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The Effectiveness of Armoured Vehicles in Urban Warfare Conditions

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ABSTRACT

Since the Second World War, the major armed conflicts have been occurred in or in the vicinity of the urban areas rather than rural areas, amongst conventional armies and armed groups or terrorists/insurgents. The architectural and construction characteristics of the urban area increase the opportunities for armed groups to ambush, easily escape, conceal, relocate and attack. Additionally, the narrow streets, the blocked roads by the debris of buildings, and IED threats make the urban areas one of the most dangerous conditions for infantries and armoured vehicles. The majority of present armoured combat vehicle types due to the limited visibility, low manoeuvre capability, and limited firing power, they are insufficient for performing the standalone operation without infantry forces and combat engineer support in urban warfare conditions. In this study, 13.400 data belonging to 676 attacks towards armoured vehicles during the counter-terrorism operations against PKK/PYD and ISIS in the urban areas were analysed within the perspective of forensic science techniques such as forensic ballistics and shooting reconstruction. According to the examinations and analyses carried out within the scope of this study; the leading critical features that an armoured combat vehicle that will operate in the urban areas may be listed under five general headings: Structure, Ballistic Protection and Armour, Self Defence and Weapon Systems, Situational/peripheral Awareness and C4I2 Systems and Integrated Warfare Systems.

Keywords: Urban warfare; Armoured vehicles; Improvised explosive device; Ballistic protection

1. INTRODUCTION

From the last 25 years, most of the armed conflicts have erupted among regular armies and terrorist/insurgent groups in urban areas rather than conventional war of two regular armies. The urban areas are the centre of strategic infrastructure, public institutions, health facilities, religion places, economic and social life centres. According to UN estimations that by 2050 over 68 percent of the world's population will live in urban areas[1]. Due to these characteristics of demography, the large-scale armed conflicts have been taking place in or in the vicinity of the urban areas since the Second World War[2]. The axiom of Sun Tzu on the urban warfare is "The worse policy is to attack cities. Attack cities only when there is no alternative"[3]. In addition, the architectural and construction characteristics of the urban area increase the opportunities for armed groups to conceal, relocate and attack (Fig. 1). These characteristics of the urban areas make as a target and conflict area of terrorist groups.

The effectiveness of armoured vehicles was mentioned at first by Leonardo da Vinci and he designed the first tank concept[4]. The armoured vehicles provide both the precision firepower with remote-controlled weapon systems and ballistic protection for infantries during the penetration of enemy lines. But in urban warfare conditions, armoured combat vehicles due to the limited visibility, low manoeuvre capability, and limited direct firing power, very vulnerable and easy targets for RPG and anti-tank weapons, they cannot perform the standalone operation without infantry forces and combat engineers support[5].

The point of this study is analysing and defining the effectiveness and technical requirements of armoured vehicles according to urban warfare conditions.

2. METHODOLOGY

In this study, 13.400 data belonging to 676 attacks towards armoured vehicles (wheeled and light combat, reconnaissance or personnel carrier armoured vehicles) during the counter-terrorism operations against PKK/PYD and ISIS in the urban areas were analysed within the perspective of forensic science techniques such as forensic ballistics and shooting reconstruction. These attacks were committed with a wide variety of weapons such as small arms and light weapons – SALW (assault rifle, anti-material rifle, sniper rifle), IED (Improvised Explosive Devices), EFP (Explosively Formed Projectiles), and RPGs. Since more than one attack was carried out on some of the armoured vehicles at different times, the number of attacks analysed was higher than the number of armoured vehicles. Due to the security and confidences regulations, this study cannot disclose the attack incidents' information.

The armoured vehicles designed according to conventional armed conflict conditions need to be modified and redesigned, depending on the characteristics and requirements of the urban warfare environments. Within the scope of the study,

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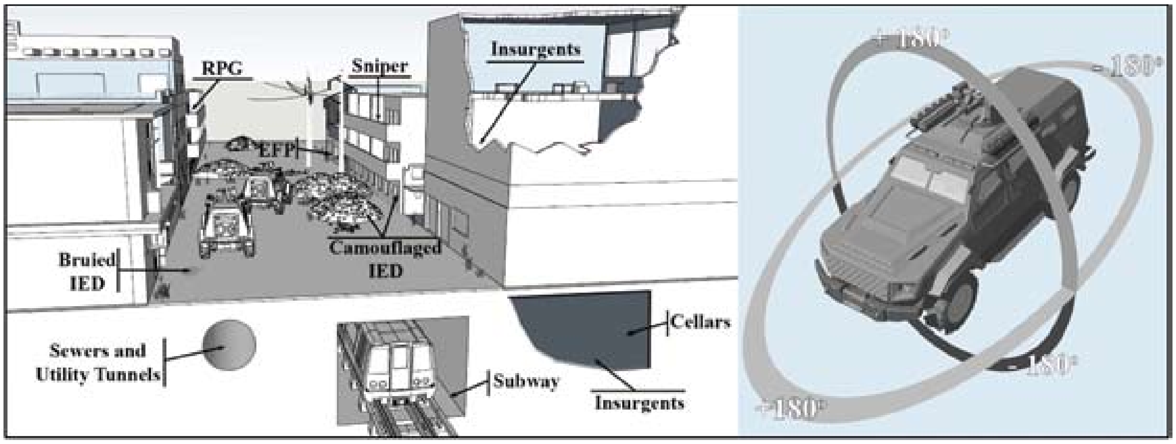


Figure 1. The multidimensional urban warfare conditions and 360°×360° threats.

the data of attacks are analysed and the characteristics that the armoured vehicles should have in accordance with the urban conflict conditions are evaluated beneath five main headings that mentioned below.

(i) Structure specifications
(Ii) Ballistic protection and armour specifications
(Iii) Self defence and weapon systems
(Iv) Situational/peripheral awareness systems
(V) C4I2 systems and integrated warfare systems.

3. RESULTS AND DISCUSSION

3.1 The Analysis of Attack Incidents

The attack incidents towards armoured vehicles were examined an aspect of the types of weapons, attack range, attack directions and the effects of RCWS (Remote Controlled Weapon Systems) and situational/peripheral awareness systems on the attack ranges. As mentioned in the methodology, the attacks on the armoured vehicles were committed with small arms, IED, EFP, and RPGs. The percentage distribution of attack types is shown in Table 1.

Table 1. The percentage distribution of the 676 attacks based on types

SALW	RPG	IED	EFP
80 %	5 %	12 %	3 %

Due to the nature of urban warfare, infantry conflicts are the majority and the usage rate of SALW in attacks is more than other weapon types with the 80 percentages. The RPG attacks were less than IED attacks. One of the reasons is the need for a minimum of 20 meters to standoff the distance between launcher and target in order to avoid explosion debris and shrapnel. And also, there should be at least 30 meters clear standoff distance from the backside of the launcher to avoid the firing back blast[6]. So, terrorists have to get out of their dugouts for using the RPG and in this case, they become targets for security forces. Because of these operational limits, the usage of RPG in urban warfare conditions wasn't as common as SALW. There are unlimited suitable concealing places for deploying the IEDs in the urban areas, such as debris of buildings, manhole, culverts, post, cable tv or telephone cabins, trash containers, parked vehicles, under the paved roads, and buildings. The 12 % of attacks to armoured vehicles were carried out with IEDs. And in these attacks, approximately 50 kg TNT or equivalent explosives (Table 2) were used in the IEDs. These amounts of explosive are caused devastating effects for armoured vehicles. It is observed in this study is 50 % of the SALW attacks and 60 % of RPG attacks have occurred in 50 meters or fewer ranges. The other data from this study on the attack distance is that the minimum attack range to RCWS equipped armoured vehicle isn't less than 40 meters.

Table 2. The relative TNT factors for equivalent explosive calculations[7]

Explosives	The relative TNT factor	Explosives	The relative TNT factor
Ammonium nitrate	0,42 / 0,56	Amatol %50AN/%50TNT	1,24
Black Powder	0,50	Tetryl	1,25 / 1,30
Mercury Fulminate	0,51	C3	1,26
ANFO	0,74	C4	1,30 / 1,34
TATP	0,80	Semtex 1A	1,35
Ammonium Picric	0,99	A3	1,35
TNT	1,00	Nitro-glycerine	1,40 / 1,54
Nitro Guadin	1,04	RDX	1,51 / ,60
Nitrocellulose	1,10 / 1,25	PETN	1,45 / 1,66
Picric Acid	1,12 / 1,17	HMX	1,50 / 1,70

The weapon threats and attack angles of the conventional combat conditions (Fig. 2(a))[8] are different than urban or irregular warfare conditions (Fig. 2(b)). Because of the terrorists or insurgents deploy at the upper storey of the buildings in the urban warfare conditions, the armoured vehicles are at a lower level, and the SALW and RPG attacks occur at high angles to 60 degrees; or in some incidents, the insurgents deploy at the underground levels and attack to the armoured vehicles from −5 degrees angle[9]. In the attack incidents examined within the scope of this study, it was determined that shots fired from the basements of the buildings with -10 degrees angle (Fig. 2(b)). The 15 percentage of the attacks examined within the scope of

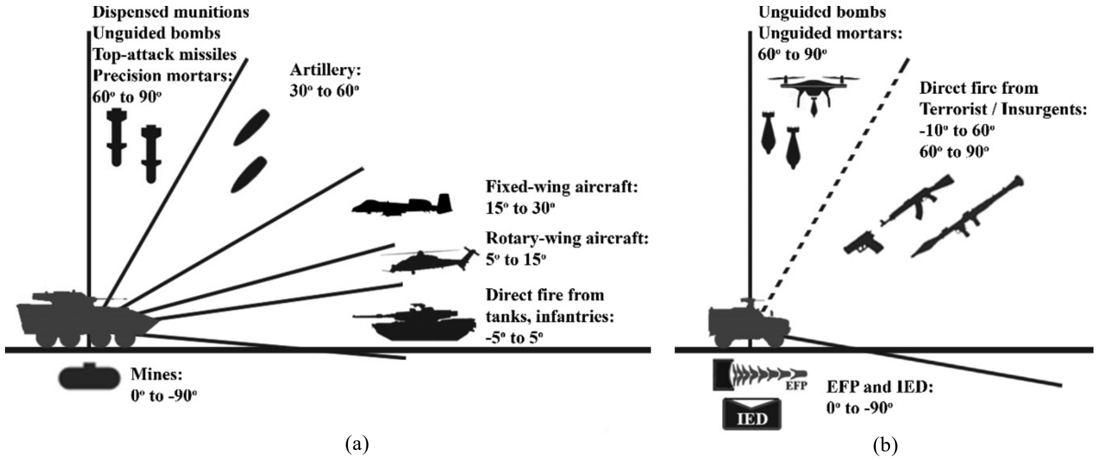


Figure 2. (a) Conventional combat condition vertical attack angles (Re-Illustrated)[8] and (b) Urban/irregular warfare condition vehicle attack angles.

this study were directed to the roof of the armoured vehicles from the upper storey of the buildings (Fig. 3(a)).

The other difference is observed in the mine, IED and EFP threats. In conventional combat conditions, the mine threats are defined in the different military standards or international agreements. However, in the urban warfare conditions, the IED and EFP threats' levels are in a wide variety and it depends on the provided explosive amount and insurgent's imaginary power. In some cases, 50 kg TNT is used in IED-making and in some cases, 500 kg ANFO can be used. There is no standard in this regard nor is there a protection standard for these amount explosives. As mentioned before the 12% of examined attack incidents in this study were carried out with the IEDs, and the 4% is *roadside* and *V-IED* (Vehicle Improvised Explosive Devices), 5% is *buried*, and 3% is placed in the *culverts*.

The azimuth attack angles distribution of the examined incidents mentioned in the Fig. 3(b). Most of the attacks occurred in front of the vehicles with 32 percentage. The right side of the vehicles in the second line with 31 percentage. The driver side is in the third line with 26 percentage and the backside of vehicles is the last line with 11 percentage. There are operational and tactical reasons for the highest percentage of the attacks is on the front side of the vehicle. The operational reason is that the front side of the armoured vehicle due to the moving direction is longer duration on the firing line and the terrorists have more opportunities for attacking. One of the tactical reasons for the frontal attack is that the motor compartment, wheels, and driver aimed and also the front part of the vehicle is to first to enter the target/sight area of the insurgents. The second reason is that the RCWS's optical instruments and ammunition box are targeted by the insurgents. Additionally, the front wheels and steering systems of the armoured vehicles are the most vulnerable parts. In order to immobilise the vehicle insurgents attack wheels, steering system and components with the small scale IED and anti-personnel RPG projectile.

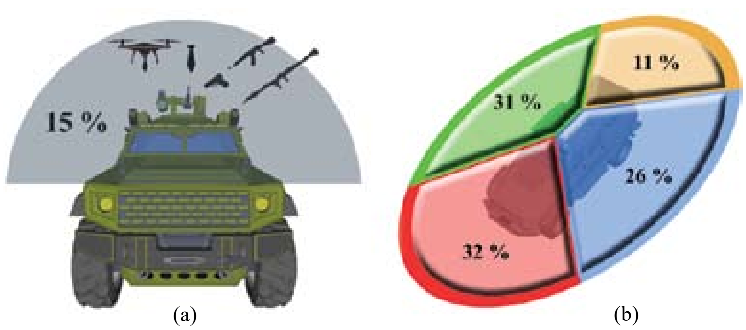


Figure 3. According to examined incidents the distribution of attack angles.

The right side of the vehicles with 31 percentage and left side with 26 percentage were targeted (Fig. 3(b)). Although there is not a significant difference between the attacks on both sides of the armoured vehicles, one of the reasons for the higher number of attacks from the right side is that the vehicle driven closer to the right side of the road in normal traffic conditions and this provides an advantage to terrorists for attacking from this side.

Depending on the direction of the armoured vehicle movement, the vehicle stays on the firing line for a shorter period of time, the firing range increases, and the hit probability decreases. Consistent with this assessment, only 11% of the attacks examined within the scope of the study occurred to place on the back of armoured vehicles.

3.2 The Evaluation of Attack Incidents

The armoured vehicles attacks are evaluated in accordance with urban warfare conditions, needs and requirements and beneath four main headings mentioned below.

3.2.1 Armoured Vehicle Structure Specifications

As mentioned in the previous paragraphs, armoured vehicles should be designed or modified according to the specific conditions and needs of urban warfare. First, the concept of a single-type and multi-role (all-in-one) vehicle for performing each task ought to be given up, and armoured vehicles should be classified as armoured personnel carriers, tactical light combat vehicles, and armed reconnaissance vehicles. The tactical light combat vehicles and armed reconnaissance vehicles are the best solutions with their optimised dimensions, armour systems, high manoeuvrability, and weapon systems for the urban warfare. With the three crews (driver, commander, RCWS operator) and two infantry carrying capacity, the tactical combat vehicle's personnel compartment should be monocoque hull structure and provide the 360×360 degrees ballistic protection. The distance between the front and rear drive-shaft should be shortened for increasing the manoeuvrability. And The personnel compartment should be localised on the gravity centre between the front and rear drive-shaft for good balance.

IED constitute the most widespread and destructive threats in urban conflicts. For increasing the ballistic and blast protection of the underneath hull armour shape of armoured vehicles ought to be designed with the "V-shape" hulls for the dispersing and reflecting the explosion pressure. And the ground-clearance should be a minimum of 40cm. Additionally, the inner compartment base (floor) plate should not directly contact the belly armour of the vehicle hull[8-10].

The doors' shape, opening directions, numbers and the durability of hinges are another important design issue. To increase the ballistic and blast protection, the minimum door place ought to be on the hull. Predominantly, the three-door configuration is used. If the five-door configuration applied, the front and rear door hinge direction should be opposite to each other. In this design, a sheltered (Ballistic Protected) zone will be established between the front and rear doors that open to provide ballistic protection for infantry abandoning the vehicle (Fig. 4).

In addition, the current design of armoured vehicle doors makes it difficult to manually close the vehicle from inside thence the doors should be designed to be closed via a hydraulic or electric motor by remote control. The other risk of armoured doors is the breaking of latches, locks, and hinges with the explosion pressure and falling down. In this situation, the soldiers may be severely affected due to toxic gas and fire residues. Specifically, the designs of latches, locks, and hinges should be tested in the finite element models[11]. As a precaution, there should be the automatic mine-locks system on the armoured vehicle doors, able to be opened from the outside by rescue teams. Also, another the weak points of the armoured vehicle hull are the joints of the windows and firing port covers with the hull. In the IED explosion case, the covers and windows may throw inside and caused injuries. Thence the joints, locks, and slot design of the windows and firing port covers should be strengthened.

3.2.2 Ballistic Protection and Armour Specifications

In traditional armed conflicts, armoured vehicles are more likely to be hit from the front than in other directions; therefore, the front and side armours are usually thicker and the more protected than the backside and roof armour[12]. This is common practice to optimally distribute the vehicle armour regionally according to the threat severity aspects for the weight/horsepower efficiency of vehicles[8-10]. In the urban warfare conditions, the threat is 360×360 degrees and in 50-100 meters range. Conventional warfare conditions are defined as "horizontal conflict" and urban conflicts are defined as "vertical conflict". In the conventional conflicts, the firearms and rockets are threat between −5/+5 degrees elevation for the armoured vehicles, whereas, in urban combat, these threats are seen between −5/+60 elevation degrees. And according to the data concerning the urban warfare of the US army in Iraq and Afghanistan, and also the Russian army in Chechnya and the British army in Northern Ireland; the hit ratio of the roof armour of the armoured vehicles in urban conflicts is between 17% and 20%[5-8-13]. Therefore, it is expected that the armoured vehicles to be used in urban warfare will provide the equivalent level of ballistic protection on the side and roof armour panels. But as this critically affects the vehicle's weight/horsepower efficiency negatively; the modular and the hybrid composite armour solutions should be preferred which provide the lighter and the more effective protection of square meter weight.

The urban warfare conditions like narrow streets and passages limit the manoeuvrability of the armoured vehicles and increase the effectiveness of IED and EFP. Due to the IEDs and EFPs prepared with a high explosive charge the armoured vehicles must be designed according to the NATO AEP–55(C) Volume–3 standard, which defines IED threats rather than mine threats identified in NATO STANAG-4569[14]. Even this standard may be insufficient in some cases; for example, in the Middle East region, the IED explosive charge detected over 500 kgs. The armoured vehicle design procedures are highly cost and time consumer period. To reduce the production cost and short the research time, the finite element and experimental analyses programs should be implemented for the effective post-blast load calculation and the examination of the different vehicle hull geometry for dissipating the blast wave[15].

Notably in the Middle East region, the distinguishing characteristics of armed conflicts and threats are so dynamic. Terrorist groups obtain sophisticated weapons and modern ammunition from various sources and countries[16]. The exchanging of weapons, ammunition, and technologies among terrorist groups such as PKK/YPG, ISIS, and the Taliban is documented[17]. These terrorist groups also produce sophisticated weapons and/or ammunition. For instance, the workshop

Figure 4. The sheltered (ballistic protected) zone provided by the armoured doors.

manufactured 12,7×108mm and 14,5×114mm calibres anti-material rifles are produced by terrorist organisations in the Northern Syria region[18-19]. According to this ballistic threat diversity and more severity than 7,62mm AP-I ammunition, the ballistic protection of armoured vehicles should be upgraded with composite add-on armour sets[20].

The moving armoured vehicles are the difficult target for RPG or Sniper attacks. To immobilise the vehicles; the drive components of wheels are commonly targeted via the small scale IED and anti-personnel RPG projectile attack. These components and equipment should be shielded against small scale shrapnel and fire. Besides, all of the tires should be a run-flat-tire system against bullet hits and burst. But in the massive multi shrapnel hit conditions, the run-flat-tire system also might be inadequate (Fig. 5). In this case, the industrial heavy load vehicle rubber solid-tire technology may be adaptive to armoured vehicles according to the military-standards.

3.2.3 Self Defence and Weapon Systems

The RCWS adequately provide the advanced tactical precision firepower in the urban warfare conditions such as within the limited sight and awareness states, under the intensive enemy fire, and narrow roads, in all weather conditions. Besides these advantages RCW System generates negative psychological effects on the terrorists[22]. On account of these tactical advantages of the RCW systems are the priory target of the terrorists' sniper and rocket attacks. With the purpose of disabling the RCW systems, the electro-optics systems, the weapon's ammunition feeding mechanisms, and the elevation/azimuth motors are intensely targeted. In order to provide ballistic protection to the RCWS, the upgrades mentioned below should be made:

a. The electro-optics systems' bodies should be shielded by composite armour panels and the optic parts/lenses should be protected with AION.
b. The weapon's feeding mechanisms and the elevation/azimuth motors should be shielded by composite armour panels against the attacks from upper side and side surfaces.
c. The ballistic protection level for the electro-optics, the weapon's feeding mechanisms, and the elevation/azimuth motors should be minimum NATO STANAG-4569 Level-1.

The RCWS have two critical usage difficulties in urban warfare situations. The first of these is about the feeding mechanism. Most of the RCWS have an external ammunition box and the staff have to get outside of the armoured vehicle for changing the ammunition box and loading the weapon. While the loading procedure, the crew is the indefensible position toward the foe shooting threat. Thereof the in-hull loading/feeding systems of the RCWS may be developed.

The second difficulty of using the RCWS is that the low elevation angles are insufficient to close the targets on the upper floors of the multi-story buildings from close range. In order to decrease the above dead space, the elevation angle of the RCWS barrel should be at least +75 degrees (Fig. 6)[23]. The fact that the Russian T72 main battle tank barrel couldn't be directed higher than +14 degrees and lower than -6 degrees in the Grozny war created wide dead zones. The Russian army used the ZSU-23-4 aircraft repellent system with an elevation angle of +85 degrees to compensate for this weakness (Fig. 7)[24]. Additionally, in the near future to maximise the tactical and strategic mobility in the narrow and ruined harsh streets, the 105mm gun equipped middle-class tanks can be effective with direct fire capability in the -10 / +42 degrees elevations. [25-26-27].

The accidental firing is a major risk of RCWS and for investigating the case of unintentionally firing, the system should have a recording system for monitoring the RCWS's motors, switches, signals, barrel orientations, and weapon trigger. Additionally, the cameras' records should be an undeletable format.

According to the experience gained during urban warfare; the 12,7×109 mm calibre machine guns with armour-piercing ammunition and the 40mm automatic grenade launcher with thermo-baric ammunition are remarkably effective against the terrorists' positions. In this circumstance, the RCWS should be the dual weapon in the combination of 12,7×109 mm main weapon 7,62×51 mm co-axial weapon or 40mm grenade launcher main weapon 7,62×51mm co-axial weapon. The new weapon system of the armoured vehicles for urban warfare is Laser Defence System (LSS). The LSS can be used

Figure 5. The example of the massive shrapnel damage on the run-flat-tires[21].

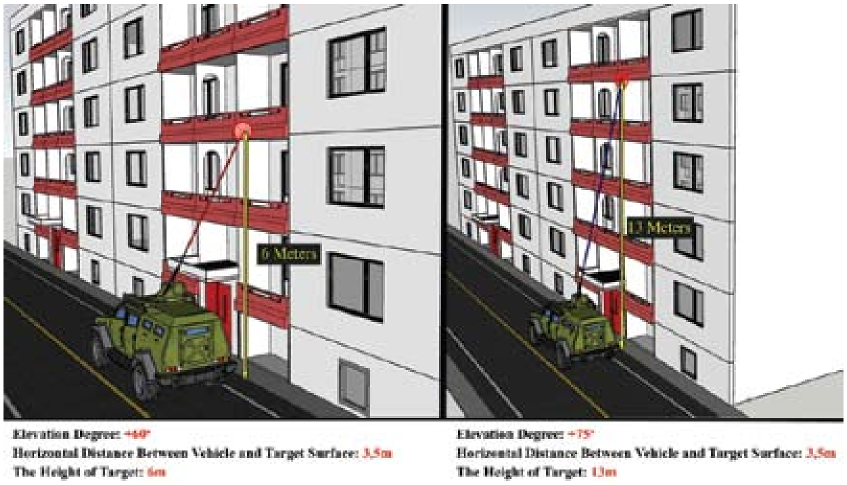
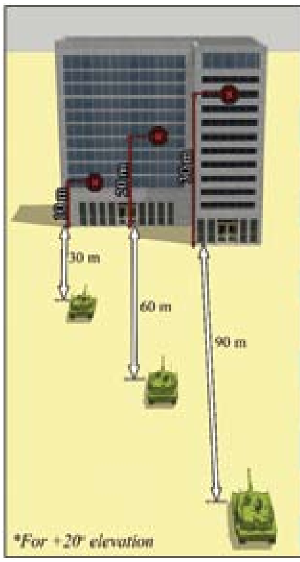


Figure 6. The comparison the +60° and +75° elevation angles of RCWS.



The Elevation Angles of Tank Main Guns

Leopard 2A4	**-9°**	**+18°**
Challenger 2	**-10°**	**+20°**
Leclerc	**-8°**	**+15°**
M60A2	**-10°**	**+20°**
M1Abrams	**-9°**	**+20°**
T55	**-5°**	**+18°**
T62	**-5°**	**+18°**
T72	**-6°**	**+14°**
T80	**-4°**	**+18°**
T90	**-6°**	**+14°**
K1A1	**-10°**	**+20°**

Figure 7. The comparison table of the elevation angles of tank main guns[23-28].

for destroying the mini and micro UAV threats, cleaning the camouflages such as visual obstacles (ex. tarpaulin), disposing of the buried/camouflaged or the deployed roadside IED, and dismissing the suspected packages from at least 200 meters[29].

In urban warfare, the anti-tank shaped charge rocket projectile attacks against the armoured vehicles occur mainly in the range of 30-50 meters. The rocket nets or metal bar/slat armour systems[30-31-32-33] are widely used as the passive protection systems against this kind of threat. Since the passive rocket protection systems disposing of the detonation system by using the kinetic energy of the projectile, the higher the speed of the projectile, the greater the efficiency of the protection system. The most common anti-tank shaped charge rocket projectile is the RPG ammunition. This type of projectiles reaches the maximum speed between 200 – 250 meters, 11 meters after leaving the barrel. In this context, considering the urban warfare rocket attack range, the passive rocket protection systems should be able to capable of disposing of the rocket detonation system in 30 meters or less ranges.

With contemporary technological developments, active protection systems are available for armoured vehicles. The active protection systems (APS) are a countermeasure technology for disposing of the ATG missiles and RPGs. The active protection systems are divided into two types the soft-kill and hard-kill systems. The soft-kill technology can't affect on the unguided projectiles such as RPG-7. The more proper solution is a hard-kill active protection system for the RPG and ATG missile threats in the short-range[34]. The critical issue is minimising damage or injury to nearby the allies[35]. The last protection layer of the armoured vehicle against RPG and ATG missiles is the Spall-Liner panels. To reduce the shrapnel injury, the interior surfaces of armoured vehicles should be covered with the Spall-Liner panels. The Spall-Liner panels reduce the angle of the shrapnel dispersion cone and catching the most of fragments or shrapnel, and decreasing the rate of possible casualties[35].

The smokescreen or smoke grenade is typically used for masking and hiding the movement or location of armed units such as infantry, amphibious vehicles, tanks, aircraft or ships in the combat zone from the electro-optics systems and block the laser range finder or laser target designator sensors. In the conventional warfare concept, the smoke grenade launcher (discharger) or smoke dispenser nozzle direction and angle are determined and fixed concerning the dimension of the vehicle. Also, in the urban warfare conditions, the usage of the smokescreen method against the RPG and small arms assaults was very effective in Chechnya, North Ireland, Lebanon, and Iraq conflicts[36]. But in the urban warfare conditions, there isn't a specific threat direction or angle and the armoured vehicles may be needed the smokescreen in the various directions, angles as well locations. Therefore, the smoke grenade launcher or smoke dispenser nozzle direction and angle should be adjustable.

Gunshot location systems (GLS) are using for detecting the enemy gunfire or sniper/anti-material rifle positions by using the acoustic and optical technologies integrated with Geography Information Systems. In rural areas, GL systems effectively can be used by the infantries or as a platform on the vehicles[37]. GL systems can be connected and integrated with the RCWS and the RC weapon automatically directed the shooter position[38]. However, owing to the acoustic and optic confusions and reflections, the short distance between friendly and enemy fires, and also terrorist/insurgent snipers' countermeasures the mislead alarms may occur in the GLS in the urban warfare regions. Even though the GLS still isn't as reliable as in rural or peace time urban conditions, it undoubtedly gives an advantage to the armoured vehicles in the urban areas.

The other critical self-defence technologies of the armoured vehicles are in-hull explosion detection and fire suppression systems. When the RPG or ATG Missiles penetrate the armour, UV-IR sensors detect the fire in 3ms and suppression system is activated in 6ms. As mentioned before, the RPG threat is very common in urban warfare and explosion detection and fire suppression system will increase the survivability of vehicle.

In recent years in urban warfare in the Middle East region, one of the ancient defence techniques that stretching a rope between two buildings or trees for dropping the driver of the war cart or cavalry was seen. In the modern era, this technique has been used with the thick steel wire against the armoured vehicles' RCWS, and soldiers in the manual weapon towers. The countermeasure to the ancient time defence technique also comes from ancient times; the mounted "wire cutter" on the vehicle. The wire cutter is mounted in front or on the roof of the armoured vehicle and cut the wires are in the moving direction (Fig. 8).

3.2.4 Situational/Peripheral Awareness Systems

The first issue that stands out in the design of armoured vehicles is the reduced the number and size of windows. The major reason is that the areal density of the frequently used transparent Armor and the negative effect on the location of the vehicle's centre of gravity. During the design process of the armoured vehicles, the optimum location of the centre of gravity is calculated for advanced balance. As the nature of the IED protected vehicle designs, the ground clearance of the vehicle is a minimum of 40cm and the gravity centre is higher than standard military vehicles. In connection with this high location of the centre of gravity, the tendency of the vehicle to roll-over also increases.

The standard and commonly used soda-lime bulletproof glass's areal density is greater than most of the opaque Armor materials (Table 3). And if this type of glass is more used than the regular usage rate on the vehicle hull, the location of the centre of gravity moves to higher than normal as a result, the vehicle balance is lost especially in the curved roads and IED attacks. Therefore, the observation windows on the side of the vehicle are either small size or limited number.

However, one of the most critical weaknesses of armoured vehicles, especially in urban warfare environments, is the insufficient situational/peripheral awareness. Owing to most of the attacks are occurring in the urban from higher positions than the vehicle, observing the upper floors of the multi-story buildings is as important as observing the surroundings of the vehicle. Thence the additional ballistic protected observation windows should be installed on the roof Armor of the vehicle.

Table 3. The areal densities of ballistic armour materials[10-40-41-42]

Armour types	Ballistic armour materials	Areal density (kg/m^2)
Transparent armour	Soda lime glass	170
	AlON/Glass/PC	80
	Spinel/PC	58
	AlON/PC	51
	Sapphire/PC	51
Opaque armour	RHA (380 BHN)	114
	HHA (530 BHN)	92,8
	5059-H131 Aluminium alloy	136,2
	6082-T6 Aluminium alloy	56,2
	6061-T651 Aluminium alloy	138,2
	AZ31B-H24 Magnesium alloys	135,4
	AZ31B-O Magnesium alloys	55,8
	Alumina/5083	50
	B4C/6061	35

For increasing the situational/peripheral Awareness of the armoured vehicle crews, the electronic systems were also developed such as "360 Degree Visual Awareness" and "Driver Thermal Camera". The 360 Degree Visual Awareness system is an effective assisting driving system that the vehicle driver from being aware of potential accidents, especially during the manoeuvres in narrow streets or areas. The Driver Thermal Camera system with the front and back cameras is providing an ultimate advantage in inadequate light conditions and especially under dimming driving.

The telescopic mast surveillance system, which can observe the target area over the obstacles, ensure a critical capability in urban warfare, additionally be used without any preparation

Figure 8. The mounted wire cutters[39].

in the conflict zone. The telescopic mast surveillance system should rise at least 3 meters from the vehicle roof level, and consist of the thermal/day camera and laser range finder with motion detection-tracking software and be directly connected with the RCWS.

3.2.5 C4I2 Systems and Integrated Warfare

Urban war conditions are more dynamic and variable than traditional war. For this reason, it is very important to provide information on the current status of threats and the positions of friendly forces to the troops in the field. In this environment, today's effective Command, Control, Communication, Computer, Information and Intelligence (C4I2) capabilities can support the troops with the updated information, the detailed digital maps and real-time aerial video and photographs. Especially for the armoured vehicles with limited observation and visual contact capability in urban warfare conditions, the C4I2 technologies will increase their tactical and operational capabilities and survival chance[43-44].

4. CONCLUSIONS

Considering the weapons and defence technologies of conventional armies, small-scale armed insurgent groups or terrorists are expected to prefer urban areas as a battlefield to survive and succeed. The specific conflict characteristics of urban warfare have made it necessary to change the design of armoured vehicles produced for conventional war conditions.

First of all, in armoured vehicles, all-in-one concept design should be abandoned, and particular armoured vehicle design should be preferred according to the needs of armed conflicts in urban warfare. Compared to the variable ballistic threats of urban warfare, lighter and more effective composite modular armour systems should be implemented in armoured vehicles. Armoured vehicles must have active protection systems for self-defence against RPG and ATGM threats, and dual-weapon RCWS with a barrel upgrade of at least + 75 degrees.

C4I2 Systems and Integrated Warfare Systems and situational/environmental awareness systems must be brought to armoured vehicles in order to safely drive armoured vehicles with limited visibility and survival on the battlefield.

In the environment of increasing urban conflict in the near future, the most important support vehicles of infantry and special forces will be armoured vehicles with RCWS.

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