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Contribution of Science and Technology to the Country's National Security

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Abstract

In the face of Nepal's constant vulnerability to major geopolitical forces, the country has yet to fully harness technology to safeguard its national interests. This paper highlights how states, in demanding times, have wielded scientific technology to safeguard their security and address their interests. This paper draws attention to the importance of investment in innovation and research for the survival of a nation. Drawing upon historical, technological, and geopolitical perspectives, this paper explores the pivotal role of scientific and technological breakthroughs in shaping military strategies, and war efforts. The paper examines key moments when innovations such as the development of bow and arrow, gunpowder, RADAR, proximity fuse, cryptography, and computer malware have provided nations, civilizations, and communities with a vital advantage in safeguarding their security. Furthermore, the paper explores the mutual relationship between scientific research, innovation, and economic growth. It highlights how investments in science bolster a country's defence capabilities and foster innovative ecosystems that drive economic prosperity. Ultimately, this paper seeks to provide a comprehensive overview of the contributions of science to national security and well-being. Analyzing the relationship between innovation, strategy, and global dynamics; the paper highlights the imperativeness of nations to adapt, collaborate, and harness scientific advancements, to safeguard their interests in an increasingly complex world. Through an enriched understanding of the past and present contributions of science in national defence, Nepalese policymakers, military leadership, and the country's scientific community can navigate the intricate landscape of national safe guardianship to ensure a secure and prosperous future for Nepal.

Keywords: Technology, national security, economy, cyberwarfare

Introduction

In a time marked by mindboggling technological advancements, the relationship between science, technology, and national security plays a crucial role in determining the adaptability, resilience, and strategic capabilities of nations. The integration of technology and geopolitics has not only transformed global dynamics but also has been a determinant in a nation's ability to safeguard its interests and citizens. As we navigate through complex geopolitical events, the

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central focus of this paper is understanding the part science and innovation play in protecting a state's national security. This investigation examines the multi-dimensional application of science, innovation, and research in the defense of a nation.

The symbiotic relationship between scientific technology and security enhances transformative advancements in diverse fields, ranging from cyber security and intelligence gathering to the protection of critical infrastructure and response in case of natural disasters. This research endeavour seeks to unravel how states leverage their technological prowess to fortify their national security apparatus. By investigating multiple ways in which innovation intersects with strategic imperatives, this study sheds light on the contribution of innovation in ensuring the state's safety. This study aspires to offer a comprehensive understanding of the challenges faced by states and opportunities to solve those challenges using science. Moreover, the paper explains the connection between a state's negotiating power and the technological and industrial advancement the country obtains, while underscoring the need for constant investment and advancement in science, technology, and innovation for the survival and prosperity of the nation.

Methodologies

This qualitative research is centered on the analysis of secondary data sourced from reputable books, articles, journals, and trusted websites. The study is correlational in design and employs inductive reasoning to the information acquired from the available literature to explore the utilization of technology by countries and civilizations at various points in time as a response to threats endangering their survival and prosperity.

Understanding the relationship between Science, Technology, and Security

Throughout history, humans have leveraged available resources to develop innovative and efficient solutions for zero-sum survival challenges. A prime example is the prehistoric use of the bow and arrow for hunting. This tool allowed hunters to acquire food swiftly and safely by launching high-speed projectiles from a distance, avoiding close-quarter confrontations with prey and dangerous carnivores (Chauviere, 2014). Fast forward several centuries, the objective of hunting for food by nomads was replaced by swiftly neutralizing the enemy defences by Genghis Khan's forces during the mid-1600s (History of Archery, and the NAA, 1996). Instinctual drive for food is replaced by aggression for territorial interest where a bow and arrow serve as a vital tool.

The pursuit of gaining a strategic advantage of engaging the enemy from a greater distance fueled the development of gunpowder-propelled weapons. Ancient Chinese alchemists and military leaders swiftly recognized the potential of gunpowder, an accidental invention of 142 A.D., in providing an advantage of distance during battles (Needham, 1986, p.50). This revolutionary discovery became a vital component of military arsenals for centuries. A pivotal moment occurred in 994 when the Song dynasty's army repelled a massive Liao dynasty force, numbering 100,000 troops, by employing flaming arrows (gunpowder-propelled arrows), and gunpowder-based bombs during the siege of Zintong (Needham, 1986, p.148). This event marked the first documented use of an explosively propelled projectile, showcasing the transformative power of technological superiority in shaping the courses of war. These flaming arrows also proved instrumental for the Chinese in warding off the invading Mongolian Army (Andrade 2016, p.44).

After facing the Chinese flaming arrows Mongolians quickly adopted gunpowder for their war efforts. This adoption of gunpowder by the Mongol army not only aided their conquests in Europe but also disseminated the knowledge of gunpowder to the European continent. The fusion of this newfound explosive power with the Europeans' longstanding expertise in metal craftsmanship resulted in the creation of a more devastating weapon: the cannon (Norris, 2003, p.19)

The earliest documented use of cannons in Europe dates to 1247 A.D. in Seville, where cannons crafted from a combination of iron, bronze, firestone, and iron balls, were employed. However, it was during the siege of Constantinople in 1453 A.D. that gunpowder artillery truly demonstrated its potential. The Ottomans, leveraging heavy cannons, successfully breached the city's formidable walls, illustrating the immense impact of technological superiority on securing a state's interests and territorial ambitions (Rauf, 2016, p.27).

Perhaps one of the most conspicuous displays of military technology transpired during the First World War. Centuries of weapon development, coupled with the unprecedented manufacturing capabilities provided by the Industrial Revolution, bestowed mankind with unprecedented wartime industry. The breakthrough in science and technology of the time paved the way for one of the most prominent war machines: the tank. Though the idea of armoured fighting vehicles started much before the 19th Century, it was the newfound breakthrough of track wheels that gave the British success in building the Mark-I. (Hammond, 2009). The tank though slow, and vulnerable to artilleries of the time succeeded in breaking Germany's defensive lines along western Europe, giving the British forces an upper hand during the Battle of Somme.

During that time, another groundbreaking technological advancement, heavier-than-air aircraft, helped in enhancing both the defensive and offensive capabilities of the military. The sluggish and less nimble zeppelins were replaced by swift and highly maneuverable aircraft designed for bombings of enemy targets. The first ever tactical bombing mission occurred during the Battle of Neuve Chapelle in 1915 when British troops used airplanes to drop bombs targeting German rail lines to disrupt logistics (Squadron-Leader (pseud.), 1927, Gale & Polden).

Another example of technology turning the tide of war is the battle during the battle of Britain. The superior aircraft like the Spitfire, a result of years of research and development works on aircraft engines and airframe designs, helped Britain protect itself from determined German forces and their sophisticated V-1 flying bombs. The Spitfire with its semi-monocoque structure exhibited remarkable structural capacity to execute tighter turns while carrying heavy armaments on their belly. Its elliptical wings reduced the induced drag helping with its range and speed (Morgan and Shack Lady 2000, pp. 614–616.). Multiple years of research paid off when the Spitfire proved itself in the skies over Britain.

Nonetheless, attributing the success of the British forces during the Battle of Britain solely to their agile aircraft would be an oversight. The valuable impact of a sophisticated network of RADAR systems known as 'Chain Home' in World War II cannot be overstated. This network of RADAR served as an early warning mechanism, alerting the British Air Force promptly whenever a threat emerged. The Chain Home radar proved exceptionally effective in providing crucial information to the British Royal Air Force, including the Luftwaffe's formational strength, their intended targets, and mobilisations (Neale 1985, p. 73).

This invaluable intelligence enabled the RAF to scramble in time, effectively countering the imminent threats posed by the enemy forces.

A comprehensive account of aerial battles during World War II would be incomplete without acknowledging the groundbreaking contribution of the proximity fuse for anti-aircraft shells. This pivotal innovation emerged from the collaborative efforts of Section T; a group led by physicist Merle Tuve at Johns Hopkins University's Applied Physics Lab. Their achievement lay in successfully integrating Doppler radar with artillery shells (Brown, July 1993.) Their ingenious design used a wet-bulb power cell for powering the electronics. Hence solving the issue of making the shell safe for handling and reliable on target. In addition, their design could protect the electronics inside the shell from the acceleration of 20,000g during the firing (Brennan, 1968). This breakthrough drastically reduced the number of shells needed to down a single aircraft from 20,000 to 2,500, marking a ten-fold decrease in resources required for countering enemy bomber aircraft (Baxter 1968, p. 221). This monumental advancement not only bolstered anti-aircraft efficiency but also significantly eased the economic burden, enabling nations to allocate resources more effectively during wartime.

The Allied forces' triumph in World War II can be largely attributed to crucial technological advancements, among which the breakthrough at Bletchley Park stands as one the greatest of achievements. British cryptographers, through persistent and clandestine efforts, successfully automated the decryption of German communications encoded using the Enigma machine. Alan Turing's design for an electromechanical deciphering machine, codenamed Bombe, was realized by the British Tabulating Machine Company. The Bombe, as described by Gordon Welchman, significantly reduced the complex Enigma settings, employing a brute force technique to analyze twenty settings per second and output probable solutions (Welchman, 2005, p.120). This remarkable machine became the linchpin of British Intelligence, decrypting vital information essential for safeguarding their homeland and supporting their war efforts against Axis forces across Europe, Asia, and Africa.

Among the scientific advancements, the development of nuclear weapons by the USA during World War II is one of the most impactful in human history. The United States and the allied forces invested significantly in developing fission weapons, commonly known as the atomic bomb. Under the leadership of J. Robert Oppenheimer, the USA-led Manhattan Project galvanized the intellectual resources of multiple allied nations toward creating this groundbreaking weapon. Despite economic constraints imposed by war, a staggering budget of US$2 billion was allocated for the development of the atomic bomb (Nichols 1987, pp. 34–35.). In the remote deserts of New Mexico, a specialized town emerged to accommodate the scientists, technicians, and engineers dedicated to this research (Jones 1985, p. 33.). The controversial decision to employ atomic weapons, although debated, undeniably elevated the United States to an unparalleled position of influence and negotiation prowess on the global stage.

The post-World War II era was defined by the Cold War, during which both power blocs, the USA, and the USSR, engaged in a fierce race for supremacy. This competition spurred the advent of space exploration, driven by the need for constant surveillance between adversaries. Both nations harnessed satellite technology with high-resolution earth observation capabilities, enabling vigilance on the adversary regarding troop movements, strategic build-ups, and military hardware. Space-based surveillance systems developed during this period were very influential in shaping strategic decisions and policies for both the USA and the

USSR. US President Lyndon B. Johnson's statement in 1967 while addressing a gathering underscored the significance of this pursuit, emphasizing the invaluable knowledge gained through space photography (Heppenheimer, 1998, p.191, 198). The information obtained from satellite reconnaissance not only revealed the true extent of the USSR's missile capabilities but also exposed misjudgments in the USA's strategies, leading to a reevaluation of their military initiatives and fostering a more informed approach to their national security.

Like satellites' ability to provide information on hostile activities, the advancement of computer networking and electronic communication in recent times has given security apparatuses the capability of being vigilant for looming threats. After the attacks of 9/11, the National Security Agency (NSA), a United States clandestine agency conducted mass surveillance against a vast suspect pool both inside and outside the USA for their allegiance to Al-Qaeda or any hostile non-state actors. Though the actual efficiency or inefficiency of the mass surveillance program has not been public yet, US President Barack Obama in 2013 said that the surveillance by the NSA "…. averted at least fifty threats related to terrorism…" (McLaughlin, 2015).

In 2010, a significant example of cyber capabilities thwarting a perceived threat emerged with the discovery of Stuxnet, a computer worm. This sophisticated computer malware, targeting Siemens Step7 software controlling automated manufacturing lines, was found to have specifically aimed at Iranian uranium enrichment centrifuge machines in Nantan ("Stuxnet worm hits Iran..." (2010)). Stuxnet exploited zero-day vulnerabilities, altering centrifuges' rotations to the point of destruction while evading detection by the diagnostics and control system (Albright et al.,2010). Its origin remains elusive, but the malware's high level of sophistication suggests involvement from cyber superpower nations. Reports hint Stuxnet to be a collaborative effort between the National Security Agency's Equation Group (USA) and Unit 8200 (Israel), (Halliday, 2010) exemplifying a state's covert use of technology to counter perceived threats.

These examples offer valuable insights into the aid science provides to states during their struggle for survival. Aligned with national security ambitions, technology has become a powerful tool enabling countries to uphold security, peace, and order with minimal economic burdens. By strategically leveraging technology, nations can fortify defences, deter potential threats, and navigate modern security challenges effectively, ensuring the safety and stability of their citizens.

Relationship of Science & Technology with the Economy

In addition to safeguarding national security interests, technological advancements are an important factor in fostering economic growth ─an important parameter for national security. Specifically, progress in applied science equips the nation's industries with the expertise needed to produce superior products and competitive services, thereby bolstering the competence of domestic industries. The United States' unwavering commitment to aerospace research has positioned it as a global hub for aerospace industries. In 2022, the USA's aerospace exports amounted to US$102.8 billion, significantly surpassing France, the second-largest exporter, with US$32.8 billion (Statista, 2023). Apart from aerospace, the USA's investment in the development of information technologies has been incredibly fruitful. The USA has listed itself as a leading figure in IT services. The USA's IT sector generates US$1.9 trillion and accounts for 12.1 million jobs in the country (stated by the International Trade Administration).

Likewise, Israel's steadfast support for companies specializing in cyber capabilities has established the country as a global hub for both defensive and offensive cyber solutions providers. Notably, the Pegasus spyware, developed by Israeli cyber arms company NSO Group, incurs substantial costs for government agencies, with expenses reaching $650,000 to spy on ten phones, and an additional cost of $800,000 for a hundred more targets (Greengard, 2023). Moreover, NSO Group's annual charges for software maintenance on target devices have contributed significantly to its revenue. By offering cyber vigilance services to government agencies worldwide, NSO Group generated annual revenue of approximately US$40 million in 2013 alone which rose to US$150 million, (Stone et al., 2015) thereby enhancing Israel's economic influx.

Additionally, South Korea's focus on electronics and telecommunications has propelled it to become a global leader in producing consumer electronics. Companies like Samsung and LG have become synonymous with cutting-edge consumer electronics. South Korea's investment in research and development (R&D) has yielded revenue of US$18.5 billion in 2023 (Consumer Electronics: Market Data & Analysis, 2023) and is only expected to increase in the coming years. The country's economic growth, driven by technology and innovation, has made it a powerhouse in the global economy.

Likewise, Germany, known for its engineering prowess, has made significant investments in Industry 4.0, the fourth industrial revolution marked by automation and data exchange in manufacturing. This strategic focus on industry, supported by innovation, has bolstered Germany's manufacturing sector, making it one of the globe's foremost exporters of high-quality industrial machinery and products (BMBF-Internetredaktion, 2016). The economic stability of the country significantly enhances its national security resilience.

In each of these examples, technology has not only driven economic growth but also enhanced national security by providing advanced capabilities in areas such as cybersecurity, telecommunications, and infrastructure development. These nations serve as models showcasing the transformative power of technology in uplifting economies when harnessed strategically.

Assessment of Scientific and Innovative Landscape in Nepal

In Nepal, despite allocating numerous national-level programs aimed at fostering scientific innovation, the results have failed to materialize. Experts and analysts attribute this stagnation mostly to the country's insufficient investment in science (Pokharel, 2021). This issue becomes even more evident when compared to the strategies employed by other developing nations, particularly China.

China, currently the global leader in scientific research, has consistently allocated 2% of its annual GDP to research and development (Normile, 2021). This substantial investment has propelled China to the forefront of innovation, enabling the country to make significant strides in various fields, from cutting-edge defence technologies to competitive yield in industries.

In sharp contrast, Nepal has struggled to allocate adequate financial resources to support scientific and technological research and development initiatives. As of 2020, Nepal allocated only 0.45% of its GDP to research, a figure significantly lower than the global average. While there has been a marginal increase from the 0.1% allocated in 2009, the current investment remains far too low to drive meaningful progress (Pokharel, 2021)

The consequences of this underinvestment are multipronged. First, it hampers the country's ability to compete on the global stage. In an increasingly interconnected and technology-driven

world, nations that invest significantly in research and development are better positioned to innovate, create high-quality jobs, and enhance their overall economic competitiveness (Wang, Chien, and Kao, 2007). Without substantial investment, Nepal has been falling behind, missing opportunities for economic growth and development.

Additionally, Insufficient investment in research and innovation not only impedes Nepal's progress in various sectors but also undermines the nation's ability to tackle critical national security challenges. These challenges encompass a wide range of issues, including safeguarding against security threats, addressing climate change impacts, managing public health crises, ensuring food security, and advancing infrastructure development. Research and innovation are imperative in discovering sustainable solutions to these pressing concerns. Without substantial funding, Nepal's advancements in these areas remain severely restricted.

To address this pressing issue, Nepal's policymakers must recognize the necessity of science, technology, engineering, and mathematics (STEM) in the country's development. Increased investment in research and development must be prioritized, not only in terms of funding but also in creating an encouraging environment for progress in STEM fields. This includes investing in education, supporting research institutions, fostering collaboration between academia and industry, and promoting entrepreneurship (Pokharel, 2021).

Furthermore, partnerships and collaborations with other state and non-state international partners will be beneficial in bridging the knowledge gap. By engaging with global research networks, sharing knowledge, and learning from the experiences of more developed nations, Nepal can accelerate its progress in the fields of science and technology.

In conclusion, while Nepal has taken some steps towards increasing investment in scientific research and development, these efforts must be significantly amplified. A substantial and sustained commitment to funding research, coupled with strategic collaborations and a nurturing environment for innovation, can pave the way for Nepal to harness the full potential of its scientific and technological capabilities, leading to a brighter and more prosperous future for the nation and its people.

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