Quantifying History Across Eras: Benchmarking the Battle of Granicus from Troy to WWII through DEA Analysis

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The paper aims to suggest Data Envelopment Analysis (DEA), as a preliminary tool of military efficiency. This approach examines battles as a decision-making unit (DMU) characterized by multiple inputs and outputs. Data: Data are measurable indicators such as battles won, territorial expansion, casualties, and historical impact. By assigning quantitative values, the study facilitates cross-temporal comparisons of military effectiveness. The strategic performance of Alexander the Great at the Battle of Granicus River (334 BCE) serves as a primary case study of DEA employment. The scope of analysis extends to a range of historically significant conflicts, from the Trojan War to World War II to compare with and be used as benchmarks. The study demonstrates the practical utility of quantifying historical events into a single comparable metric, facilitating clearer comparisons across diverse battles ranked from highest to lowest values.

Introduction

Historians, poets, storytellers and scholars have shown interest in accounts of battles since the era of the Homeric epics. Indeed, Homer includes some numerical details in the Iliad, especially in the passage of Book 2, lines 484–759 known as the "Catalogue of Ships" (Homer 1990). While the ancient authors did not aim for a systematic mathematical analysis, they perceived the importance of documenting numerical data.

Herodotus (c. 484–425 BCE) known as the “Father of History” provides detailed accounts of battles, populations, and armies with numbers in a more systematic way than earlier epic poetry. Specifically he gives numbers for Persian and Greek forces in battles like Marathon and Thermopylae (Herodotus 2013). This distinction solidifies Herodotus as the father of quantitative historical record-keeping and the pioneer of quantifying history. The accuracy of Herodotus’s

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accounts was validated by the discovery of the Xerxes Canal, constructed during the Persian Wars around 480 BCE. Modern geophysical technologies have confirmed that its dimensions closely match Herodotus's descriptions. Notably, the existence of this ancient canal had been doubted (Karastathis, Papamarinopoulos and Jones 2001).

Recent research suggests that ancient records may be unreliable and often exaggerate accounts of glory. Oka et al. (2017) compiled a dataset (Dataset S2) containing figures on troop sizes and casualty-to-winner (C/W) ratios for several ancient battles, including the Battle of Granicus. Based on this assumption, the authors use population size as a more reliable proxy to examine the scale of ancient warfare.

Building on this research, Keenan-Jones, Duncan, and Hebblewhite (2019) demonstrate that ancient sources such as Arrian, Diodorus Siculus, Plutarch, and Justin, report inflated figures for troop sizes and casualties in Alexander the Great's battles, especially when compared to the indicators provided by Oka et al. (2017).

The case of Sparta shows that Oka's et al. (2017) assumptions cannot predict war group size in ancient word. It is known that Sparta had a small population but a disproportionately large and trained military force, reflecting its militarized social structure (Strechie 2021). The Spartan system enabled the king to put in the battlefield the necessary army size (Lazenby 2012). Moreover, using population size as a proxy, effectively annuls the critical roles of strategy, tactics, leadership, battlefield conditions, topography, spying and betrayal. Military outcomes are shaped by complex factors. The case of Thermopylae (480 BC), in which 300 Spartans were led by Leonidas, serves as unique example in military history of how the battle's outcome would have been different if Ephialtes had not betrayed the secret path (Gengler 2011; Herodotus 2013, Book 7). Without Ephialtes' betrayal, the ratio of Persian casualties per Greek soldier could have been dramatically higher, reflecting the tactical advantage of the narrow pass and the Greeks' superior fighting skills. Additionally, the assumption overlooks critical differences in weaponry and military technology, which greatly influenced combat effectiveness and casualty rates. A compelling example is the atomic bombing of Hiroshima, where a single weapon caused mass casualties independent of population or army size (Junod 1982). Although bombs did not exist in the ancient world, accounts of unusual technologies, such as the mysterious soldier Echetlaios setting fire to the Persian ships in the Marathon Battle with an unspecified device (Plutarch 1928), along with references to divine intervention, can be interpreted as early forms of secret or symbolic military technology.

Secret incendiary devices and explosives, such as the liquid fire in Byzantine, represent innovative or poorly documented technologies that produce terror and achieve disproportionate effects (Davidson 1973). Although rare and fragmentary in the historical records, the secret technologies had a high contribution to battlefield effectiveness, though their details have yet to be uncovered by archaeology.

A contemporaneous analogy is Israel's early nuclear program known as The Bomb in the Basement (Karpin 2007) where small size forces can leverage secret capabilities to counterbalance larger size opponents. Therefore, both historical accounts and modern reality supports the plausibility of similar secret innovations whose exact nature remains unknown in the ancient era.

Contagious diseases were often detrimental in ancient military camps, weakening armies before battles even began. For instance, the Plague of Athens (430 BCE) devastated the Athenian forces during the Peloponnesian War, and disease similarly crippled Persian troops during Xerxes' campaign in Greece (Littman 2009; Rangos 2020; Koehler 2001). The Athenian and Persian armies suffered heavy losses due to disease, of approximately 25% and 35%, respectively. During Hernán Cortés's conquest of the Aztec Empire in the early 16th century, smallpox—introduced by Europeans—decimated the native population, weakening resistance more than direct combat (Fenner et al. 1988; TCI 2021). Similarly, during Napoleon's campaigns, particularly the invasion of Russia in 1812, typhus and dysentery ravaged his troops, contributing significantly to his army's collapse (Thomas 2007; Allen 1998). These examples underscore how disease, often underestimated, could be as destructive as any weapon on the battlefield.

Finally, the case of the Trojan Horse falls entirely outside the rationale proposed by Oka et al. (2017) as it was not a matter of troop size or population capacity, but rather a singular act of strategic deception that determined the outcome of the war.

Porter (2015) discusses that quantification in social studies is not the key to all mysteries, but is a powerful set of tools and concepts, that should be used in conjunction with theoretical reasoning. In contrast, this article aims to explore how quantification can, in fact, serve as a key to uncovering certain historical and analytical mysteries. Fienberg (1985) argues that wartime data and statistical techniques, particularly those developed during World War II, have significantly contributed to various areas of military analysis and planning.

2 Modeling Wars

Modeling wars using mathematical formulas dates back over a century, with Lanchester's pioneering work in 1916 laying the foundation for modern combat modeling. His equations, known as Lanchester's Laws, describe the dynamics of force attrition in battles and remain influential in military science today. Although earlier historical analyses and strategic writings exist, Lanchester's work is widely recognized as the first formal mathematical treatment of warfare (Lanchester 1916).

Post-Lanchester developments in Military Modeling and Quantitative Analysis can be retrieved during the WWII under the term Operational Research first introduced by A. P. Rowe (1948) in Britain and later developed in the United States by Philip M. Morse and George E. Kimball (1951). Their work focused on tactical analysis and experiments with gunnery equipment, and tactics. After the war, OR's mathematical models contributed to the growth of this discipline in business and industry.

Another new discipline based on mathematics was Game Theory introduced by John von Neumann, Oskar Morgenstern and Ariel Rubinstein (1944) which has been extensively applied to model strategic military decisions and conflict scenarios (Jormakka and Mölsä 2005; Ho et al. 2022). Concepts like Nash equilibrium were used to analyze conflict or predict outcomes of military battles (Ripla and Liebovitch 2018).

During the 1950s–1970s researchers expanded Lanchester's laws, introducing randomness, elements of chance (stochastic models), and terrain effects into combat modeling simulation. This discipline is also referred as Attrition Models (Taylor 1983; Hartley and Helmbold 1995).

In the 60s at the University of Michigan, J. David Singer initiated the first significant attempt to collect empirical data on a systematic basis. His pioneer work in developing the first database of inter and intra state wars since 1816, is known as the Correlates of War (COW) Project which is still evolving and being revised. The data refer to conflict frequency, participants, duration, battle deaths and more. Many quantitative studies on war build on this foundational database (Singer 1972; Singer and Small 2006).

In the fields of social studies and the humanities, scholars such as Peter Turchin have introduced an interdisciplinary approach known as *cliodynamics*, which combines history, sociology, cultural evolution, warfare intensity, geographical factors, and various other variables. Turchin introduced the term *cliodynamics* derived by the synthesis of *Clio*, the muse of history in Ancient Greek mythology, and *dynamics*, referring to the use of mathematical modeling. His idea is that detectable patterns exist in the rise and fall of states, wars and many other facets of human societies. These patterns can be analyzed and tested using models. His work traces social dynamics back to societies before the Axial Age (before 800 BCE). This ongoing research effort contributed to the development of the Seshat: Global History Databank, which provides a foundation for large-scale statistical analysis of historical processes (Turchin 2008; Turchin et al. 2013, 2020). Nevertheless, Maini (2020) criticizes the misinterpretation of historical events caused by flawed mathematical applications. The authors of the present paper contend that cliodynamics advances history beyond mere narrative and record-keeping, establishing it as a branch of scientific discipline. Mathematical modeling and empirical analysis provide the foundations of a pioneering approach that transfigures the study and understanding of historical processes.

Lately, a subcategory or method within OR appears in literature of defense and military applications. DEA (Data Envelopment Analysis) was first introduced by Charnes, Cooper, and Rhodes (1978) and falls under the umbrella of a linear programming method used to measure the relative efficiency of decision-making units. It handles complex, problems with multiple inputs and outputs. The method was initially designed to measure the efficiency of government programs but today, is widely used to assess the efficiency of any organization like hospitals, schools, banks, airports, and support policy decisions and operational improvements. Similarly, DEA is a very realistic scenario for defense organizations. A few years later, DEA authors introduced the method to 56 US Army Recruiting Command (USAREC) in order to extend the emerging theory to a growing list of applications (Ali et al. 1986).

The article of Ivan Okromtchedlishvili (2022) includes a list of 16 studies of DEA employment in the defense sector area. Specifically, these studies focused on support functions (recruitment, maintenance, hospital, logistics, finance etc.). His DEA metrics though on 31 countries (NATO members and partner countries) was focused on the efficiency of military spending. Nakabayashi and Tone (2005) also used the DEA methodology to verify that the end of the Cold War occurred in 1995. Wu et al. (2014) developed a military transport path selection model using DEA and multiobjective fuzzy decision-making, incorporating factors like travel time, risk, response capability, and cost.

DEA models have been applied in various areas of the defense sector. For example, Bansal et al. (2020) used DEA as a performance index to evaluate battle tanks, while Nourani, Lu and Ting (2020) assessed the impact of vicarious warfare on the economic performance of aerospace companies. Additionally, Solana-Ibañez, CaravacaGarratón and Soto Meca (2020) explored broader DEA applications within the field of Defence Economics. However, despite this growing body of research, no prior study has been found that applies DEA methodology to historical battles. This paper seeks to fill that gap by applying DEA methodology to historical battles, using them as decision-making units (DMUs) to evaluate strategic efficiency across different time periods.

3 Methodology

The effort to quantify warfare through battle statistics has gained momentum in recent decades. Large-scale projects such as the Correlates of War (COW), PRIO/UCDP, and the Dupuy Institute have sought to compile structured data on armed conflicts. These databases provide valuable typologies, classifications, war categorizing and metadata—such as conflict types, durations, and geopolitical context—but they often lack the raw numerical inputs needed for efficiency analysis, such as force sizes and casualties per engagement (Sarkees and Wayman 2010; Herre and Rodés-Guirao 2023). Other datasets fall outside the temporal scope, as their data postdate the period examined in this study (Lacina and Gleditsch 2005). Additionally, some databases include variables, such as city level data, that extend beyond the focus of the present research (The Dupuy Institute 2002).

While these resources are essential for broader military or security-oriented conflict research, they follow a predominantly defense and strategic studies framework. In contrast, the present study adopts a social science perspective, using DEA as a comparative tool to analyze military efficiency across time and historical contexts. This divergence in scope and orientation makes such datasets less suitable for the specific goals of this research. As a result, this study draws on historical reconstructions, classical narratives, and critical secondary sources, including academic research, to obtain the quantitative variables necessary for modeling battles across eras (Herodotus 2003; Hammond 1980; Library of Congress n.d.; War History Fandom contributors n.d.; Fienberg 1985; Beevor 2012; Brewer 2001; Philippides and Hanak 2011; Katsikas and Krinaki 2020; Strantz von 1898; Doherty 2021; Aksamitowski 2023; Turner 2010; Brice2020).

As an initial pilot analysis using DEA, a comparison was made between two entities: Alexander the Great and Darius III. The analysis was based on two straightforward variables: the number of soldiers (Greeks, Persians, mercenaries) in infantry, cavalry and archers and the number of casualties. The result of the battle was also calculated under 0-1 dichotomy for loss and victory. The analysis successfully produced interpretable efficiency scores for both kings.

The pilot analysis validated the applicability of DEA to ancient battles, even with simplified variables. The method enabled the extension of the method to a broader framework encompassing a dozen key battles across different periods. More inputs/outputs categories were measured like number of dead, injured, captured, and disease/famine victims.

In this research all the variables are quantitative and reflect the Greek side. The inputs include the troop sizes and cavalry and territorial gain. The outputs include own losses, enemy causalities, and finally the result of the battle (win or loss).

For clarity and space considerations, the mathematical formulation of DEA is not included in the text. However, the methodological foundation of DEA is well established in the literature, and readers can refer to the cited sources (e.g., Charnes, Cooper and Rhodes; Cooper, Seiford, and Tone 2007) for detailed technical explanations. The present study applies a standard input-oriented DEA model using battle-related variables, with a focus on interpreting results rather than exploring mathematical derivations. The efficiency scores were calculated using DEAFrontier software. All DMUs (battles) were treated equally, regardless of era. It is assumed that efficiency is scale-invariant so the CRS model (Constant Returns to Scale), was employed.

4 Results

The study evaluates the relative efficiency of military campaigns by employing DEA. Calculations were employed in three phases. In Phase I, DEA was employed between the troops of Alexander the Great and Darius III in the Granicus River Battle. Both armies were treated as DMUs (decision-making units). Alexander consistently scored closer to the efficiency frontier (1.00), demonstrating a high ratio of enemy casualties inflicted per unit of military input. Darius's performance appeared highly inefficient (0.12), where greater numerical inputs yielded comparatively less effective outcomes. The relative efficiency score for Darius III was found 0.1185 which means that Darius's performance at the Battle of Granicus was only 11.85% as efficient as Alexander's. Additionally, employing the percentage difference formula, the result shows that Alexander's performance is 744% higher than Darius's. This means Alexander was more than 7 times as efficient as Darius.

To address concerns regarding potentially exaggerated or glorified historical figures, a second DEA - Phase II- was performed under the assumption that both armies were of equal strength.

In the first scenario Alexander's army size is intentionally adjusted to match the much larger force of Darius III. Results showed that the new relative efficiency of Darius III was found 0.166 which means that Darius's performance at the Battle of Granicus was only 16.6% as efficient as Alexander's. The result is a little higher than the first calculation where, the armies' sizes were based on figures from ancient sources. The percentage difference calculation shows that Alexander's performance is 502.11% higher than Darius's. This means Alexander was more than 5 times as efficient as Darius.

In the second scenario, Darius's army size is reduced to match the historically smaller force of Alexander. This adjustment simulates how efficiently Darius III might have performed if he had been constrained by the same limited resources as Alexander. Results showed that the new relative efficiency of Darius III was found 0.148 which means that Darius's performance at the Battle of Granicus was only

14.8% as efficient as Alexander's. The result is a little higher than the first calculation where the armies' sizes were also based on figures from ancient sources. The percentage difference calculation shows that Alexander's performance is 575.68% higher than Darius's. This means that Alexander remains almost 6 times more efficient as Darius. Both scenarios are not realistic, even though they prove the accuracy of figures from ancient sources.

The resulting radar diagram (Figure 1) demonstrates that even when equalizing the size and resources of the two forces, Alexander's strategy still proves more efficient. This outcome reinforces the conclusion that his tactical superiority and not sheer numbers, was the decisive factor, leaving little room for ambiguity in the interpretation of the results.

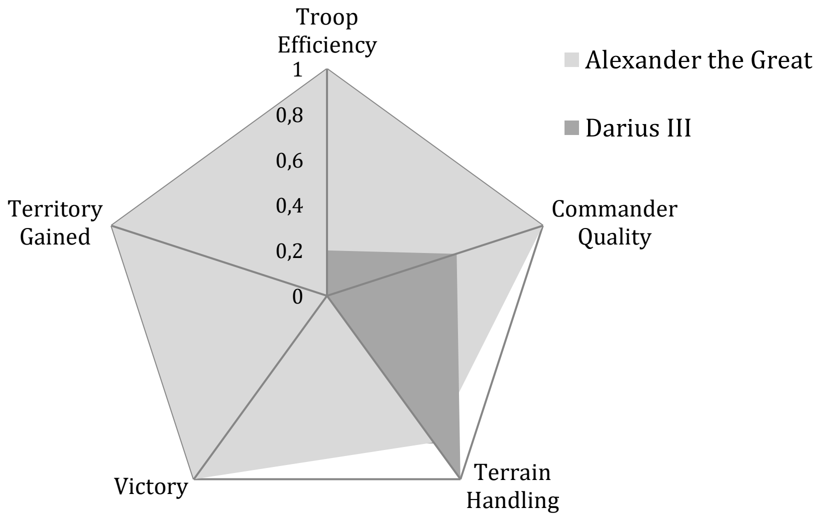

Figure 1. Military Efficiency – Battle of Granicus Under Equal Force Assumptions

While both scenarios are hypothetical and do not reflect the actual historical conditions of the Battle of Granicus, they serve as data cross-verification. By normalizing army sizes either increasing Alexander's forces to match Darius's or reducing Darius's to match Alexander's, the analysis isolates strategic performance as a virtue independent of numerical advantage. Alexander endures the battle and wins Darius by a factor of 5 to 7, regardless of troop figures. The consistency of results across both cases reinforces the reliability of ancient historians like Herodotus, Arrian, Plutarch, and Diodorus regarding troop asymmetry. This also validates that ancient reports on Alexander's strategic outperformance are not just literary exaggeration, but align with performance quantitative analysis.

It should be noted that DEA is a model with limitations as leadership efficiency is unlikely to scale linearly with troop size. Therefore the virtual adjustments cannot capture Alexander's and Darius III challenges to command larger or smaller forces. The scenarios serve both as a sensitivity analysis and as a test of the works by Oka et al. (2017, Dataset S2) and Keenan-Jones, Duncan, and Hebblewhite (2019), which questioned the reliability of the ancient accounts by generating new figures, that if used uncritically, could lead to erroneous conclusions.

In DEA, the winner of the battle is always deemed more efficient than the opponent and the efficiency gap between the adversaries remains mostly unchanged even when troops sizes vary dramatically. DEA quantifies relative efficiency under controlled conditions rather than aiming to predict historical feasibility. In the case of the Battle of Granicus, Darius's defeat corresponds to lower relative efficiency compared to Alexander, and their real command constraints of both leaders are not reflected in DEA's calculations as the present analysis do not capture them in a frame of inputs/outputs figures. Future work could incorporate a non-linear adjustment factor to approximate the impact of leadership capacity to scale on army efficiency. Moreover, although both Alexander and Darius, as members of royal families, received extensive training in military strategy, it is worth noting that Alexander led his troops at the front of the battlefield, fighting with them, whereas Darius remained at a distance, observing the engagement. This difference had a significant impact on Alexander's forces morale, making them more determined and confident. Additionally, to counter this morale advantage, the sole aim of the Persians was to kill Alexander in the engagement (Fuller 1960). The fighting spirit and the Alexander's direct command in the battlefield are the intangible components that are not modeled in DEA which focuses on the effective use of resources. DEA's rigid methodology by design, considers only components that can be quantified, assigned a value, and transformed into input-output figures. This reflects a limitation of the DEA methodology which cannot incorporate intangible or stochastic components unless they are quantified, rather than a flaw in the analysis.

Following the satisfactory results from this initial DEA application (Phase I and II), the study proceeded to Phase III. The scope of the present paper is broader and beyond the quantification of Alexander the Great's strategic efficiency in the Battle of Granicus. It also seeks to facilitate comparative analysis across a range of historically significant battles. To this end, the study employs DEA as a methodological framework to assess and compare the relative efficiency of military engagements, treating each battle as a DMU characterized by multiple inputs and outputs. For illustrative and future reference purposes, a selection of prominent historical battles throughout human history has been quantitatively evaluated using DEA.

In Phase I, the strategic performance of Alexander the Great at Granicus River Battle served as a primary case study. Phase II served as a validation process of Phase I. In Phase III, the analysis extends to a range of historically significant conflicts, including the Battle of Salamis, the Battle of Thermopylae, the Trojan War, the Persian Wars, the Fall of Constantinople, the Greek War of Independence (1821), the Greco-Turkish War of 1897, and World War I and II.

By assigning quantitative values to these engagements, the study facilitates cross-temporal comparisons of military effectiveness. Results derived through DEA are presented in Table 1, demonstrating the method's applicability for evaluating complex, multidimensional historical phenomena.

Table 1. Military Efficiency in distinct conflicts produced by DEA

Historical Event	**Year of Engagement**	**DEA Score**
Granicus Battle	334 BCE	1.00
Battle of Salamis	480 BCE	0.95
Battle of Marathon	490 BCE	0.90
Battle of Thermopylae	480 BCE	0.85
World War II	1939-1945	0.84
Greek War of Independence	1821-1829	0.80
World War I	1914-1918	0.77
Trojan War	13th century BCE	0.38
Persian Wars	5th century BCE	0.30
Fall of Constantinople	1453	0.12
Greco-Turkish War of 1897	1897	0.10
Roman Conquest	2nd century AD	0.05
Asia Minor Catastrophe	1922	0.00

The resulting radar diagram (Figure 2) visually represents the relative efficiency of the selected engagements based on their DEA scores. The radar chart allows for a quick visual comparison, highlighting not only the ranking of each event but also the disparity in performance across centuries and geopolitical contexts. Each axis of the chart corresponds to a specific battle or war, while the distance from the center indicates its efficiency score on a scale from 0 (lowest) to 1 (highest). The diagram illustrates that certain battles, regardless of era, excel for their effectiveness, while others reflect strategic failure despite potentially greater resources or state support.

In particular, the Battle of Granicus achieves a perfect efficiency score of 1.00, which aligns with the prior detailed analysis. The Battle of Salamis (0.95) and the Battle of Marathon (0.90) also rank remarkable high, reflecting outstanding strategic performances. The Battle of Thermopylae (0.85), while eventually was a defeat for the Greeks, achieves a high score, which reflects the efficiency of the defensive tactics employed under daunting challenges.

Similarly, the Greek War of Independence (0.80) exhibits a remarkable efficiency, despite the absence of a Greek state to organize and train a regular army or provide resources. The conflict was fought primarily by small, irregular forces led by local chieftains, highlighting the effectiveness of decentralized battlefield strategy. For this reason, the Greek War of Independence stands out as a key historical benchmark, in contrast to battles conducted under the authority and support of organized governments.

Conversely, in large-scale conflicts of the modern times such as World War I (0.77) and World War II (0.84), DEA scores show moderate efficiency levels. This reflects the extensive destruction in respect to broad committed resources and casualties that affected operational efficiency.

Lower scores in campaigns such as the Trojan War (0.38),Persian Wars (0.30), and Fall of Constantinople (0.12), highlight less efficient outcomes, potentially critical roles of diplomacy, alliances, and the scale of geopolitical influence.

On the other side, conflicts such as the Roman Conquest (0.05) and the Asia Minor Catastrophe (0.00) are positioned near to the center, illustrating their low strategic efficiency. The Roman Conquest (2nd century AD), reflects the strategic collapse of the Greek world. The death of Alexander the Great marked a turning point in history, as his empire reduced into competing Hellenistic kingdoms ruled by his former generals. Meanwhile, the Greek mainland retained its traditional city-state political structure. This fragmented political landscape made it easier for Rome to gradually dominate the region, conquering it piece by piece. The lack of political unity during the Hellenistic period ultimately manifests the weakening of defense structures to external threats. It also encourages strategic reflection, as the concentration of imperial power in the hands of one man exposed the fragility of such a system once leadership collapsed. So the Roman Conquest reveals that the concentration of power in Alexander's hands was effective in the short term but vulnerable in long-term.

The Asia Minor Catastrophe (0.00), as the name suggests, receives the lowest possible score, underscoring that failed campaigns often stem from strategic shortcomings, resource deficiencies, or the absence of strong alliances. It serves as another key historical benchmark, illustrating that the presence of a government does not guarantee success, especially when alliances prove ineffective.

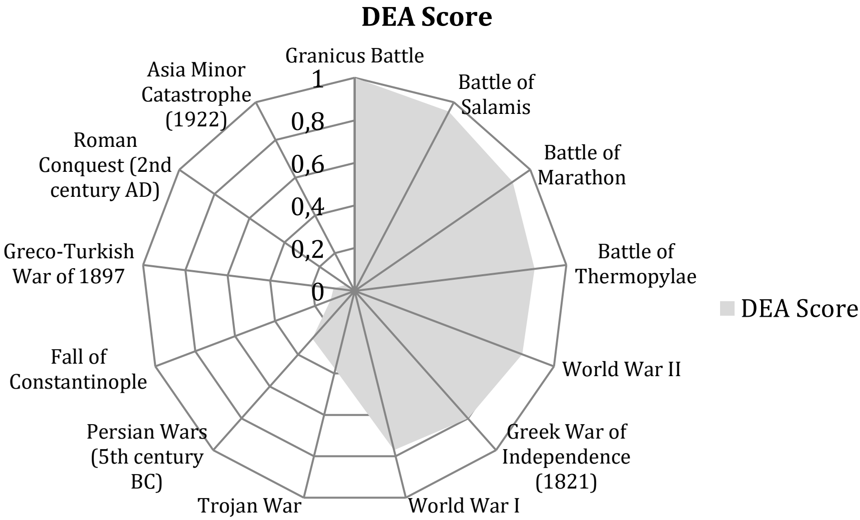

Figure 2. DEA scores - Military Efficiency benchmarking

Overall, the DEA results provide a compelling quantitative framework to compare and contrast military efficiency across diverse historical contexts, reinforcing known historical narratives while also inviting deeper investigation into the factors contributing to efficiency or inefficiency in warfare.

5 Discussion

Quantifying history isn't just counting; it's a way to take the pulse and temperature of historical events, turning their intensity, scale, and trajectory into measurable data. Numerical interpretation of key historical moments helps further scientific analysis by comparing different events or strategies and analyze patterns or anomalies across time or conflict. Ultimately, representing complex historical phenomena as a single number, simplifies the communication and understanding of intricate events, making it more accessible to a wider audience. This numerical distillation allows historians, researchers, and even the general public to quickly grasp the relative significance or impact of events without getting lost in excessive details. It acts as a common language that bridges gaps between different fields of study, enabling clearer comparisons and more effective discussions about history's vast and multifaceted nature.

Without assigning numerical values to key historical moments, some notions may remain abstract and hard to grasp unless they are quantified. For instance, what score would a general need to earn the title "the Great", as seen in figures like Alexander the Great, Napoleon Bonaparte, or Tsar Peter the Great?

While attempting to generate a formula for assessing a general's entire military career, a "greatness score" could be calculated based on a range of factors; for instance, the number of battles won, the expansion of territory due to battle outcomes (measured in square kilometers or hectares), battle casualties, resources expended, and other variables or sub-indicators, such as the birth of a new empire or the securing of freedom from opponent's occupation.

Comparing the three generals, a short employment of greatness formula can be based on the following data. Alexander won 20 battles, secured over 5 million square kilometers of territory, and caused about 100,000 deaths or captured soldiers. The historical impact indicator (HII) created on purpose, can be measured on a scale from 1 to 100. For Alexander is attributed a perfect score of 100 due to his enormous influence on history. The greatness score could be expanded by considering variables such as the foundation of cities, the dissemination of culture, the number literature books, PhD Thesis, academic papers and books on his achievements, archaeological treasures, art produced, movies, folklore tails, songs, poems and a nonstop list of perpetual outcomes. Keeping the more simple data, a greatness formula can be the following:

Greatness Score = Won Battles + (Territory expansion/1000) + (Casualties/1000) + HII

Employing the above formula Alexander scores first.

Alexander Greatness Score = 20 + 5000 + 100 + 100 = **5220**

Napoleon Greatness Score = 60 + 720 + 500 + 90 = **1370**

Peter Greatness Score = 10 + 470 + 100 + 80 = **660**

Comparing these results, it's clear that although Napoleon Bonaparte won three times as many battles as Alexander, he gained less territory and suffered more casualties. This *ad hoc* example illustrates how numerical scores make it easier to compare complex historical data and draw meaningful conclusions.

Additional modeling can be used for further examination. For example, modeling human intelligence and personality involves quantifying complex traits and cognitive abilities into measurable components, which can then be combined mathematically to form predictive or descriptive formulas. While human intelligence and personality are multifaceted and not fully reducible to numbers, certain models and frameworks attempt to represent key aspects quantitatively. Human intelligence is measured by the IQ score formula, but can be modeled as a weighted sum of various cognitive domains like verbal abilities, reasoning, memory, motivation and emotional functioning (Matzel and Sauce 2017; Braaten and Norman 2006).

Models often separate intelligence into biologically based problem-solving (fluid intelligence) and intelligence produced by experience and skills acquired through learning (crystallized intelligence). Both components are then combined for an overall score (Cattell 1963; Horn and Cattell 1967; McGrew 2009).

Psychology offers several frameworks for organizing personality traits, collectively known as personality models. One of the earliest was the Great Man Theory of leadership, which emphasized the role of influential individuals in shaping history (Carlyle 1841; Grethlein 2015). Over time, more empirically grounded models emerged, such as Cattell's 16 Personality Factor (16PF) model (Cattell 1965) and the widely recognized Big Five Personality Traits**,** also known as the Five-Factor Model (OCEAN)**.** This model categorizes personality into five dimensions: Openness, Conscientiousness, Extraversion, Agreeableness**,** and Neuroticism, each measured on standardized scales (McCrae and Costa 1987).

The psychological approach has many challenges due to the **c**omplexity of human behavior that draws influence by genetics, environment, and experience. Moreover there is a dynamic fluid nature in human's decision making as both intelligence and personality can evolve over time. Finally, cultural and contextual factors can't be always mirrored in mathematics.

The present study explores the quantification of historical military events through the mathematical modeling of DEA Analysis. The Battle of Granicus River is used as the opening case study for several reasons. First is one of the most enigmatic battle in history not only because of topography puzzling but also for its short duration. It lasted less than one day. Building on this foundation, the study examines how numerical representations of strategic and historical outcomes can simplify complex phenomena and facilitate comparative analysis. The authors propose a "Greatness Score" formula to assess military leaders based on measurable indicators such as battles won, territorial expansion, casualties, and historical impact. By applying this framework to figures like Alexander the Great, Napoleon, and Peter the Great, the study demonstrates the utility of quantification in historical interpretation.

The analysis was conducted in three stages. In the first and second stage, the Battle of Granicus was selected as a pilot case, and DEA was applied to compare the two opposing armed forces. This initial phase focused on evaluating efficiency within the context of a single, shared military engagement. The phase confirmed applicability of DEA and offered unique structured comparison of military efficiency in the battlefield and a reproducible framework for further historical-military analysis. The clear, at-a-glance comparison provided by the initial results acted as a stepping stone toward Phase III of the analysis. In Phase III, the analysis was extended to include a larger set of battles and commanders. This second stage incorporates multiple battles across classical antiquity and modern era. Totally 13 war engagements were evaluated. Additional input/output variables were measured in the model. The DEA results served as an efficiency benchmarking across time and geography. Notably, the Battle of the Granicus River ranked first, indicating it was the most efficient battle in the dataset.

Ancient accounts, particularly those detailing measurements, were long met with skepticism regarding their accuracy. This distrust often impedes further research considered it as pointless and keeping potential valuable information forever hidden. Assuming older accounts are inaccurate by default introduces bias. DEA is not the golden standard or the machine of truth that provides precision but is rather a benchmarking tool designed to identify the most efficient observation within a dataset. Archaeology and ongoing research can help build the reliability of ancient accounts as new technologies and methods are employed, allowing to validate historical data from different perspectives and disciplines. In this research DEA showed that the Battle of Granicus River holds its first rank among the most known battles and wars in history. Therefore confirms the remarkable outcomes described in both ancient sources and modern studies about Alexander's strategic and tactical efficiency, proving that historical narratives are not exaggerated.

Finally, the paper further contextualizes the involvement of history quantification, suggesting innovative, borrowed and interdisciplinary mathematical tools in historical scholarship.

6 Conclusions

The use of DEA in warfare and defense is gaining momentum in academic research. Most existing applications focus on contemporaneous DMUs, primarily aimed at streamlining expenses and optimizing logistics. The present study is, to the best of current knowledge, among the first to apply DEA in a historical and general efficiency scoring context. In doing so, it also contributes to the creation of a comparative benchmark across key battles and commanders, enabling systematic assessments of military effectiveness over time and geography. The study provides a clear starting point for deeper, case-specific analysis of individual battles or entire wars. DEA analysis relies heavily on the availability of reliable data, and any deviation from historical accuracy inherently limits the scope and robustness of the study. Estimation bias is a significant limitation; however, in certain battles, the differences in data are sufficiently pronounced to still allow meaningful comparisons. In battles of antiquity, precise troop numbers are often unnecessary, as broad estimates are typically sufficient to capture the scale and outcomes relevant for efficiency analysis.

The DEA demonstrated that the Battle of the Granicus River is both the archetype and the gold standard of military efficiency among historic engagements. This exemplary efficiency contributes a valuable perspective to the complex historical narrative of the Battle of the Granicus River under Alexander's the Great command. Sometimes, it takes just one wooden horse to end a decade-long war. But DEA looks at the ten years before the deception; the prolonged investment of troops, time, and resources. While the Trojan Horse delivered the final blow, the model captures the cumulative cost of reaching that moment. This highlights both the power and the limitations of DEA in analyzing warfare: it measures efficiency across the full duration of a conflict, not the brilliance of a single decisive act.

While history as a science provides a contextual account, data and figures serve as a dictionary that translates facts into a complementary narrative, adding depth and cultivating a more holistic understanding of the past.

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