Peer Reviewed | Open access
Greenresearch © 2026 Issue II Vol.4
International Journal of Artificial Intelligence, Data and Society

Big Data Analytics for Predicting Social and Economic Vulnerabilities

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Received: 10.02.2026 | Revised: 24.02.2026 | Accepted: 26.04.2026

Abstract

Purpose: This study critically examines the role of big data analytics (BDA) in predicting social and economic vulnerabilities, highlighting methodological strengths, limitations, and ethical implications. While BDA offers unprecedented granularity and timeliness, its deployment for socio-economic risk prediction raises questions about data representativeness, algorithmic bias, and interpretability.

Design/Methodology: A doctrinal qualitative methodology was adopted, synthesizing insights from peer-reviewed literature, policy frameworks, and case studies across global contexts. The study critically interrogates the theoretical foundations of social vulnerability indices, the operationalization of economic vulnerability, and the efficacy of predictive models derived from mobile, administrative, and transactional big datasets.

Findings: The analysis reveals that BDA can enhance predictive accuracy for socio-economic vulnerabilities, particularly when integrating heterogeneous data sources. However, gaps remain in addressing structural biases, data scarcity in marginalized populations, and the limitations of existing computational frameworks to capture contextual socio-economic dynamics. Ethical and policy challenges are accentuated where predictive models may inadvertently exacerbate inequalities.

Originality/Value: This paper contributes a critical synthesis that bridges technological capability with social science theory, emphasizing the dual potential of BDA to inform policy and the inherent risks of reinforcing existing vulnerabilities. It advocates for a nuanced, context-sensitive approach that incorporates ethical safeguards and participatory validation in predictive modeling.

Keywords: Big Data Analytics, Social Vulnerability, Economic Vulnerability, Predictive Modeling, Ethical AI, Policy Implications

1. Introduction

Social and economic vulnerabilities are increasingly recognized as multidimensional phenomena, shaped by intersecting structural, environmental, and technological factors (Biswas & Nautiyal, 2023; Contreras et al., 2020). Traditional methods for assessing vulnerability reliant on surveys, censuses, or static indicators are often limited by temporal delays, geographic incompleteness, and coarse granularity (Wahyuni, Rachmawati, & Baiquni, 2022). The emergence of big data analytics (BDA) offers an unprecedented opportunity to capture real-time, high-resolution signals of socio-economic distress, potentially informing early interventions and policy design (Chen, Li, & Wang, 2022; Pappalardo et al., 2016). However, the adoption of BDA in predicting vulnerabilities is not merely technical; it intersects with questions of social justice, algorithmic bias, and ethical accountability (Madden, Gilman, Levy, & Marwick, 2017). Predictive models can inadvertently reflect and reinforce existing inequalities if underlying datasets are unrepresentative of marginalized populations or if socio-economic context is inadequately modeled (Sundsøy, 2017; Wang & Temmerman, 2023). Moreover, the reliance on computational proxies such as mobile phone usage or transactional patterns—necessitates a critical interrogation of the assumptions embedded in these datasets and the validity of inferences for diverse socio-economic contexts (Abarca-Alvarez, García, & Arranz, 2019). This study aims to critically synthesize the literature on BDA applications for socio-economic vulnerability prediction, with a focus on the methodological rigor, theoretical framing, and ethical implications of these approaches. Specifically, it addresses three core questions:

- How effectively can BDA capture complex social and economic vulnerabilities?
- What are the methodological and ethical limitations of current predictive frameworks?
- How can BDA inform policy interventions without exacerbating existing inequities?

By approaching BDA not as a neutral tool but as a socio-technical system embedded within ethical and structural contexts, this paper seeks to contribute to a more nuanced understanding of its potential and limitations in vulnerability prediction (Ali, Qadir, Rasool, Sathiaseelan, & Zwitter, 2016; UNDP, 2024).

2. Literature Review

2.1 Conceptualizing Social and Economic Vulnerability

Social vulnerability refers to the susceptibility of individuals or communities to harm due to social, economic, and political inequalities (Biswas & Nautiyal, 2023; Contreras, Chamorro, & Wilkinson, 2020). It is multidimensional, encompassing income, access to resources, education, health, and social capital, and often intersects with geographic and environmental exposure to hazards (Contreras et al., 2020). Economic vulnerability, while related, specifically emphasizes the potential for income loss, unemployment, or financial instability under conditions of social or environmental stress (Wahyuni, Rachmawati, & Baiquni, 2022). Both constructs are inherently relational and dynamic, challenging static measurement approaches (Madden, Gilman, Levy, & Marwick, 2017). Traditional assessment tools, such as composite indices or household surveys, offer insights into vulnerability but suffer from limitations in timeliness, coverage, and granularity (Biswas & Nautiyal, 2023). Data scarcity in marginalized populations exacerbates these limitations, producing skewed or incomplete pictures of vulnerability (Sundsøy, 2017). Moreover, these approaches often treat socio-economic vulnerability as exogenous, ignoring feedback mechanisms where social and economic stressors mutually reinforce each other (Wang & Temmerman, 2023). Consequently, a more dynamic, data-intensive approach is necessary to capture the complexity of vulnerability in contemporary socio-economic systems.

2.2 Big Data Analytics and Predictive Modeling

Big data analytics (BDA) leverages high-volume, high-velocity, and high-variety datasets to extract insights through computational modeling, machine learning, and statistical inference (Chen, Li, & Wang, 2022; Ali, Qadir, Rasool, Sathiaseelan, & Zwitter, 2016). In the context of vulnerability prediction, BDA offers three potential advantages:

Real-time monitoring: Mobile phone usage, social media activity, and administrative transaction data allow near real-time assessment of socio-economic stressors (Pappalardo et al., 2016; Sundsøy, 2017).

Heterogeneous integration: BDA can combine environmental, demographic, and behavioral datasets, allowing multi-layered modeling of vulnerability (Kondraganti, Narayanamurthy, & Akter, 2022).

Predictive accuracy: Machine learning models such as decision trees, neural networks, and ensemble approaches can identify patterns that traditional statistical methods may miss (Abarca-Alvarez, García, & Arranz, 2019).

However, BDA is not without limitations. Methodologically, predictive models often rely on proxies that may inadequately represent socio-economic conditions. For instance, mobile phone data may underrepresent populations with limited access to digital technologies, while transactional data may ignore informal economic activity prevalent in low-income communities (Madden et al., 2017; Wang & Temmerman, 2023). Moreover, predictive accuracy must be weighed against interpretability: complex models may produce high predictive performance but limited transparency, posing challenges for policy translation and ethical oversight (Cesario, 2023).

2.3 Applications of Big Data in Vulnerability Assessment

Empirical studies have demonstrated the potential of BDA for identifying social and economic vulnerabilities across diverse contexts. Abarca-Alvarez et al. (2019) employed neural networks and decision trees to predict household-level vulnerability in urban environments, demonstrating that algorithmic models could surpass traditional indices in sensitivity to socio-economic heterogeneity. Similarly, Pappalardo et al. (2016) developed a framework to nowcast population well-being using mobile phone data, capturing behavioral patterns linked to income, mobility, and social networks. In disaster and humanitarian contexts, BDA has been increasingly applied to map risk and guide interventions. Kondraganti et al. (2022) systematically reviewed the use of BDA in disaster response, noting that predictive analytics improved resource allocation, early-warning systems, and vulnerability mapping. However, they also emphasized challenges related to data quality, representativeness, and ethical accountability. These findings align with Wahyuni et al. (2022), who demonstrated that spatial and temporal analysis of socio-economic indicators during the COVID-19 pandemic could inform targeted policy interventions but required careful consideration of data gaps and privacy concerns.

At a macro level, Cesario (2023) argued that BDA could inform smart city initiatives, leveraging real-time economic and social data to identify vulnerable urban populations. This potential is complemented by the development of composite "Digital Social Vulnerability Indices" by UNDP (2024), integrating heterogeneous datasets to quantify socio-economic risks at multiple scales. However, such indices must be critically interrogated for their assumptions, biases, and limitations in representing marginalized or informal populations.

2.4 Methodological and Ethical Considerations

Despite its promise, the deployment of BDA for vulnerability prediction raises significant methodological and ethical questions. First, predictive models are constrained by data representativeness: populations excluded from datasets are systematically rendered invisible in risk assessments, potentially exacerbating social inequities (Madden et al., 2017; Sundsøy, 2017). Second, algorithmic bias can arise from unbalanced training data, model overfitting, or assumptions embedded in computational frameworks (Ali et al., 2016). Third, privacy and consent issues are paramount when leveraging personal digital traces, particularly in contexts where individuals lack legal protections or bargaining power (Madden et al., 2017).

Methodologically, combining heterogeneous datasets presents both opportunities and challenges. Multi-source integration allows for richer, context-sensitive models but requires careful alignment of temporal, spatial, and thematic dimensions (Kondraganti et al., 2022). Furthermore, there is a tension between predictive accuracy and interpretability: highly complex models (e.g., deep neural networks) may yield accurate predictions but are difficult for policymakers to interpret or validate (Cesario, 2023). This raises the question of whether technical sophistication alone is sufficient for socially responsible vulnerability assessment.

2.5 Theoretical Insights and Critiques

Critical scholarship emphasizes that BDA should not be viewed as a neutral or purely technical tool. Predictive models operate within socio-political contexts that shape the availability, meaning, and use of data (Madden et al., 2017). For example, Wang and Temmerman (2023) argued that structural inequalities, such as differential access to education, credit, or technology, are often inadequately captured in algorithmic models, limiting their capacity to identify root causes of vulnerability. Sundsøy (2017)

similarly highlighted the need for ethical frameworks that prevent the reinforcement of existing inequities when interpreting behavioral proxies. From a theoretical perspective, combining social vulnerability theory with predictive analytics requires a careful translation of qualitative constructs into quantitative measures. Contreras et al. (2020) demonstrated that spatial heterogeneity in vulnerability cannot be fully represented by standardized indices, suggesting the need for models that account for local context, historical patterns, and social networks. UNDP (2024) further emphasized participatory validation, arguing that predictive models must be assessed in collaboration with affected communities to ensure legitimacy and relevance.

2.6 Gaps in Current Literature

Despite advances, critical gaps remain in the literature. First, there is a scarcity of studies integrating socio-economic vulnerability theory with algorithmic modeling in a rigorous, ethically informed manner (Biswas & Nautiyal, 2023; Ali et al., 2016). Second, methodological attention to the representativeness of marginalized populations remains limited; BDA often privileges digitally connected populations while overlooking informal or rural sectors (Sundsøy, 2017; Madden et al., 2017). Third, ethical frameworks for the use of predictive models in social policy remain underdeveloped, with limited guidance on mitigating harm, ensuring transparency, or embedding accountability mechanisms (Cesario, 2023; UNDP, 2024). Finally, empirical validation of predictive models against longitudinal social and economic outcomes is rare. Most studies focus on cross-sectional proxies or short-term indicators, limiting confidence in the models' capacity to anticipate systemic vulnerability shocks (Wang & Temmerman, 2023; Boakye, 2019). These gaps suggest the need for integrated, multi-disciplinary approaches that combine computational rigor, social science theory, and ethical oversight.

2.7 Synthesis and Critical Implications

The literature indicates that BDA holds significant promise for advancing vulnerability assessment, offering timeliness, granularity, and predictive capacity beyond conventional methods (Chen et al., 2022; Pappalardo et al., 2016). Yet, predictive power alone is insufficient. Without critical engagement with data representativeness, ethical implications, and contextual socio-economic realities, BDA risks reproducing existing inequalities (Madden et al., 2017; Sundsøy, 2017).

In response, this review advocates a critical socio-technical perspective, emphasizing:

- Ethical rigor: Incorporating privacy, consent, and fairness in model development.
- Contextual validity: Ensuring models reflect local socio-economic realities rather than globalized proxies.
- Participatory assessment: Engaging communities to validate and interpret predictions.
- Methodological transparency: Balancing predictive performance with interpretability and policy relevance (Cesario, 2023; UNDP, 2024).

Such an approach transforms BDA from a purely technical tool into a mechanism for socially responsible vulnerability prediction, bridging computational innovation with social equity imperatives.

3. Methodology

3.1 Research Design

This study employs a qualitative doctrinal research design, focusing on a critical analysis of existing academic literature, policy frameworks, and empirical case studies related to big data analytics (BDA) and social/economic vulnerability prediction (Biswas & Nautiyal, 2023; Ali et al., 2016). Doctrinal research, traditionally applied in legal studies and policy analysis, has been adapted here to interrogate computational, ethical, and theoretical dimensions of BDA. Unlike empirical quantitative studies, this approach emphasizes conceptual rigor, normative critique, and cross-disciplinary synthesis, enabling a deep understanding of the social and ethical implications of predictive modeling (Madden et al., 2017; UNDP, 2024).

The methodology is particularly suitable because the focus is not on generating new primary datasets, but rather on examining, comparing, and critiquing existing models, frameworks, and data-driven strategies. This allows for a rigorous assessment of methodological strengths, limitations, and potential biases in predictive models applied to socio-economic vulnerability (Kondraganti et al., 2022; Wang & Temmerman, 2023).

3.2 Data Sources

Data for this doctrinal analysis were sourced from the 15 pre-approved academic studies and reports, which cover:

- Predictive modeling frameworks for vulnerability assessment (Abarca-Alvarez et al., 2019; Boakye, 2019).
- Theoretical and conceptual discussions on social and economic vulnerability (Biswas & Nautiyal, 2023; Contreras et al., 2020).
- Ethical and policy considerations in the deployment of BDA (Madden et al., 2017; UNDP, 2024).
- Empirical case studies applying BDA in disaster, urban, and pandemic contexts (Pappalardo et al., 2016; Wahyuni et al., 2022).

The study systematically examined methodological approaches, model architectures, data types, ethical considerations, and policy implications, ensuring comprehensive coverage of both technical and socio-ethical dimensions.

3.3 Data Analysis Approach

The analysis followed a three-stage critical synthesis process:

Thematic Categorization: Literature was coded into four primary themes: (i) conceptualization of vulnerability, (ii) BDA methodologies and model architectures, (iii) ethical and representational challenges, and (iv) policy implications.

Critical Interrogation: Each theme was analyzed for methodological rigor, theoretical robustness, and practical applicability. Particular attention was paid to potential biases in data selection, limitations in predictive validity, and ethical risks of marginalizing vulnerable populations (Madden et al., 2017; Sundsøy, 2017).

Cross-Source Synthesis: Comparative analysis was conducted across multiple studies to identify convergence, divergence, and gaps, enabling the derivation of critical insights regarding the socio-technical feasibility and implications of predictive BDA frameworks (Cesario, 2023; UNDP, 2024).

This methodology emphasizes reflexivity, requiring the researcher to remain critically aware of the assumptions inherent in the source literature, including methodological, cultural, and socio-political biases (Ali et al., 2016; Wang & Temmerman, 2023).

3.4 Justification of Doctrinal Approach

The doctrinal qualitative approach is justified for several reasons:

Ethical and Social Focus: Predictive BDA is inherently socio-technical. Quantitative replication alone cannot reveal ethical, legal, or social constraints that shape model applicability (Madden et al., 2017; UNDP, 2024).

Complexity of Vulnerability Constructs: Social and economic vulnerabilities are multidimensional, dynamic, and context-sensitive. Doctrinal analysis allows conceptual unpacking and integration across theoretical perspectives (Biswas & Nautiyal, 2023; Contreras et al., 2020).

Policy Relevance: By synthesizing insights from multiple empirical and theoretical sources, the study provides actionable guidance for policymakers seeking to implement BDA responsibly (Cesario, 2023; Wahyuni et al., 2022).

5. Results

The results section synthesizes critical insights drawn from the doctrinal review, structured around key analytical dimensions: methodological robustness, predictive capacity, ethical considerations, and policy relevance.

5.1 Methodological Robustness of BDA Models

Analysis reveals that BDA methodologies vary in complexity and transparency. Neural networks and decision trees have demonstrated high predictive performance in detecting household- or community-level vulnerabilities (Abarca-Alvarez et al., 2019). Ensemble models integrating multiple data sources—such as mobile phone usage, social media interactions, and financial transactions—offer superior granularity and timeliness compared to traditional survey-based indices (Pappalardo et al., 2016; Boakye, 2019). However, methodological limitations are significant. Many models underrepresent marginalized or digitally disconnected populations, creating structural blind spots (Madden et al., 2017; Sundsøy, 2017). Overreliance on proxy variables, such as mobile data for socio-economic status, can misrepresent informal economic activity or rural livelihoods (Wang & Temmerman, 2023). Furthermore, high-complexity models often lack interpretability, constraining their utility for evidence-based policy interventions (Cesario, 2023).

5.2 Predictive Capacity

BDA demonstrates measurable improvements in the timeliness and granularity of vulnerability detection. Pappalardo et al. (2016) showed that behavioral data can

nowcast well-being with a sensitivity that traditional socio-economic indicators cannot match. Similarly, Wahyuni et al. (2022) highlighted the utility of spatial-temporal analytics during COVID-19 to identify economically vulnerable communities and guide targeted interventions. Nevertheless, predictive accuracy is not uniform. Models trained on incomplete, biased, or non-representative datasets can produce false positives or negatives, potentially misallocating resources or misidentifying vulnerable groups (Kondraganti et al., 2022; Wang & Temmerman, 2023). Critically, predictive models often fail to capture structural and historical inequalities, emphasizing the need for hybrid approaches that integrate quantitative modeling with socio-theoretical analysis (Biswas & Nautiyal, 2023; Contreras et al., 2020).

5.3 Ethical Considerations

Ethical scrutiny reveals that BDA may exacerbate vulnerabilities if not deployed responsibly. Key concerns include:

- Data Representativeness: Populations with limited digital access or financial documentation are systematically excluded, reinforcing invisibility in risk assessments (Sundsøy, 2017; Madden et al., 2017).
- Algorithmic Bias: Predictive models can replicate existing inequalities if trained on skewed datasets (Ali et al., 2016).
- Privacy and Consent: Mobile and transactional data often involve personal traces, raising issues of informed consent and data protection (Madden et al., 2017; UNDP, 2024).

Addressing these challenges requires participatory and context-sensitive validation, ethical oversight, and transparent reporting of model assumptions (Cesario, 2023; UNDP, 2024).

5.4 Policy Relevance

From a policy perspective, BDA can inform resource allocation, social protection programs, and disaster preparedness, offering high-resolution insights for targeted interventions (Boakye, 2019; Wahyuni et al., 2022). The development of Digital Social Vulnerability Indices illustrates how heterogeneous datasets can guide

decision-making at both local and national scales (UNDP, 2024). However, the results emphasize that predictive accuracy alone is insufficient. Policy translation requires interpretability, accountability, and social legitimacy, ensuring that interventions do not inadvertently reinforce structural inequities (Madden et al., 2017; Wang & Temmerman, 2023). Critical synthesis indicates that the most effective applications combine computational rigor with participatory validation, socio-theoretical insight, and ethical safeguards.

5.5 Key Findings

In summary, the doctrinal analysis identifies several critical insights:

- **Integration is essential:** Multi-source BDA improves predictive granularity but requires careful alignment of data types, temporal scales, and thematic dimensions (Kondraganti et al., 2022; Pappalardo et al., 2016).
- **Predictive models are socially situated:** Algorithms do not operate in a vacuum; social, economic, and political contexts profoundly shape their validity (Madden et al., 2017; Sundsøy, 2017).
- **Ethical oversight is non-negotiable**: Bias, exclusion, and privacy concerns must be addressed proactively to prevent harm to vulnerable populations (UNDP, 2024; Cesario, 2023).
- **Policy utility requires interpretability:** Models with high predictive performance but low transparency may be unsuitable for public policy applications (Wang & Temmerman, 2023; Boakye, 2019).

Thus BDA offers substantial promise for predicting social and economic vulnerabilities, but its application must be critically informed by methodological rigor, ethical reflection, and socio-theoretical insight.

6. Discussion

The doctrinal and critical analysis of big data analytics (BDA) in predicting social and economic vulnerabilities reveals both opportunities and systemic limitations. The results demonstrate that BDA can offer timely, granular, and predictive insights that exceed the capabilities of traditional survey-based or census-based methods (Pappalardo et al., 2016; Chen, Li, & Wang, 2022). By integrating heterogeneous datasets, including mobile phone usage, administrative records, financial transactions,

and spatial data, BDA can detect emergent patterns of socio-economic stress and identify high-risk populations with unprecedented resolution (Kondraganti, Narayanamurthy, & Akter, 2022; Boakye, 2019).

However, predictive capacity alone does not guarantee equitable or accurate representation of vulnerabilities. The review highlights structural biases inherent in datasets and models. Digitally excluded populations, rural communities, and informal economic actors are systematically underrepresented in most BDA applications (Sundsøy, 2017; Madden, Gilman, Levy, & Marwick, 2017). This exclusion risks reinforcing pre-existing social inequities by misallocating resources, misidentifying priority populations, or failing to capture localized contextual factors that shape vulnerability (Biswas & Nautiyal, 2023; Contreras, Chamorro, & Wilkinson, 2020).

Ethical considerations are central to this discourse. The literature consistently emphasizes that algorithmic decisions are socially situated, and predictive models must be interrogated for fairness, transparency, and accountability (Madden et al., 2017; UNDP, 2024). Issues of privacy and consent emerge prominently when using personal digital traces, raising the question of whether technical innovation can coexist with ethical governance in high-stakes socio-economic interventions (Ali, Qadir, Rasool, Sathiaseelan, & Zwitter, 2016; Cesario, 2023). Without robust safeguards, BDA may inadvertently amplify vulnerabilities, disproportionately affecting those already marginalized.

From a theoretical standpoint, the synthesis indicates that predictive analytics must be anchored in socio-economic vulnerability frameworks. Vulnerability is multidimensional, relational, and dynamic, reflecting the interplay of income, education, social capital, environmental exposure, and policy context (Biswas & Nautiyal, 2023; Contreras et al., 2020). BDA frameworks that rely solely on algorithmic outputs risk oversimplifying this complexity, converting rich social phenomena into reducible proxies (Wang & Temmerman, 2023). Therefore, a critical socio-technical lens is essential: BDA should not be treated as neutral or universally applicable but as a tool whose effectiveness depends on contextual alignment, participatory validation, and theoretical coherence (UNDP, 2024; Cesario, 2023).

Policy implications are profound. BDA can inform resource allocation, early-warning systems, social protection programs, and urban planning by providing high-resolution

indicators of vulnerability (Wahyuni, Rachmawati, & Baiquni, 2022; Boakye, 2019). Nevertheless, the literature emphasizes that interpretability and policy relevance must accompany predictive accuracy. Complex models that achieve high predictive performance without transparency risk eroding trust among policymakers and communities (Cesario, 2023; Wang & Temmerman, 2023). Participatory model validation, ethical auditing, and inclusive data practices are therefore critical to translating analytics into actionable, equitable interventions.

Finally, the doctrinal synthesis identifies gaps and research priorities. There is a need for:

- Hybrid socio-technical methodologies that integrate computational analytics with socio-economic theory to capture the multidimensionality of vulnerability (Biswas & Nautiyal, 2023; Contreras et al., 2020).
- Ethically grounded frameworks to guide model development, deployment, and governance, including participatory validation and algorithmic auditing (UNDP, 2024; Madden et al., 2017).
- Empirical longitudinal validation of predictive models to assess their reliability in forecasting systemic socio-economic shocks over time (Wang & Temmerman, 2023; Boakye, 2019).
- Inclusivity in data sourcing, ensuring representation of digitally excluded populations, rural sectors, and informal economies to reduce structural bias in predictions (Sundsøy, 2017).

Thus, the discussion emphasizes that BDA is a transformative but socially embedded tool: its predictive power is contingent upon careful methodological, ethical, and contextual alignment. Its application to vulnerability prediction must balance technical sophistication with social justice, interpretability, and participatory legitimacy.

7. Conclusion

This study critically examined the role of big data analytics in predicting social and economic vulnerabilities, synthesizing insights from theoretical, empirical, and ethical perspectives. The findings confirm that BDA offers substantial advantages in predictive capacity, timeliness, and granularity, capable of identifying emergent vulnerabilities in both urban and rural contexts (Pappalardo et al., 2016; Boakye, 2019). However, the analysis also demonstrates that technical capability alone is insufficient. Predictive models are embedded within socio-political contexts, and their outputs are shaped by data representativeness, algorithmic bias, and assumptions inherent in computational frameworks (Madden et al., 2017; Sundsøy, 2017). Ethical concerns—including privacy, consent, and equity—are particularly salient, emphasizing the need for participatory validation, transparency, and accountable governance (UNDP, 2024; Cesario, 2023). Methodologically, this study illustrates the value of a doctrinal qualitative approach, which allows for critical interrogation of theoretical constructs, ethical frameworks, and computational methodologies. By synthesizing evidence across disciplines, the analysis reveals both the promise and limitations of BDA, highlighting the tension between predictive accuracy, interpretability, and social legitimacy.

The implications are threefold:

Theoretical: Vulnerability prediction requires models that are not only data-driven but also theoretically grounded in social and economic realities.

Practical: Policymakers can leverage BDA for targeted interventions, but only when models are transparent, context-sensitive, and inclusive of marginalized populations.

Ethical: The deployment of BDA must integrate rigorous ethical oversight to prevent the reinforcement of existing inequalities or the creation of new forms of social exclusion.

Thus, big data analytics represents a powerful but socially situated tool for predicting vulnerabilities. Its effective application demands integrated socio-technical frameworks that combine computational innovation, theoretical rigor, ethical safeguards, and participatory validation. Future research should prioritize longitudinal validation, hybrid methodological designs, and ethical governance to ensure that predictive analytics contributes to equitable, inclusive, and actionable insights in social and economic vulnerability assessment.

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