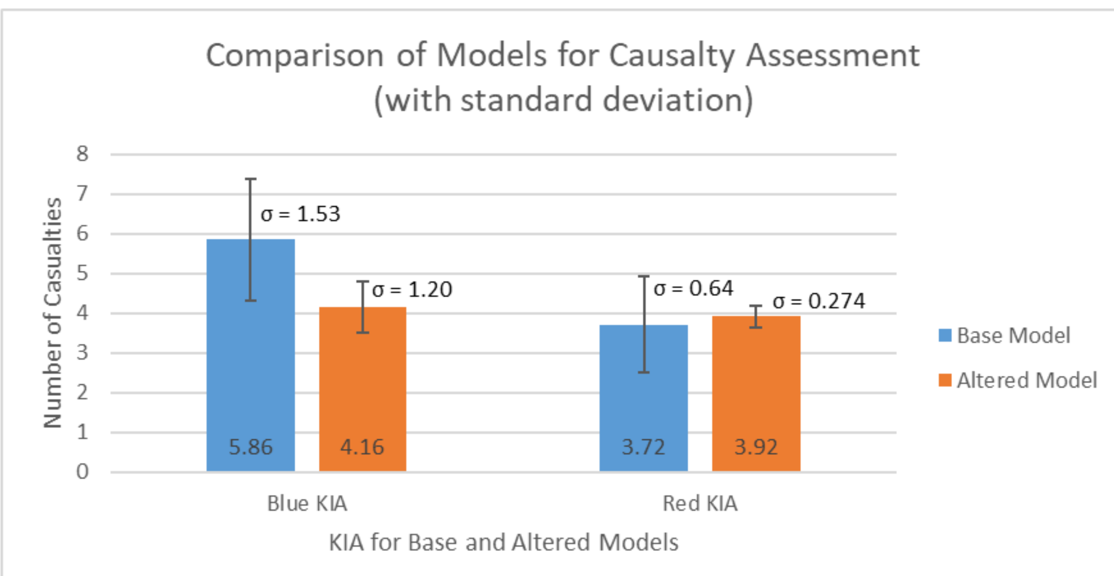

Figure 4. Comparing the number of friendly and enemy casualties between the models

After collecting the averages and standard deviations for the number of individuals killed in action, the data was transformed into confidence intervals for further analysis. Confidence intervals for number of casualties were calculated using Equation 1:

$$CI = \bar{x} \pm t_{\alpha,n-1} \frac{s}{\sqrt{n}} \quad (1)$$

The confidence interval is equal to the average of the sample, $\bar{x}$, plus or minus the t-value of a 95% confidence interval for a sample size, n, multiplied by the standard deviation, s, over the square root of the sample size. The study utilizes a 95% confidence interval to maximize the confidence in the mean for the sample size of KIA. The confidence intervals for the number of both blue (friendly) and red (enemy) personnel killed in action is displayed in Table 2.

Table 2. Confidence Intervals for KIA

95% Confidence Interval for Blue and Red KIA			
	Name	*Lower Limit*	*Upper Limit*
Blue KIA	Base Model	5.505	6.215
	Altered Model	3.881	4.440
Red KIA	Base Model	3.571	3.869
	Altered Model	3.856	3.984

The data concludes that the study is 95% confident that the number of friendly casualties lies between 3.881 and 4.440 for the updated model, well below the confidence interval for the base model. When looking at the average number of Blue KIA, there is approximately a 30% decrease in casualties with the implementation of robotics in the infantry squad. One may initially assume that the change is due to replacing the sapper with a robot meaning there is one less death immediately, but the model is showing that there is a larger impact due to the changes in performance data as well as the need to not provide cover for a robot. The reduction in Blue KIA is partially due to the sapper operating the UGV from a remote location, hence enhancing their survivability. An additional increase in blue survivability was realized from the infantry squad not needing to provide cover for the sapper which allows them to not be exposed to enemy fire during the breach stage of the mission. When observing each individual run, most of the friendly casualties occurred when the teams subjected themselves to enemy fire while providing cover. These individual observations helped determine the impact of removing human agents from the mission prior to breaching the minefield. Not only are more friendly forces surviving missions, the average number of enemy soldiers killed in action increased from 3.72 to 3.92, over a 5% increase.

The data collection also allowed the study to focus on the number of shots fired from the friendly force. The hypothesis is that the robotics model will have fewer shots fired because of a decrease in reaction time and force call probability. The altered model also removes the need of an infantry team having to provide cover for the sapper, contributing to the decrease in number of shots fired. Figure 5 shows the average number of shots for each model with their standard deviations. This data shows that over 50 runs, the number of shots on average decreased by approximately 29%. The base model data shows an average of 143 shots fired per scenario with a fairly wide standard deviation. When robots are introduced to the simulation, the average number of shots decreases to 101.48 and the standard deviation becomes tighter. This means the agents in the second model are becoming more consistent with shooting and do not need to fire their weapons as much to defeat the enemy.

The final aspect the study looked at is the number of civilian casualties. Four civilians were taken hostage and positioned next to the enemy personnel, two in each building. Due to the decrease in force call probability, it was predicted that the friendly force would have trouble differentiating between a combatant and non-combatant, leading to more civilian deaths on average. In the second model, the integration of robots increases the force call probability, ultimately leading to the hypothesis that fewer scenarios would have civilian KIAs. Figure 6 shows the aggregate number of non-combatants killed out of the 50 runs, indicating an increase in civilian deaths in the base combat simulation. The collected data directly shows a correlation between the integration of the robotic mule and IED robot and civilian deaths. It can be inferred that because the physiological responses are strengthened in the altered model, the friendly forces are more likely to hit the proper target and decrease harm to noncombatants.

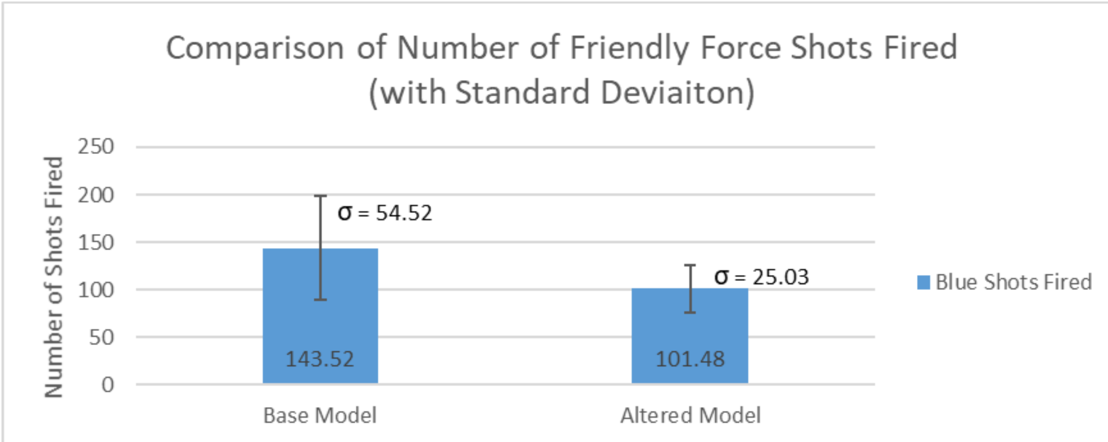

Figure 5. Number of friendly shots fired for both models

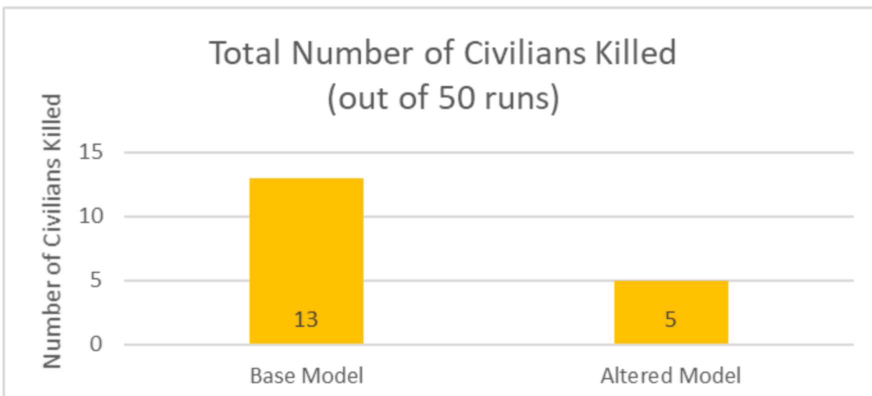

Figure 6. Total number of civilian casualties out of 50 runs

6. Model Limitations

Although the model gives valuable data showing the benefits of implementing robotic technology into warfare, it is important to note the limits of the model. As stated before, IWARS has not integrated UGVs into the software. Although a model can be built with unmanned aerial vehicles and other modes of transportation, there is currently no device that fully mimics the use of UGVs. The model had to specifically tailor a system using the IWARS database to act in a manner that is concurrent with UGV operation.

The study is also limited by the mission set. Each model simulates an urban operation with an infantry squad destroying enemy personnel in adjacent buildings. The study chose to focus on a single model to gather enough data for analysis and is not applied in other environments. The main reason for this is because urban operations are relevant to current combat scenarios, especially since IEDs are common in high-population areas. It would be beneficial to see the effects of robot integration in rural areas, within larger units, or with a different mission set.

The third and final limitation of the model is the number of runs to collect data. Since data collection occurs over a long duration, the sample size was only 50 replications. By only having 50, the confidence intervals could not be as accurate as possible and the data may possibly be skewed. Moving forward, it would be beneficial to conduct output analysis and determine the number of runs necessary to obtain a reasonable confidence interval.

7. Conclusion and Future Work

Robotics is a field that remains relevant to the United States Army. General Mark Milley notes that robotics plays "a limited role on the ground" and expects there to be a "rapid introduction of robotic systems in ground warfare" (Lopez, 2017). The nature of warfare is rapidly changing and it is important to determine what the new environment will look like. Even today, TARDEC is requesting a West Point capstone group to design and build a robotic system to interface with the SMET and IED robot. The models that this study analyzes incorporate the new technologies to determine the effects on friendly, enemy, and civilian forces. When robotic devices are introduced into the combat scenarios, the number of friendly casualties on average go down, meaning an increase in soldier survivability. The Army wants to protect its soldiers and increase mission readiness, and the data proves the benefits of implementation.

Looking toward the future, further simulations should be developed involving new terrains and a multitude of enemy forces. With the rise of a near-peer threat in Russia, it is important to analyze how robots could help or hinder operations against a sophisticated force. Although the implementation of robots appears to benefit urban operations, it would help to consider the effects of cyber attacks and enemy robotic capabilities.

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