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Comparison of Ballistic Performance Between Conventional and Modern Artillery Weapons: A Review on the M777 Howitzer Cannon

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Abstract—Advances in artillery weapon technology have resulted in major changes in ballistic performance from conventional to modern weapons. Within this framework, our research investigates and compares the ballistic performance between traditional and modern artillery weapons, focusing on the M777 howitzer cannon as a modern representation. With a comprehensive approach, we evaluated key parameters such as effective firing range, precision, and resistance to environmental factors. We assessed the precision capabilities and operational range of the M777 in comparison to similar conventional weapons. We used both simulation and field-testing methods to collect essential data. The results of our analysis show that the M777 has advantages in precision of fire and effective range compared to conventional artillery weapons. Nonetheless, new challenges such as digital technology integration and environmental dynamics affect overall ballistic performance. This research provides valuable insights for the development of future artillery weapons and more flexible defense strategies.

Keywords—Artillery; Ballistics; Conventional Cannon; Modern Cannon; M777 Howitzer.

I. INTRODUCTION

Artillery weapons have been a very important part of military defense systems around the world for centuries. From ancient battlefields to modern conflicts, artillery remains a key ingredient in battle strategies (Ragaee et al., 2016). From traditional cannons to more advanced modern weapons, technological advancements have played a vital role in improving their performance and effectiveness in the field. In this process, there have been major changes in the ballistic performance of artillery weapons, especially when moving from conventional to modern weapons. One striking example of this evolution is the M777 howitzer cannon, which is the latest representative of advancements in artillery weapon technology (*The K9 Vajra, M777 and Artillery Tractors 2011.*, 2019). The M777 howitzer is one type of artillery weapon used by many militaries around the world, including the Indonesian Army. Some artillery weapons like the M777 Howitzer and used by the Indonesian Army include the KH-179 Howitzer, M71 and FH-70. With these various types of artillery, the Indonesian Army can conduct artillery operations with high flexibility, both in terms of firing range, mobility, and accuracy. The combination of these weapons allows the Army to face various challenges on the battlefield, ranging from conventional combat operations to special missions that require mobility and rapid response. The integration of advanced technology in targeting and fire control systems also helps to improve firing effectiveness, ensuring that each shot can have maximum impact on the target.

In contemporary military conflicts, the 155mm caliber M777 howitzer cannon artillery gun, a product of the United States, has been used by the Ukrainian military in battles against Russia. This weapon is renowned for its advanced and accurate capabilities. The M777 is one of the modern artillery weapons that has been adopted by various military forces around the world. Some countries

that use the M777 artillery howitzer as a weapon to strengthen their military include Australia, Canada, Italy, Saudi Arabia, Thailand, and Brazil. Apart from these countries, the M777 is also used by several other armed forces that recognize the superiority and reliability of this artillery system in modern military operations. The M777 howitzer is notable for its light weight, which is a result of the use of titanium material in its construction. This lighter weight allows the M777 to be transported easily by helicopter, transport aircraft, or even ground vehicles, thus enhancing operational mobility and flexibility in varied battlefields. A key advantage of the M777 is its ability to fire various types of ammunition with high accuracy, including precision-guided ammunition such as the M982 Excalibur. This allows troops operating the M777 to provide accurate long-range fire support and minimize the risk of collateral damage. In addition, the system has proven effective in a variety of combat situations around the world, including in areas with difficult terrain and in operations that require rapid response. With its superior reliability and firepower, the M777 continues to be the top choice for many countries looking to strengthen their artillery capabilities. With its superior technology and design, the weapon offers improvements in firing precision, operational range, and adaptability in various battlefields (Krause, 1916). Nonetheless, to truly understand the differences between conventional and modern artillery weapons such as the M777, a comprehensive review involving in-depth ballistic analysis is required.

This research aims to uncover the extent to which technological advancements have improved the effectiveness of modern artillery in meeting today's combat challenges. By exploring and comparing the ballistic performance between conventional and modern artillery weapons, this article will explore in depth the M777 Howitzer cannon. Factors affecting its ballistic performance will be analyzed, and its significant role in contemporary combat will be explained. It is hoped that through this comprehensive review, this article will provide military and academic readers with valuable insights to understand the important differences between traditional and modern artillery weapons and their strategic implications in modern combat dynamics.

Figure 1. Types of conventional cannon artillery (Howitzer, n.d.)

Figure 2. 155-mm M777 cannon with Lightweight Field Howitzer type (Howitzer, n.d.)

II. RESEARCH METHODS

This research applies a descriptive qualitative method with the aim of describing and understanding complex social phenomena, particularly related to disaster management policies and implementation in Indonesia. This method was chosen because it allows researchers to investigate various aspects that affect disaster management in greater depth. Data collection was conducted through a comprehensive literature study and direct observation, with a focus on obtaining in-depth data to gain a holistic understanding of the phenomenon under study (Hall, S., & Liebenberg, 2024).

This research aims to conduct a thorough review of the literature relating to the ballistic performance of artillery weapons, especially in the comparison between traditional and modern artillery weapons, with a focus on the M777 Howitzer cannon. A further objective was to identify trends, findings and gaps in the research that has been conducted on the topic using the Systematic Literature Review (SLR) method (Thomé et al., 2016). The literature search was conducted through several academic databases such as JSTOR, Google Scholar, ScienceDirect, and DOAJ, using relevant keywords such as "Howitzer M777", "modern artillery weapon", "ballistic performance", and "conventional artillery weapon". The range of publication years considered was from 1974 to 2024, with a focus on quality literature from relevant journals or conferences. Literature selection was rigorous, prioritizing relevance to the research topic, scientific quality, clarity of research methodology, and peer reviewed. Each selected article will be data extracted, including information on the research design, methodology, main findings, and relevant conclusions. The extracted data will be organized into a synopsis for each article, and then synthesized to provide a comprehensive overview of the research topic (Moher, D., Liberati, A., Tetzlaff, J., & Altman, 2010).

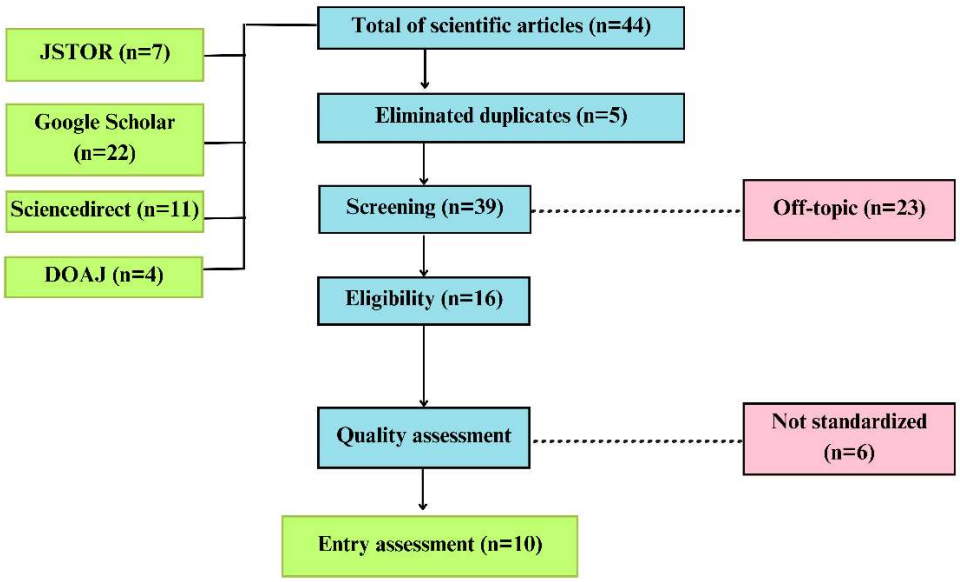

Figure 3. SLR diagram

III. RESULTS AND DISCUSSION

Based on the method, the relevant literature is obtained, namely:

Table 1. Comparative research results of conventional and modern artillery

No.	Researcher (Year)	About	Ballistics	Research Results
1.	Alan Catovic, et al (2024)	Estimation of stresses on 155mm artillery projectiles during launch phase.	Internal ballistics	No plastic deformation occurs during launch even if the base pressure value, interior ballistics data, is increased by 20% (for a safety measure in the hole) (Catovic et al., 2024).
2.	Al-Desoky Ezzat Sayed, et al (2016)	M777 155mm Velocity Enhanced Long-Range Artillery	Ballistic External	Projectile Maximum range 41 km at long barrel 39 times caliber and maximum range 55 km at long barrel 52 times caliber (Sayed, 2016).
3.	Yu-wei Wang, et al (2018)	Deterred propellant with large web size	Internal ballistics	The burning rate law of deterred propellant with large web size can be obtained by closed bomb experiments (Wang et al., 2018).
4.	Rastislav Balon, et al (2006)	155-mm ERFB/BB Projectile Trajectory	External Ballistic	Point Mass Trajectory Model modified with additional provisions for projectile Base. Burn standardized to STANAG 4355 (Balon & Komenda, 2006).
5.	Bernadette Quémerais, et al (2015)	Characterization of atmospheric emissions	External ballistics	Potential health risks associated with particle exposure for artillery soldiers. Formaldehyde was also detected at concentrations of 7.1 and 3.6 µg/m3 for the left and front locations, respectively (Quemerais & Poulin, 2015).

6.	John J. Ritter, et al (2010)	Dynamic Pressure	Internal ballistics	Pressure decays rapidly, in milliseconds, as the projectile moves down the barrel, then high pressure for a longer period of 30-60 seconds, before exploding (Ritter et al., 2010).
7.	Nikolaj Dobržinskij, et al (2009)	A Short-Barrelled 105-mm Howitzer	Internal ballistic	Instability of resistance to projectile motion, or as we will identify here, pressure resistive (Dobržinskij, N., & Juozapavičius, 2019).
8.	J. R. Kelso, et al (1979)	Ballistics Perforati on Propellant in the 155-mm	External Ballistics	The specific benefits demonstrated are: (1) lower nominal pressure wave levels; (2) less round-to-turn variability in the pressure wave; and (3) lower sensitivity of the maximum chamber pressure to the variability of the pressure wave (Kelso, 1979).
9.	H. A. Abou-Elela, et al (2014)	Effect of Base Bleed Dimensions	External ballistics	The range of base bleed projectiles increased by 1.7% when compared to its counterpart supplied with a base bleed unit having a constant exit diameter and the same base bleed grain (Abou-Elela et al., 2014).
10.	Kostiantyn Boriak, et al (2023)	Ballistic Characteristics of Artillery Projectiles of 152- and 155-mm Calibers	External Ballistics	When flying along a ballistic trajectory, the projectile rotates in the air with a high angular velocity in the range of 200-500 revolutions/minute, and therefore, the dynamics of its rotating motion is like the rotation of a rigid rotor. By virtue of the presence of manufacturing tolerances in the metalworking of the body, an artillery projectile can have a large amount of dynamic imbalance and imbalance, which can exceed the allowable norm for rigid rotors by 15-20 times and unexpectedly affect the dynamics of the projectile when moving along the ballistic trajectory (Boriak, 2023).

Based on the systematic literature review (SLR) above, the authors describe that in the following discussion:

A. Conventional Artillery

Conventional artillery weapons are a type of combat equipment that uses the thrust from propellant explosions to deliver projectiles to distant targets. Their function is essential in the military force structure to support operations on the ground as well as influence combat from a distance. Conventional artillery weapons generally include cannons, howitzers, mortars, and artillery rockets (Catovic et al., 2024).

1. Cannons are artillery weapons that have long barrels, placed either on land or on ships. These cannons often have a wide range and high accuracy, which makes them well suited for striking distant targets with great accuracy.
2. Howitzers are artillery weapons with shorter barrels than cannons but can fire projectiles to greater heights. The howitzer's function is often to provide fire support to troops on the battlefield or to bomb protected enemy positions.
3. Mortars are artillery weapons that can be placed on the ground and are used to fire projectiles high into the air. The projectile then falls onto the target with a steep angle of incidence. Mortars are usually used to attack protected targets or provide close fire to enemy troops.

4. Artillery rockets are artillery weapons that use rockets as propellants to launch projectiles at targets. They can deliver fire from long distances quickly and effectively, although they are often less accurate than cannons or howitzers.

The important role of conventional artillery weapons in support of military operations includes attacking enemy positions, providing fire support to ground troops, and providing fire cover during combat. With the continued development of technology and military tactics, artillery weapons have seen improvements in accuracy, range, and destructiveness, making them a crucial component of modern military forces (*155mm Artillery Ammunition Why Us ? Our 155mm Artillery Ammunition*, n.d.).

A. Modern Artillery

Modern artillery weapons are an evolution of conventional artillery weapons that integrate advanced technologies to improve performance and effectiveness in combat. Compared to their predecessors, modern artillery weapons offer higher levels of precision, range, destructiveness, and mobility. The use of global navigation systems, sensors and computer software allows these weapons to target and hit targets with greater accuracy, even in difficult weather or terrain conditions (Balon & Komenda, 2006). Modern artillery cannons are often equipped with global positioning systems that allow rapid calculation and adjustment to target coordinates. They may also have automation and monitoring capabilities to increase response speed and reduce reliance on human operators. Technologies such as advanced propellants and optimized projectile designs can increase destructiveness and firing range (Sayed, 2016). In addition, mobility is an important focus in the development of modern artillery weapons. Artillery systems are designed to be quickly moved to strategic locations and deployed at short notice, either by ground or air. This provides the necessary flexibility in support of dynamic and responsive military operations. In addition to hardware, the integration of advanced information and communication systems enables modern artillery weapons to operate in an integrated manner within the battle network. This enables real-time data exchange between weapons, sensor platforms, and other elements of the fighting force, improving the coordination and overall effectiveness of military operations (Ritter et al., 2010).

In the era of modern artillery weapons, innovation continues to push the boundaries of performance, both in terms of accuracy, speed, and efficiency. The ability of modern artillery weapons to provide accurate and lethal fire support against enemy targets makes them an essential element in national defense and security strategies for many countries around the world (Sayed, 2016).

C. Ballistic Performance Comparison

A comparison of ballistic performance between conventional artillery weapons and modern artillery weapons can involve several factors including firing range, accuracy, projectile velocity, reliability, and effectiveness in striking targets.

Table 2. Summary comparison of conventional and modern artillery weapons (Wang et al., 2018)

Parameters	Conventional Artillery	Modern Artillery
Shooting range	Shorter	Further
Accuracy	Less accurate	Less accurate
Speed	Lower	Higher
Reliability	Less reliable	More reliable
Effectiveness	Less effective	More effective
Cost	Cheaper	More expensive

D. M777 Howitzer Cannon

The M777 howitzer cannon is one of the modern artillery weapons that has the best ballistic performance today. The M777 is manufactured by BAE Systems' Global Combat Systems division. Its core contract management is centered in Barrow-in-Furness, UK, while its titanium structure and related components are manufactured and assembled there as well. The final integration phase

and weapon testing is conducted at BAE's facility in Hattiesburg, Mississippi, USA. In 2008, the cost per unit of the M777 exported was US$2.025 million, which increased to US$3.738 million in 2017 (Quemerais & Poulin, 2015).

Table 3. Howitzer M777 cannon specifications compared to conventional cannons (Howitzer, n.d.)

Specification	Conventional cannon	Howitzer M777 cannon
Weight	1,200 - 6,000 kg (varies with model)	4,200 kg
Length	3 - 6 meters	Combat: 10.7 m Travel: 9.5 m
Barrel	Steel, rifled or smoothbore	5,08 m
Personnel	Typically, 4-6 crew members	7+1 orang
Drive	Towed or self-propelled	M107, M549, M712 Copperhead, M795, ERFB, M982
Caliber	75mm - 155mm	155 mm
Carriage	Split trail, box trail, or self-propelled	Split trail
Elevation	-5° to +70°	0° to +71.7°
Rate of Fire (RoF)	4 - 10 rpm	Normal: 2-4 rpm (max 8 rpm)
Muzzle Velocity	500 - 900 m/s	827 m/s
Effective Distance	10 - 30 km	M107: 21 km M795: 24.7 km ERFB: 30 km Excalibur: 40 km

The M777 has a muzzle velocity of 827 m/s (2,710 ft/s) using Super Charge 8 propellant. Its maximum firing range is 24.7 km with unassisted rounds and 30 km with rocket-assisted rounds. When equipped with Raytheon/Bofors XM982 Excalibur GPS/Inertial Navigation guided by a 155mm projectile, the M777 can achieve a maximum range of 40km with an accuracy of 10m. Tests at the Yuma Proving Ground by the US Army placed 13 out of 14 Excalibur rounds, fired from 24 km, within 10 m (33 ft) of their target, indicating a possible circular error of 5 m (16 ft). In 2012, the M777 fired an Excalibur projectile at a range of 36 km (22 mi) in Afghanistan, which was the longest operational shot in the history of the M777 howitzer. The M777 can fire up to five rounds per minute under intense firing conditions and maintain a rate of fire of two rounds per minute. Extensive use of titanium allows it to weigh only 4,200 kg (9,300 lb), which is 41% lighter than the M198 howitzer it replaces. In summary, the M777 howitzer exhibits excellent range, accuracy, and rate of fire capabilities particularly well when using Excalibur ammunition (Kelso, 1979; Ritter et al., 2010).

The main differences between the M777 howitzer and other howitzers include:

1. Weight and Mobility: The M777 is significantly lighter than other howitzers such as the M109A7 Paladin, weighing only 4,200 kg (9,300 lb) compared to the Paladin's nearly 40 tons. The M777's lightweight design, due to the use of titanium, allows it to be more easily moved and transported. The M777 can be carried by aircraft such as the C-130, V-22 Osprey, and CH-47 Chinook. In contrast, the heavier Paladin can only be carried by larger aircraft such as the C-17 and C-5M (Abou-Elela et al., 2014).
2. Range and Accuracy of Fire: The M777 has a maximum firing range of 24.7 km with unaided rounds, and up to 40 km when equipped with Excalibur precision-guided ammunition. The M777 has demonstrated high accuracy, with tests showing 13 out of 14 Excalibur rounds fired from 24 km landed within 10 m of the target (Boriak, 2023).
3. Rate of Fire: The M777 can fire up to 5 rounds per minute under intense firing conditions and maintain a rate of 2 rounds per minute. This is slightly lower than the maximum velocity of some other howitzers such as the Panzerhaubitze 2000 (Abou-Elela et al., 2014; Wang et al., 2018).

IV. CONCLUSION

The results confirmed that the M777 howitzer cannon, as a representation of a modern artillery weapon, showed superiority in ballistic performance compared to its conventional version. A thorough evaluation showed that the M777 has a higher accuracy rate, wider firing range and faster response time. In addition, the integration of cutting-edge technologies in the M777, including fire control and navigation systems, enhances adaptability in various combat scenarios, which in turn strengthens the effectiveness and efficiency of the use of military resources. These findings have significant strategic implications in the development of a country's defense policy and military strengthening. By understanding and utilizing the technological advantages possessed by modern artillery weapons such as the M777, countries can enhance their survivability in combat through improved fire precision, mobility, and situation response. Furthermore, this comparison provides a solid foundation for continued development in weapon innovation, both to improve performance and develop more advanced systems to support overall defense needs.

REFERENCES

[1]. *155mm Artillery Ammunition Why Us ? Our 155mm Artillery Ammunition*. (n.d.).

[2]. Abou-Elela, H., Ibrahim, A., Mahmoud, O., & Abdel-Hamid, O. (2014). Effect of Base Bleed Dimensions on the Ballistic Performance of Artillery Projectiles. *The International Conference on Applied Mechanics and Mechanical Engineering*, *16*(16), 1–24. https://doi.org/10.21608/amme.2014.35485

[3]. Balon, R., & Komenda, J. (2006). Analysis of the 155 mm ERFB/BB projectile trajectory. *Advances in Military Technology*, *1*(1), 91–114.

[4]. Boriak, K. (2023). The Improvements of Ballistic Characteristics of Artillery Projectiles of 152 and 155 mm Calibers. *Bulletin of the Military University of Technology*, *72*(2), 83–96. https://doi.org/10.5604/01.3001.0054.3657

[5]. Catovic, A., Kljuno, E., & Razic, F. (2024). *Estimation of stresses on 155mm artillery projectiles during launch phase using numerical simulations*. *January*. https://doi.org/10.21533/pen.v12i1.3685.g1352

[6]. Dobržinskij, N., & Juozapavičius, A. (2019). Investigation of the gunpowder stabilizer content in 105 mm howitzer ammunition. In Transport means 2019. *Sustainability: Research and Solutions: Proceedings of the 23rd International Scientific Conference: October 02-04, 2019, Palanga, Lithuania. Kaunas University of Technology.*, *3*, 1079–1082.

[7]. Hall, S., & Liebenberg, L. (2024). Qualitative Description as an Introductory Method to Qualitative Research for Master's-Level Students and Research Trainees. *International Journal of Qualitative Methods*, *23*.

[8]. Howitzer, F. (n.d.). *155mm Lightweight Field HowitzerM777*.

[9]. Kelso, J. R. (1979). *TECHNICAL LIBRARY MEMORANDUM REPORT ARBRL-MR-02968 BALLISTIC EVALUATION OF 19-PERFORATI ON PROPELLANT IN THE 155-MM*. *02968*(644).

[10]. Krause, J. (1916). *From Balletics to Ballistics : French Artillery , 1897-1916*. 1897–1916.

[11]. Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2010). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg*, *8*(5), 336–341.

[12]. Quemerais, B., & Poulin, I. (2015). *Characterization of Atmospheric Emission Produced by Live Gun Firing : Test on Characterization of atmospheric emissions produced by live gun firing : Test on the M777 155 mm Howitzer Defence R & D Canada*. *September 2007*.

[13]. Ragaee, R., Yang, G., & Ge, J. (2016). Launching dynamic analysis for truck mounted howitzer by using flexible multi-body techniques. *Journal of Vibroengineering*, *18*(4), 2384–2402. https://doi.org/10.21595/jve.2016.16785

[14]. Ritter, J. J., Homan, B. E., & Thalman, W. (2010). *Dynamic Pressure Testing of a 155-mm Howitzer Ballistic Window Using a Closed Bomb Vessel.pdf*. *August*.

[15]. Sayed, A. E. (2016). *Ballistic Performance of 155mm VelocityEnhanced Long-Range Artillery Projectile*. 2016.

[16]. *The K9 Vajra, M777 and artillery tractors 2011.* (2019). 2018.

[17]. Thomé, A. M. T., Scavarda, L. F., & Scavarda, A. J. (2016). Conducting systematic literature review in operations management. *Production Planning and Control*, *27*(5), 408–420. https://doi.org/10.1080/09537287.2015.1129464

[18]. Wang, Y. wei, Zhu, W. fang, Di, J. wei, & Hu, X. hong. (2018). Study on the analysis method on ballistic performance of deterred propellant with large web size in large caliber artillery. *Defence Technology*, *14*(5), 522–526. https://doi.org/10.1016/j.dt.2018.07.027