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A Systematic Review of Quantitative Methods for Estimating the Economic, Human, and Environmental Damages of War: Challenges, Applications, and Biases in Recent Crises

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Abstract

Abstract: Armed conflicts impose substantial physical, economic, human, and environmental costs. However, estimates of war-related damages vary considerably depending on the methodological approach, type of damage, data availability, and assessment objectives. This study aims to systematically review existing approaches for estimating the economic and broader consequences of armed conflicts and to develop an integrated framework for combining complementary methods while minimizing double counting. A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Relevant studies and institutional reports published between 1988 and January 15, 2026, were identified through searches of international and domestic scientific databases and relevant institutional sources. After screening and eligibility assessment, 67 sources were included in the qualitative synthesis. The reviewed approaches were organized into four major methodological categories: direct cost-based methods for estimating physical asset damage; econometric and assessment methods, including the Synthetic Control Method (SCM) and Damage and Needs Assessment (DaNA); human valuation methods, including the Value of a Statistical Life (VSL) and Present Discounted Value (PDV); and remote sensing-based methods for identifying and measuring physical damage. The reviewed evidence indicates that no single method can comprehensively capture all dimensions of war-related damage. Direct cost-based approaches are useful for estimating physical asset damage, while SCM and DaNA provide complementary approaches for assessing economic losses and recovery requirements. VSL and PDV can be used to incorporate mortality, disability, and human-capital losses, whereas remote sensing and Earth observation techniques can provide spatially detailed evidence of physical destruction. The findings also indicate that differences in accounting boundaries, time horizons, and data sources may lead to overlapping estimates when multiple methods are combined.

Keywords: War Damage Estimation, Synthetic Control Method, Value of Statistical Life, Post-Crisis Needs Assessment, Systematic Review.
JEL Classification: D74, C18.

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1. Introduction

Accurate and transparent estimation of these damages is important for reconstruction planning, humanitarian assistance, compensation analysis, economic recovery assessment, and historical documentation. However, war-damage estimation is complicated by incomplete data, restricted access to affected areas, heterogeneous valuation methods, rapidly changing prices, and substantial differences between physical, economic, human, and environmental dimensions of damage. Recent conflicts in Ukraine, Gaza, Syria, Lebanon, Sudan, and other conflict-affected settings have highlighted the limitations of conventional damage-assessment approaches. These settings differ substantially in the availability of administrative data, accessibility of affected areas, physical patterns of destruction, duration of conflict, and the extent of environmental and human losses. Consequently, no single estimation method can adequately capture all dimensions of war-related damage.

2. Research Background and Literature Gap

The existing literature can be organized into four major methodological categories: direct cost-based methods, econometric and assessment methods, human valuation methods, and remote sensing-based methods.

Direct cost-based methods: estimation of physical damage to buildings, infrastructure, productive assets, and other tangible assets."

"Econometric and assessment methods: estimation of economic losses and reconstruction requirements using approaches such as the Synthetic Control Method (SCM) and Damage and Needs Assessment (DaNA)."

"Human valuation methods: estimation of mortality, disability, and human-capital losses using approaches such as the Value of a Statistical Life (VSL) and Present Discounted Value (PDV)."

"Remote sensing-based methods: identification and measurement of observable physical damage using satellite imagery, Earth observation, and related computational methods.

Despite this diversity, a fundamental gap is observed in the scientific literature of this field: Although previous studies have examined individual methods or specific conflict settings, relatively few studies have systematically compared these methodological approaches within a single analytical framework. Existing studies are either limited to a specific method, or have focused solely on one crisis (such as the World Bank, 2023), or have a descriptive aspect and do not address methodological critique. However, in Iran, the

authors' search in domestic scientific databases (such as Noormags, Magiran, Elmnet, and SID) shows that. The only available information relates to news reports about damage estimates from a hypothetical conflict, which lack scientific methodology and a peer-review process. It should be noted, however, that in the field of economic research related to international pressures (such as sanctions), some studies have been conducted in Iranian scientific journals. For instance, Adeli *et al.* (2022) employed the Synthetic Control Method (SCM) to examine the effect of sanctions on Iran's exports. Although this study did not directly address war damage estimation, it is closely related to the present research both methodologically (the application of SCM to assess the impact of an external shock on the macro economy) and thematically (the assessment of economic losses resulting from international pressures), and it can be cited as a domestic example of applying econometric methods to damage assessment.

The main objective of the present study is to provide a systematic review of existing methods for estimating war damages, analyze the strengths and weaknesses of each approach based on the experiences of recent crises, and propose a combined framework. Therefore, four main questions can be stated for this research as follows:

• What are the main methodological approaches for estimating physical, economic, human, and environmental dimensions of war damage, and how can they be categorized?

• What are the strengths, weaknesses, accuracy, speed, and vulnerability to bias of each method in the context of real crises (Ukraine, Gaza, Syria, Lebanon, Sudan)?

• What research and methodological gaps exist in the field of war damage estimation?
• Given the existing limitations, what combined framework can provide a more realistic and valid estimate of war damage?

To the best of the authors' knowledge, relatively few studies have systematically compared these methodological categories within a single analytical framework and examined their potential integration.

3. Research Methodology

This study is a systematic review based on the PRISMA guidelines. The systematic review approach was chosen over meta-analysis for the following reasons:

• Severe heterogeneity of methods and data: Existing studies have used completely different methods (cost-based, econometric, human valuation, remote sensing) that cannot be statistically combined.

• Diversity of damage dimensions: War damage includes physical, economic, human, and environmental dimensions, each of which requires its own specific methods.

Search strategy and date. A systematic search was conducted on January 15, 2026 (final search date) across the following databases: Web of Science, Scopus, and Google Scholar (international scientific databases), as well as the World Bank, United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), Organization for Economic Co-operation and Development (OECD), PAX, Humanity & Inclusion (HI), and Insecurity Insight (gray literature). The following Boolean search strings were used (adapted for each database):

- String 1: ("war damage" OR "conflict losses" OR "economic cost of war" OR "environmental impact of war") AND (estimation OR assessment OR valuation OR "earth observation" OR "remote sensing") AND (methodology OR model OR approach OR framework).
- String 2: (war OR conflict) AND (damage OR loss) AND (assessment OR measurement) AND (economic OR human OR environmental).

The search was limited to English and Persian languages, and studies published from 1988 up to the final search date of January 15, 2026, were considered. The inclusion and exclusion criteria for articles and studies were as follows:

Inclusion criteria

- Articles and reports that present an explicit quantitative method for estimating damage caused by armed conflict.
- Studies that have used remote sensing data for mapping or damage estimation.
- Research that has compared or critiqued damage estimation methods.
- Case studies on the crises in Ukraine, Gaza, Syria, Lebanon, Sudan, Iraq, Yemen, and Afghanistan.
- Publication within the time frame of 1988 to 2026.
- English language or having a valid English abstract (for Persian sources).

Exclusion criteria

- Purely qualitative articles without presenting a specific quantitative method.
- Purely theoretical studies without practical application in a real crisis.
- Articles that solely address countries' military budget expenditures (not damage to civilians, infrastructure, and the environment).
- Duplicate articles or those without primary data.

Quality appraisal and risk of bias assessment.

To ensure the scientific rigor of the review, each included source was appraised against three quality criteria: (1) *methodological validity*—whether the study employed an explicit, replicable quantitative method with clearly stated assumptions; (2) *data transparency*—

whether the source documented the origin, coverage, and limitations of its data; and (3) *institutional independence and transparency of mandate*—whether the assessment was conducted by an institution with a declared mandate that could influence the framing or scope of the estimate. Based on these criteria, sources were classified as high, moderate, or low quality. Particular attention was paid to two forms of bias that are especially relevant to war damage estimation: *political framing bias* (the influence of how a conflict is labeled and framed on the choice of assessment components and final figures) and *methodological bias* (systematic distortions arising from the structure of a method itself. These bias assessments were then incorporated into the thematic analysis and are reflected in the comparative discussion of methods in Section 4 and Section 5.

Table1 presents the quality appraisal of the 67 included sources based on the three criteria (methodological validity, data transparency, and institutional independence and transparency of mandate), indicating the distribution of sources across high, moderate, and low-quality levels.

Table 1. Quality Appraisal of the 67 Included Sources

Quality level	Methodological validity	Data transparency	Institutional independence and transparency of mandate	Number of sources (n=67)
High	Explicit and replicable method	Fully documented data origin/limitations	Independent academic or audit institution	28 (41.8%)
Moderate	Method stated but limited assumptions	Partial data documentation	Institutional report with stated mandate	25 (37.3%)
Low	Vague or non-replicable method	Poor data documentation	Strong political framing evident	14 (20.9%)

(Note: The classification of each specific source is available in Appendix 1, the detailed classification of the included sources is provided in Appendix 1)

Screening and selection process of articles:

- The screening process was conducted in four stages in accordance with the PRISMA guidelines:
- Identification: The initial search in the databases led to the identification of 387 sources (See figure 1).
- Initial screening: Removal of duplicates (89 items) and review of titles and abstracts to remove irrelevant sources (192 items). 106 sources remained.
- Eligibility assessment: Full-text review of 106 sources and application of inclusion and exclusion criteria. 39 additional sources were removed (due to lack of quantitative method, lack of primary data, or irrelevance to war damage).

- Final inclusion: 67 sources were selected for final analysis, including 42 scientific articles, 15 reports from international organizations, and 10 reports from non-governmental organizations and research groups.

Data extraction and analysis

- For data extraction, a structured coding form was designed that included the following:
  - Bibliographic information (author, year, title, journal/publisher)
  - Type of damage estimation method
  - Type of damage (economic, human, environmental, infrastructural)
  - Geographical context (country/region involved)
  - Time frame of conflict and assessment
  - Data used (source, quality, limitations)
  - Strengths noted by the authors
  - Weaknesses and limitations noted
  - Reference to political or methodological biases

For data analysis, thematic analysis was used. Accordingly, first, the methods were classified into four main categories based on the type of approach. Then, for each category, the main themes (strengths, weaknesses, applications, challenges) were extracted. Finally, a comparative analysis between methods was conducted based on key criteria (accuracy, speed, data requirements, transparency, vulnerability to bias).

The PRISMA flow diagram summarizing the identification, screening, eligibility, and inclusion stages is presented in Figure 1.

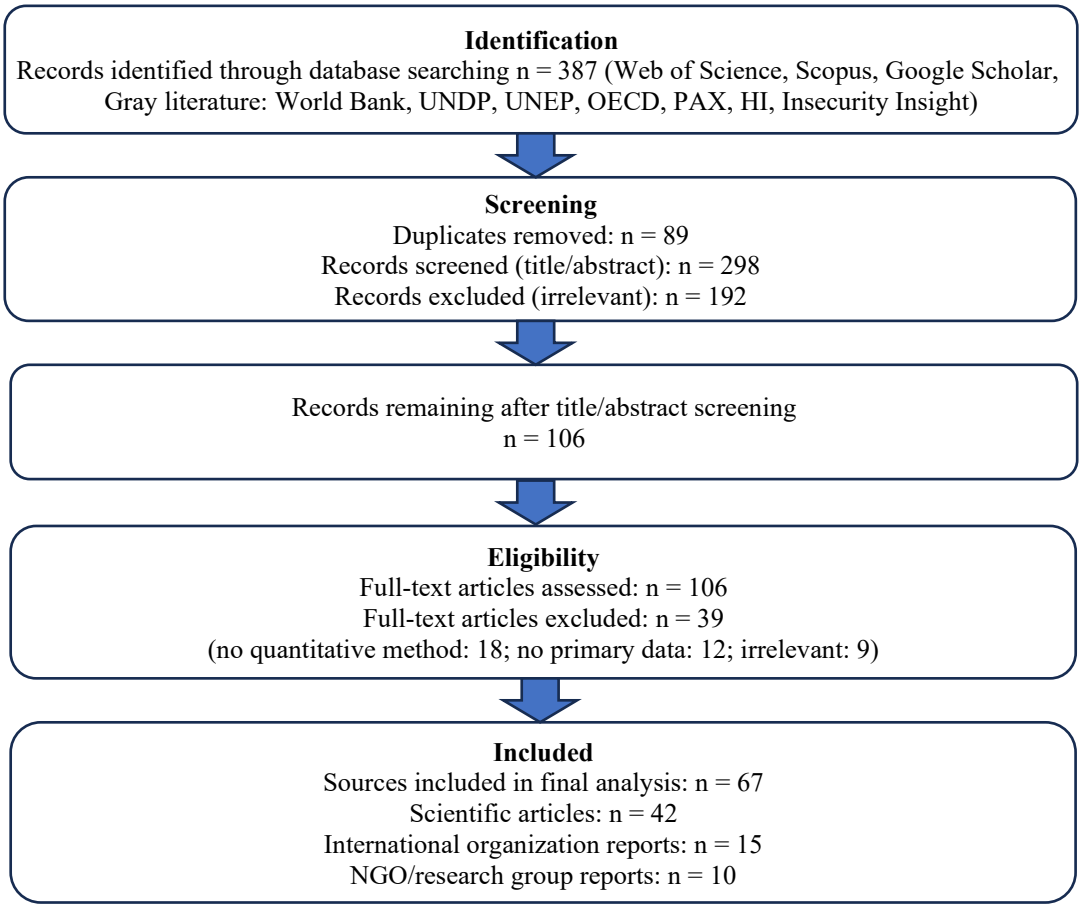

Fig. 1: PRISMA Flow Diagram of the Source Selection Process

4. Research Findings

Based on the analysis of the 67 selected sources, the methods for estimating war damage were classified into four main categories comprising five methodological approaches. The four categories are direct cost-based methods, econometric and assessment methods, human valuation methods, and remote sensing-based methods; within the second category, the Synthetic Control Method (SCM) and the Damage and Needs Assessment (DaNA) are treated as two distinct methodological approaches and are evaluated separately in Table 3. It should be emphasized that the four categories differ not only in their techniques but also in their fundamental methodological nature, and this distinction is essential for understanding their respective roles and limitations.

Table 2: Classification of War Damage Estimation Methods

Category	Subsets	Type and scope of damage covered
Direct cost-based methods	Partial estimation, replacement cost with upscaled unit values (UPVV)	**Physical and tangible** (housing, roads, schools, hospitals)

Econometric and assessment methods	Synthetic control method (SCM), damage and needs assessment (DaNA)	**Economic losses and recovery/reconstruction assessment**
Human valuation methods	Value of statistical life (VSL), present discounted value of lost income (PDV)	**Human** (loss of life, disabilities, human capital reduction)
Remote sensing-based methods	Satellite imagery (Sentinel, NASA), machine learning	**Observed physical** (mapping destruction, monitoring land use changes, water infrastructure)

4-1. Description of Methods and Case Studies

4-1-1 Direct Cost-Based Methods (CBDM)

Direct cost-based methods (CBDM) are the most widely used approach for estimating physical damage to infrastructure. These methods are based on calculating the cost of reconstruction or replacement of lost assets and are most widely used in estimating physical damage to infrastructure. One of these methods in the empirical literature is the UPVV method.

• Replacement Cost Method with Upscaled Unit Values (UPVV)

This method, which has its roots in the 1970s, provides a rapid estimate of damage by using fixed construction cost indices and indexing them based on inflation.

Case Study of Syria: In the joint damage assessment report by the World Bank and the United Nations for selected cities in Syria, the replacement cost method using pre-war prices (2010) was used as the basis for valuation. This report estimated the damage to various sectors (housing, health, education, energy, water and sanitation, agriculture, transportation) based on the number of damaged assets and the reconstruction cost of each unit. However, researchers have acknowledged that severe fluctuations in exchange rates and inflation in Syria have severely affected the accuracy of these estimates (World Bank and United Nations, 2022).

These figures are mainly calculated based on replacement-cost approaches. In Gaza, the extensive destruction of water and sanitation systems may substantially increase reconstruction costs, illustrating the importance of including sector-specific infrastructure needs in physical-damage assessments.

The main advantage of these approaches is their speed and operability in chaotic conditions, and their main limitation is ignoring non-physical economic losses (such as production stoppage, reduced tax revenues, and loss of human capital) and extreme sensitivity to price and inflation fluctuations.

4-1-2 Econometric and Assessment Methods

These methods, instead of calculating physical costs, estimate economic losses through statistical models and simulation. In the empirical literature, the following methods have generally been used to estimate economic losses.

4-1-3. Synthetic Control Method (SCM)

This method is a causal method that simulates potential economic growth in the absence of war by creating a synthetic unit from control regions (that have not experienced war). The difference between actual GDP and simulated GDP will be the estimate of war-induced loss. The validity of the estimates depends on the quality of the donor pool, pre-intervention data, and the plausibility of the counterfactual construction (Abadie & Gardeazabal, 2003). Case Study of Ukraine: Synthetic control studies have been used to estimate the economic effects of the Russia-Ukraine conflict by constructing a counterfactual based on comparable control units. The reliability of such estimates depends on the quality of pre-intervention data, the suitability of the donor pool, and the plausibility of the counterfactual assumptions.

4-1-4. Damage and Needs Assessment (DaNA) Method

DaNA is an established framework used by international organizations to assess physical damage, economic losses, and recovery and reconstruction needs. This method calculates damage using cost-based methods and loss through the difference in production levels before and after the war (United Nations Development Programme, 2022).

The main advantage of this method is its comprehensiveness and endorsement by credible international institutions, and its main limitation is its heavy dependence on field assessment teams (which is not possible in insecure conditions) and may be affected by institutional, contextual, and data-availability constraints.

4-1-5. Human Damage Valuation Methods (VHL)

The major part of war damage is non-market in nature and must be valued using specific methods. Amputation in war zones has revealed new dimensions of this challenge. In the empirical literature, the following methods have generally been used to value human damages.

• Value of Statistical Life (VSL): This is essentially a method for estimating individuals' willingness to pay to reduce the risk of death. This method is calculated based on revealed

preference studies (e.g., hazardous job wage premiums) or stated preferences (willingness-to-pay questionnaires).

• Present Discounted Value of Lost Income (PDV): To calculate the opportunity cost of lost labor force due to death or disability, the present value of the individual's future income stream is calculated using an appropriate discount rate.

Nevertheless, the main advantage of this method is that these methods can provide monetary estimates of selected human losses, but their interpretation requires careful consideration of ethical, distributional, and methodological assumptions.

4-1-6. Remote Sensing Data-Based Methods (EO)

Earth observation (EO) methods, which rely on satellite imagery and remote sensing data, play an important role in damage estimation, especially in conditions where field access is impossible or very dangerous. In this method, mapping is carried out using satellite imagery.

• Mapping Method through Satellite Imagery: Using multi-temporal satellite imagery (before and after the conflict) from Sentinel (European Space Agency), Landsat (NASA), and high-resolution commercial data, changes in land use, destruction of buildings, forests, agricultural land, and water infrastructure can be identified and mapped. Machine learning algorithms can accelerate the process of automatic detection of destruction patterns (Pax, 2025).

The main advantage of this method is providing spatially explicit evidence independent of field sources, the ability to cover vast and inaccessible areas, verifiability and reviewability, and reducing political biases, but it also faces limitations, including the method's need for high technical expertise, inability to estimate non-physical damages (such as economic and human losses), and the need for baseline data (before the conflict) for comparison.

4-2. Comparative Analysis of Methods

In this study, the war-damage estimation approaches were compared based on six key criteria, as summarized in Table 3.

Based on Table 3, no single approach can address all dimensions of war-damage estimation. The suitability of each approach depends on the research objective, the type of damage, data availability, and the assessment time frame. Direct cost-based methods are useful for rapid estimation of physical damage; SCM can provide causal estimates when the required data and identification assumptions are satisfied; DaNA provides a structured

assessment of damage, losses, and recovery needs; human valuation approaches address selected non-market human losses; and remote sensing provides spatially explicit evidence of observable physical destruction.

Criteria for comparison and basis of judgment. The six criteria used in Table 3 were selected to capture the dimensions most relevant to policymakers and researchers engaged in war-damage estimation: type and scope of damage covered, need for long-term data, speed of implementation, accuracy in crisis conditions, transparency and replicability, and vulnerability to political bias. To ensure that the comparative judgments in Table 3 are transparent and replicable, the basis for each rating is specified as follows.

To further clarify the basis of comparison, a three-level rating scale was used for each criterion: *high*, *moderate*, and *low*. A "high" rating indicates that the method performs strongly on that criterion relative to the alternatives reviewed (e.g., very fast implementation, high accuracy where reference data exist, or low vulnerability to bias); a "moderate" rating indicates partial or conditional performance that depends on data availability and context; and a "low" rating indicates a structural weakness inherent in the method (e.g., inability to capture non-observable damages, or high dependence on assumptions that are difficult to verify). Where a criterion is not applicable to a method (e.g., "need for long-term data" in the case of a purely physical replacement-cost estimate), this is indicated explicitly rather than assigned a rating. This scale is intended to facilitate comparison across methods, not to rank them in absolute terms, since the appropriateness of a method depends on the research question, the phase of the crisis, and the available data.

It should be noted that the comparative ratings in Table 3 reflect the synthesized evidence from the reviewed sources and are therefore subject to the limitations of those sources. In particular, ratings for accuracy in crisis conditions depend on the availability of reference data, while ratings for vulnerability to political bias depend on institutional context, methodological assumptions, and transparency of the assessment process.

Table 3: Comparison of Methods Based on Six Criteria

Criterion	Direct Method (CBDM/UP)	SCM	DaNA	Human Valuation (VSL/PDV)	Remote Sensing (EO)
Type and scope of damage covered	Physical only. Tangible assets (housing, infrastructure, roads, schools, hospitals).	Macroeconomic only. Production, exports, unemployment, investment.	Physical and economic. Combination of asset damage and income loss.	Human only. Loss of life, disabilities, human capital, long-term treatment costs.	Observable physical only. Buildings, agricultur, forests, water infrastructure.

Need for long-term data	Low. Requires initial maps, satellite imagery, and unit cost indices.	High. Requires sufficiently long pre-conflict time-series data and an appropriate donor pool	Moderate. Timing depends on data availability, field access, and assessment scope.	Moderate. Requires preference studies or demographic and wage data.	Moderate. Requires pre- and post-conflict satellite imagery.
Speed of implementation	Very high. Initial estimate within days.	Low. Requires data preparation and model specification before reliable estimation	Moderate. Timing depends on data availability, field access, and assessment scope.	Moderate to low. Requires adaptation to local conditions and discount rates.	High. A destruction map can be prepared quickly.
Accuracy in crisis conditions	Low. Due to price fluctuations, inflation, material shortages.	High, conditional. Reliability depends on identification assumptions and data quality.	Moderate to high, depending on data quality, field access, and assessment scope.	Moderate. Heavy dependence on assumptions (discount rate, income elasticity).	Moderate to high. Especially for vast and inaccessible areas.
Transparency and replicability	High. Clear formulas and indices.	High. Codifiable and reliant on mathematics/statistics.	Moderate. Physical part is transparent; loss part is less transparent.	Moderate. Depends on transparency of valuation assumptions and data sources.	High. Verifiable and reviewable data.
Vulnerability to political bias	Moderate. Choice of base index and scope of damage can change the result.	Moderate. Choice of base index and damage scope can affect results.	Moderate. Sensitive to model specification, donor-pool selection, and institutional context.	Moderate to high. Sensitive to valuation assumptions, income differences, and ethical choices.	Low to moderate. Provides spatially explicit evidence, but interpretation and classification choices may still introduce bias.

5. Discussion and Analysis of Findings

The findings of this systematic review showed that there is a deep gap between "what should be estimated" and "what is actually estimable" in the field of war damage. In the following, the most important challenges, biases, and opportunities identified are discussed.

5-1. Main Methodological Challenges

Heterogeneity of methods and incomparability of results. The most fundamental challenge revealed by this review is not simply that methods differ, but that they measure conceptually different quantities that cannot be aggregated or directly compared. Each method captures a distinct dimension of war damage: direct cost-based methods measure

the *stock of destroyed assets*, econometric methods measure the *flow of lost income*, human valuation methods measure the *monetary value of non-market human losses*, and remote sensing methods measure the *observable physical footprint* of destruction. A concrete illustration makes this clear: the derived from the replacement cost method, represents the accumulated loss of assets (housing, infrastructure, and capital stock), whereas the SCM-based estimate of a 30–35 percent reduction in Ukraine's GDP represents the loss of income flow (production, trade, and investment) relative to a counterfactual. These two figures are not two estimates of the same thing; they are estimates of different things. The first answers the question "how much would it cost to rebuild?", while the second answers "how much output has been foregone?". Treating them as comparable, or aggregating them, would constitute a category error. This conceptual heterogeneity prevents policymakers from obtaining a unified picture of total damage and creates serious ambiguity in reconstruction budgeting, because the two types of estimates imply different policy responses: asset losses call for reconstruction financing, while income losses call for economic stabilization and compensation (World Bank, 2023).

• The human capital challenge: Methods for valuing mortality and disability involve ethical and methodological assumptions. VSL and PDV estimates should therefore be interpreted cautiously, with attention to the assumptions used to transfer or adapt values across populations and contexts.

• The impact of institutional and methodological framing: The choice of assessment boundaries, indicators, data sources, and valuation assumptions can influence reported damage estimates. Transparent definitions and explicit accounting boundaries are therefore essential for comparing estimates across conflicts.

• Data and access limitations: In many war zones (such as Syria, Yemen, Sudan), reliable and long-term statistical data are not available, which makes the implementation of precise methods such as SCM impossible. Also, the access of field assessment teams to affected areas in insecure conditions is one of the biggest challenges of the DaNA method and causes estimates to be presented with significant delay and incomplete coverage (United Nations Environment Programme, 2022).

5-2. Opportunities and New Solutions

• The role of modern technologies and remote sensing data: Remote sensing and satellite imagery can support spatially explicit mapping of observable destruction, particularly where field access is restricted. Such data can complement field-based assessments and

provide an additional source for cross-checking physical-damage estimates. However, remote sensing alone cannot estimate non-observable human or macroeconomic losses.

• Artificial intelligence and machine learning: Machine-learning algorithms can support automated or semi-automated analysis of satellite imagery and may improve the speed and scalability of damage detection. Their reliability nevertheless depends on training data, image quality, and the transferability of models across conflict settings.

• International cooperation and standardization: International organizations such as the World Bank, the United Nations Development Programme, and the United Nations Environment Programme can help reduce the heterogeneity of methods and increase the comparability of results by creating standard frameworks and shared databases. Also, developing a global protocol for valuing human and environmental damages can reduce existing structural biases (United Nations Development Programme, 2022; United Nations Environment Programme, 2022).

5-3. The State of Research in Iran and Existing Gaps

Based on the search conducted in domestic scientific databases (Noormags, Magiran, Elmnet, and SID), the review identified limited directly relevant Iranian literature on quantitative methods for estimating war damage. The available evidence did not provide a sufficient basis for a separate methodological synthesis of Iranian studies. This finding should therefore be interpreted as a limitation of the search and evidence base rather than as evidence that no relevant Iranian research exists.

5-4. Limitations of the Review

This systematic review has several limitations that should be acknowledged. First, a quantitative meta-analysis was not possible due to the severe heterogeneity of methods and data across the included studies; the review therefore remains qualitative and comparative in nature. Second, although a comprehensive search strategy was employed, access to some gray literature sources—particularly reports from national institutions in conflict-affected countries—was limited, and some relevant sources may have been missed. Third, the review focused on studies published in English or with a valid English abstract, which may have excluded relevant Persian-language or Arabic-language sources. Fourth, the quality appraisal of sources relied on the authors' judgment against three criteria (methodological validity, data transparency, and institutional independence and transparency of mandate), and inter-rater reliability was not formally assessed. Fifth, the proposed three-phase framework is a synthesis of existing methods rather than an empirically validated model;

its operational effectiveness in future crises remains to be tested. Finally, the comparative ratings in Table 3 reflect the synthesized evidence from the reviewed sources and are therefore subject to the limitations of those sources, as discussed in Section 4.

6. Conclusion

Based on the findings of this systematic review, no single method can address all dimensions of war-damage estimation. Reliance on a single method may result in an incomplete estimate when important dimensions of damage fall outside its scope. The four main categories—direct cost-based, econometric and assessment, human valuation, and remote sensing-based—contain five methodological approaches that differ in their strengths, limitations, and data requirements:

• Direct cost-based methods are suitable for rapid estimation of physical damage but may be sensitive to price fluctuations, unit-cost assumptions, and the scope of physical damage captured.

• SCM can provide causal estimates when adequate pre-intervention data, a suitable donor pool, and credible identification assumptions are available.

• DaNA provides a structured framework for assessing damage, losses, and recovery or reconstruction needs, but its implementation may be constrained by data and field-access requirements.

• Human valuation methods can incorporate selected non-market human losses but require careful treatment of ethical, distributional, and methodological assumptions.

• Remote sensing methods provide spatially explicit evidence of observable physical destruction but cannot by themselves capture non-observable economic and human losses.

Based on the findings of this study and with the aim of more comprehensive coverage of damage dimensions, a three-phase combined model is proposed in which, depending on the time frame after the crisis, an appropriate combination of methods is used:

First phase (rapid response: 0 to 3 months after the conflict)

Objective: Attracting immediate international aid and initial decision-making. *Proposed method:* Using the replacement cost method with upscaled unit values (UPVV) for the initial estimation of physical damage to infrastructure. Complemented with remote sensing data to cover inaccessible areas and independently verify damage. *Output:* Initial estimate of physical damage (in dollars) for submission to international institutions.

Second phase (macro estimation: 3 to 12 months after the conflict):

Objective: Accurate estimation of macroeconomic losses and medium-term reconstruction planning. *Proposed method:* Implementing the synthetic control method

(SCM) to estimate GDP reduction and productivity loss. Complemented by using the standard DaNA (Damage and Needs Assessment) framework of the World Bank and the United Nations to create comparability with other crises. *Output:* Estimation of macroeconomic loss and sector-disaggregated reconstruction needs.

Third phase (full valuation: after 12 months)

Objective: covers all physical, human, economic, and environmental dimensions. Although the three phases are presented in chronological order, they are complementary rather than mutually exclusive. Updates may be incorporated as new data become available, while the accounting boundaries of each phase should remain distinct to prevent double counting. In other words, the second phase refines the estimates of the first phase, and the third phase complements the estimates of the second phase, without requiring the process to be restarted. Proposed method: Comprehensive valuation using a combination of the Value of Statistical Life (VSL) for fatalities, the Present Discounted Value of Lost Income (PDV) for disabilities and human capital reduction, and environmental cost-benefit methods, with careful separation of the components already estimated in the previous phases. Output: A final comprehensive estimate of total war damage, covering physical, economic, human, and environmental dimensions, for historical, legal, and compensation purposes.

Distinguishing damage, loss, and reconstruction needs. A crucial conceptual requirement for any combined framework is to clearly distinguish between three related but non-additive concepts: *damage* (physical asset loss), *loss* (economic flow loss), and *reconstruction needs* (future costs). Damage refers to the destruction of the **stock** of assets (e.g., a destroyed factory or a collapsed building). Loss refers to the reduction in the **flow** of income and production that results from the conflict (e.g., the factory's foregone output or the lost tax revenue). Reconstruction needs refer to the **future costs** required to rebuild and restore the damaged assets, which may exceed the pre-war replacement value due to inflation, improved standards, or the need for disaster-resilient infrastructure. These three concepts are not directly additive: adding the value of destroyed assets to the value of lost income would result in double counting, because the lost income is partly a consequence of the destroyed assets. Similarly, reconstruction needs are not simply equal to the assessed damage, as they include future costs that may not have been captured in the initial damage estimate. The proposed three-phase framework therefore explicitly separates these dimensions: Phase 1 estimates damage (stock), Phase 2 estimates loss (flow), and the reconstruction needs are derived from the damage estimate but adjusted for future costs and standards. This separation ensures that the final estimate does not conflate distinct

economic concepts and provides a clear basis for different policy responses: compensation for damage, stabilization for loss, and financing for reconstruction.

Rules for avoiding double counting. A critical operational requirement of any combined framework is the prevention of double counting, which arises when the same loss is estimated more than once across different phases. To address this, three rules are proposed. First, physical asset losses estimated in Phase 1 through the UPVV method should not be counted again in Phase 2 as reductions in GDP; the physical asset estimate and the GDP-based loss estimate should be defined using non-overlapping accounting boundaries. In other words, the loss of a residential building is an asset loss (Phase 1), whereas the loss of a factory's output is an income loss (Phase 2); only the latter should enter the GDP-based estimate. Second, the DaNA framework used in Phase 2 should explicitly separate damage (stock) from loss (flow), so that the physical component of DaNA does not duplicate the Phase 1 estimate. Third, human valuation in Phase 3 (VSL/PDV) must be conducted independently of physical damage estimates; care must also be taken not to count the same human loss twice. Adherence to these rules ensures that the three phases complement rather than duplicate one another.

Mathematical representation of non-duplication. To operationalize the rules above, the final comprehensive damage estimate can be represented as:

$$D_{total} = D_{physical} + L_{economic} + V_{human} + E_{environmental} - I_{overlap}$$

Where:

- $D_{physical}$ = Physical asset damage (Phase 1, UPVV).
- $L_{economic}$ = Economic flow loss (Phase 2, SCM/DaNA).
- V_{human} = Human valuation (Phase 3, VSL/PDV).
- $E_{environmental}$ = Environmental costs (Phase 3).
- $I_{overlap}$ = Intersection term representing only components demonstrably counted in more than one accounting component. It should be identified using explicit accounting boundaries rather than an arbitrary adjustment.

Figure 2 illustrates the operational logic of this framework, showing how the three phases are aggregated while subtracting the overlap term (I overlap) to prevent double counting.

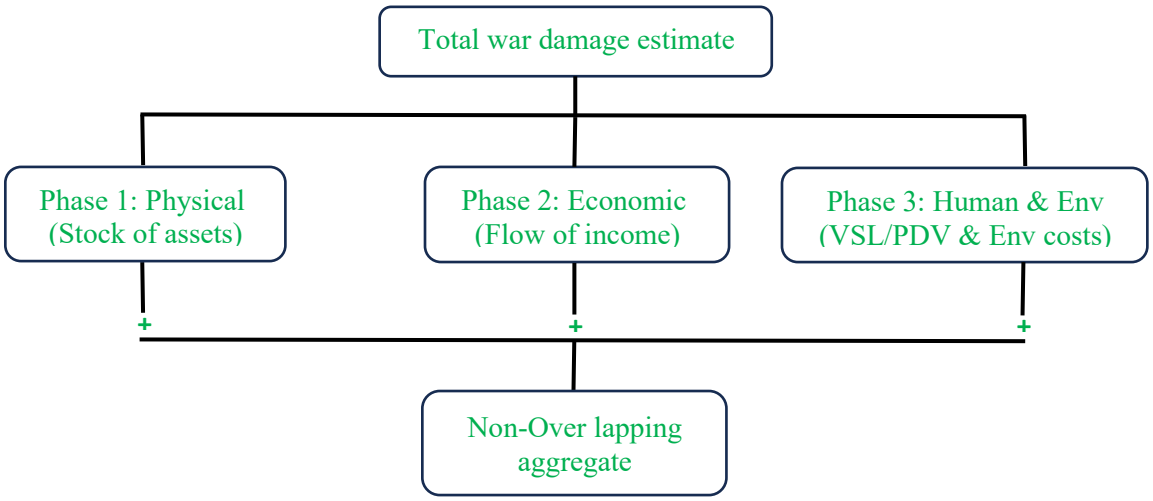

Fig. 2: Operational Logic of the Three-Phase Combined Framework for Avoiding Double Counting

Appendix 1. List of Sources Included in the Systematic Review

Editorial check required before final submission: reconcile this appendix with the eligibility window (1988–January 15, 2026). Sources published before 1988, a fter January 15, 2026, or containing unresolved bibliographic information should not be counted among the included studies.

	Tupe	References	Year	Vol.	No.	PP.	DOI
1	Journal Article	Abadie & Gardeazabal (2003). The economic costs of conflict: A case study of the Basque Country. *American Economic Review,* 93(1), 113–132	2003	93	1	113–132	https://doi.org/10.1257/00028803321455188
2	Journal Article	Collier (1999). On the economic consequences of civil war. *Oxford Economic Papers,* 51(1), 168–183	1999	51	1	168–183	https://doi.org/10.1093/oep/51.1.168
3	Journal Article	Miguel, Satyanath & Sergenti (2004). Economic shocks and civil conflict: An instrumental variables approach. *Journal of Political Economy,* 112(4), 725–753	2004	112	4	725–753	https://doi.org/10.1086/421174
4	Journal Article	Murdoch & Sandler (2002). Economic growth, civil wars, and spatial spillovers. Journal of Conflict Resolution, 46(1), 91–110	2002	46	1	91–110	https://doi.org/10.1177/022002702046001006
5	Journal Article	Koubi (2005). War and economic performance. *Journal of Peace Research,* 42(1), 67–82	2005	42	1	67–82	https://doi.org/10.1177/0022343305049667
6	Journal Article	Blattman & Miguel (2010). Civil War. *Journal of Economic Literature,* 48(1), 3–57	2010	48	1	3–57	https://doi.org/10.1257/jel.48.1.3
7	Journal Article	Smith (2013). The economic costs of military conflict. *Journal of Peace Research,* 51(2), 245–256	2013	51	2	245–256	https://doi.org/10.1177/0022343313496595
8	Journal Article	Dunne & Tian (2015). Military expenditure, economic growth and heterogeneity. *Defence and Peace Economics,* 26(1), 15–31	2015	26	1	15–31	https://doi.org/10.1080/10242694.2013.848575

9	Journal Article	Abadie, Diamond & Hainmueller (2010). Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program. *Journal of the American Statistical Association,* 105(490), 493–505	2010	105	490	493–505	https://doi.org/10.1198/jasa.2009.ap08746
10	Journal Article	Abadie, Diamond & Hainmueller (2011). Synth: An R package for synthetic control methods in comparative case studies. *Journal of Statistical Software,* 42(13), 1–17	2011	42	13	1–17	https://doi.org/10.18637/jss.v042.i13
11	Journal Article	Abadie, Diamond & Hainmueller (2015). Comparative politics and the synthetic control method. *American Journal of Political Science,* 59(2), 495–510	2015	59	2	495–510	https://doi.org/10.1111/ajps.12116
12	Journal Article	Abadie (2021). Using synthetic controls: Feasibility, data requirements, and methodological aspects. *Journal of Economic Literature,* 59(2), 391–425	2021	59	2	391–425	https://doi.org/10.1257/jel.20191450
13	Journal Article	Bluszcz & Valente (2022). The economic costs of hybrid wars: The case of Ukraine. *Defence and Peace Economics,* 33(1), 1–25	2022	33	1	1–25	https://doi.org/10.1080/10242694.2020.1791616
14	Journal Article	Chupilkin & Koczan (2022). The economic consequences of war: Estimates using synthetic controls. *EBRD Working Paper* No. 271	2022	23	4	433–447	https://www.ebrd.com/home/news-and-events/publications/economics/working-papers/economic-consequences-of-war.html?utm_source=chatgpt.com
15	Journal Article	Audretsch, Momtaz, Motuzenko & Vismara (2023). War and entrepreneurship: A synthetic control study of the Russia-Ukraine conflict. *CESifo Working Paper* No. 10466	2023	30	1	3–33	https://www.ifo.de/en/cesifo/publications/2023/working-paper/war-and-entrepreneurship-synthetic-control-study-russia-ukraine?utm_source=chatgpt.com
16	Journal Article	McCannon (2022). The Economic Costs of Conflict: Ukraine, 2014–20. *SSRN working paper*	2022	125	—	103562	https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4118671&utm_source=chatgpt.com
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22	Journal Article	Gapp *et al.* (2026). Efficient fine-tuning for building damage assessment with high-resolution optical satellite imagery: A case study for war damage in Ukraine. *ISPRS Annals* XI-3-2026, 539–548	2026	5	5	pgag124	https://doi.org/10.5194/isprs-annals-XI-3-2026-539-2026
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24	Journal Article	Sticher, Bara, Kotajoki *et al.* (2026). Advancing conflict research and response through satellite-derived data. *Nature*, 657, 891–899	2026	1	3	285–304	https://doi.org/10.1038/s41586-026-11004-6
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Author Contribution

The contribution of all authors to the writing of the article has been equal.

Conflict of Interest

In adherence to ethical publication standards, the authors affirm that there are no conflicts of interest, either personal or financial, that could have influenced the content or conclusions presented in this research.

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صص: ۳۱۵-۲۹۱

چکیده

درگیری‌های مسلحانه، هزینه‌های فیزیکی، اقتصادی، انسانی و زیست‌محیطی قابل‌توجهی ایجاد می‌کنند. برآورد این خسارات بسته به روش‌شناسی، نوع خسارت، دسترسی به داده‌ها و اهداف ارزیابی متفاوت است. این مطالعه با مرور نظام‌مند روش‌های برآورد خسارات جنگ، چارچوبی یکپارچه برای ترکیب روش‌های مکمل و کاهش شمارش مضاعف ارائه می‌دهد. مرور نظام‌مند مطابق دستورالعمل PRISMA انجام شد. مطالعات و گزارش‌های نهادی منتشرشده از سال ۱۹۸۸ تا ۱۵ ژانویه ۲۰۲۶م. از پایگاه‌های علمی داخلی و بین‌المللی و منابع نهادی استخراج شدند. پس از غربالگری، ۶۷ منبع انتخاب شد. روش‌ها در چهار دسته طبقه‌بندی شدند: هزینهٔ مستقیم خسارت دارایی‌های فیزیکی؛ روش‌های اقتصادسنجی و ارزیابی، شامل روش کنترل مصنوعی (SCM) و ارزیابی خسارت و نیازها (DaNA)؛ ارزش‌گذاری انسانی، شامل ارزش یک زندگی آماری (VSL) و ارزش فعلی تنزیل‌شده (PDV)؛ و سنجش از دور برای اندازه‌گیری تخریب فیزیکی. هیچ روش واحدی تمامی ابعاد خسارات جنگ را پوشش نمی‌دهد. روش هزینهٔ مستقیم خسارات فیزیکی، SCM و DaNA زیان‌های اقتصادی و نیازهای بازسازی، VSL و PDV تلفات انسانی، معلولیت و زیان سرمایهٔ انسانی، و سنجش از دور تخریب مکانی را ارزیابی می‌کنند. تفاوت در مرزهای حسابداری، افق زمانی و منابع داده، می‌تواند موجب هم‌پوشانی برآوردها شود. چارچوب پیشنهادی سه مرحله دارد: خسارت دارایی‌های فیزیکی، زیان‌های اقتصادی و تولیدی، و هزینه‌های انسانی و زیست‌محیطی. تعریف مرزهای حسابداری و تعدیل اجزای هم‌پوشان برای کاهش شمارش مضاعف و افزایش دقت برآوردها ضروری است.

کلیدواژگان: برآورد خسارت جنگ، روش کنترل ترکیبی، ارزش آماری زندگی، ارزیابی نیاز پس از بحران، مرور نظام‌مند.
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