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A Review of Social Impact Assessment (SIA) and Flood Risk: Recommendations for the Management of Dam Disaster

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ABSTRACT

A dam-disaster flood is considered as an extreme event having catastrophic consequences for its downstream society. It is essential to conduct pre-hazard assessment and evaluate the potential impacts of such disaster to develop appropriate response and mitigation strategy. Proper impact assessment will help the flood risk management (FRM) to initiate adaptation plans and spread awareness among vulnerable people to make them prepare against such hazards. Considering the limited number of literature on dam failure flood impacts, the study aimed to systematically review previous studies on the social impact assessment (SIA) of flood risks and develop recommendations on adopting SIA for dam failure disasters. The key findings of the study include the identification of the main flood risk variables, socio-economic and environmental loss indicators, and socio-economic and social vulnerability factors, which need to be considered before conducting any flood risk impact assessment study. Additionally, it demonstrated the common methodological process observed among past studies for flood risk impact assessments based on the findings of the SLR and content analysis. The findings are expected to contribute to the flood risk literature and support policymakers and stakeholders in effectively managing and mitigating flooding due to dam disasters.

1. INTRODUCTION

Recurring flood disasters in different parts of the world are associated with significant social, economic, and environmental catastrophes in the short and long term, especially in extreme events. Flooding disrupts social development and slows economic growth [1]. According to the Global Risk Report, 2009, the global climate change, coupled with changing socio-economic fortunes, pinpoint flooding as one of the important worldwide risks [2]. Between 2000 and 2019, it was provisionally estimated that floods constituted about 44% of all disaster events [2]. Considering these pressing issues, assessments regarding future flood impacts are necessary, above all, for highly valued environmental and socio-economic areas of interest [3].

However, there is an insufficient attention noticed in showcasing the efficacy of DRM techniques such as Social Impact Assessments (SIA) [4]. Disaster risk SIA studies face significant challenges deeply rooted in cultural and political landscapes, which directly obstruct governmental efforts to drive social resilience and sustainability [5-7]. The continuing changes and anticipated increase in flood risk can intensify the social impacts of such disasters [8]. This calls for flood risk management (FRM) to emphasize evaluating the societal impacts of flooding, whereas traditional approaches have primarily focused on economic impacts [9]. Such impact assessments are vital for pre-disaster actions and post-disaster efforts, including providing relief and conducting rescue operations [10]. Thus, understanding the potential consequences of a flood disaster is essential for efficient disaster management [11]. The Sendai Framework for Disaster Risk Reduction (SFDRR), 2015-2030 lists "understanding disaster risk" as a priority and emphasizes scientific disaster risk assessment [12]. SFDRR recommends periodic assessments of disaster risks, vulnerability, capacity, exposure, hazard characteristics, and potential cascading impacts at appropriate social and spatial scales tailored to national contexts [12]. Besides that, priority 3, of SFDRR which focuses on investing in disaster risk reduction (DRR) for resilience, also suggests promoting coordination between global and regional financial institutions to assess and anticipate disaster's potential economic and social impacts. Knowledge of potential impact of a disaster will also contribute to achieving United Nations Sustainable Development Goal (SDG)-11 by developing sustainable flood-resilient communities and safe cities [13].

Considering these, this study focuses on incorporating SIA in dam failure FRM, which is understudied in prior literature. Prior studies concerning the risk of dam failure and its societal consequences have focused on severe impacts on vital infrastructures, historical establishments, and related elements, neglecting the effects on human populations [14]. Therefore, to address the gaps in the existing flood risk literature, particularly concerning the social impact of dam failure floods, this study aims to systematically review existing research on the SIA of common flood risks and provide recommendations for managing the social impacts of dam failure flood risks.

1.1 SIA and disaster management

Assessing social, environmental, and economic impacts is essential for aligning sustainable development strategies across international organizations, governments, and businesses in response to urgent societal demands for effective solutions [15]. The International Association for Impact Assessment (IAIA) defines social impacts as the consequences of public or private actions that may change the way how people lead their lives, do work, play, connect, meet their needs, and cope as members of society [16]. Social impacts can be perceived mentally or physically, affecting each level of society differently [17]. SIA clarifies how a proposed action will affect community members' lives and suggests alternative actions to mitigate negative changes or enhance positive ones [18]. Integrating SIA into the disaster management process- preparedness, response and recovery stage, emphasizes that the conceptual model of SIA is well-equipped to account for hazards and related disaster risks [18]. Recognizing the importance of assessing the visible and invisible social impacts, Cheng et al. [19] developed an SIA framework specifically for storm surge disasters. However, adapting SIA to assess the social impacts of disasters is an emerging and promising field, necessitating renewed efforts to refine both concepts and methodologies [8].

1.2 Social impact assessment (SIA) and dam failure flood risk management (FRM)

Climate change and the rise in socio-economic activities around dam areas have heightened the risk and severity of dam failure consequences. Although there is a low probability of such a dam disaster, the potential damage is immense [20]. This situation necessitates the creation of strong and reliable emergency management plans to safeguard lives and property [21]. Therefore, accurate prediction of losses from such events is essential. However, previous studies on dam failure risk and social impact have primarily focused on the quantifiable effects on critical facilities and cultural relics, frequently overlooking the impact on people and society [14, 22]. Other authors, such as Aqilah et al. [23] and Salleh et al. [24], also addressed that, even though there is rapid progress in risk analysis in the case of dam engineering, the study on socio-economic impact assessment is still limited. Therefore, this study considers a review of existing literature regarding SIA and flood disasters to understand how SIA can be incorporated into dam failure-related flood disasters.

2. RESEARCH METHODS

To explore the answer to the main research objective, this study employed a Systematic Literature Review (SLR) by using the popular Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. Based on the insights gained from the SLR, the study aimed to offer recommendations on integrating SIA into dam disaster FRM. Specific keywords and searching criteria were used to identify related papers. The selected articles underwent a quality assessment, followed by data extraction and synthesis to explore how past studies conducted flood risk impact assessments.

Considering the variations in the searching protocols across Google Scholar and Scopus, the same searching keywords were arranged according to the searching criteria of the two databases as shown in Table 1. In Scopus, the advance search query allows the researchers to initially screen the articles based the exclusion and inclusion criteria decided by authors. Whereas in Google Scholar, other than publication year criteria, the articles can not be screened initially, rather it is needed to be done manually. Considering this, for Google Scholar, the search term was - "Social impact assessment" and flood risk, and the searching were conducted for the years 2014 to 2024. The last search was made on 12/07/2024.

Table 1. Search terms

Database	Search Terms
Google Scholar	"Social impact assessment" and flood risk Scopus
Scopus	TITLE-ABS-KEY (social AND impact AND assessment AND flood AND risk) AND PUBYEAR >2013 AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English"))

For Scopus database, we utilized advance search query option at initial stage on the title, abstract, and keywords with filters to exclude articles that were not in English, not in their final publication stage, and published before 2014, not from journal. The advanced query was- TITLE-ABS-KEY (social AND impact AND assessment AND flood AND risk) AND PUBYEAR >2013 AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English")). In Scopus, the last search was conducted on 30/06/2024. The exclusion and inclusion criteria for conducting SLR in are depicted on Table 2. The PRISMA workflow is presented in Figure 1, which shows how the articles were identified, screened, and selected after matching eligibility criteria and quality appraisal [25].

Finally, the selected articles were utilized to do the content analysis to understand how flood risk impact assessment was conducted among past studies from social perspectives. While doing content analysis, the study focused on identifying the flood risk variables which contribute to flood severity, what kind of data was needed for such impact assessment, what other factors are suggested to evaluate, prior to conduct an impact assessment of a potential hazard, and key socio-economic and environmental loss indicators assessed, methodologies and frameworks considered by them. And based on the content analysis, the study provides recommendations for dam disaster flood to conduct SIA.

Table 2. The exclusion and inclusion criteria for the SLR

Criteria	Inclusion	Exclusion
Timeline	2014-2024	<2013
Document Type	Article Journal, conference paper	Chapter in books, Books series and books
Language	English	Non-English
Content	Social Impact Assessment, flood risk	Articles not related Impact assessment, flood risk

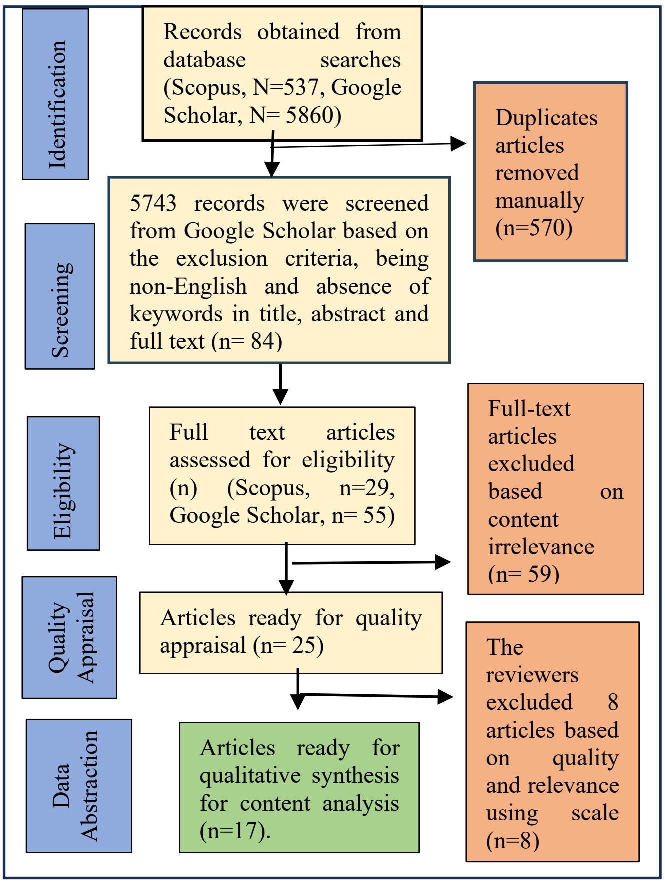

Figure 1. The overview of SLR process

3. RESULTS AND DISCUSSIONS

The selected articles included in this research, which discussed SIA and flood risk or assessed social impact, are summarized and presented in Table 3, highlighting whether SIA was conducted, methodologies, and loss elements considered in the studies. Although, societal impact is frequently mentioned across the seventeen (17) studies. Only two studies [2, 26] practically assessed SIA, while four studies predicted social impact [9, 22, 27, 28] through social vulnerability or impact indexes [29]. One study assessed social impact as part of a comprehensive or integrated impact assessment, which considers not only social impacts but also economic and environmental losses, and whereas seven articles partially assessed social impact elements considering only a few loss elements [10, 11, 30-34]. For instance, some studies ignored educational impact and impact on cultural resources [10]; some studies only considered physical impact [11], population dynamics; some studies only considered social impact of post disaster infrastructure outrage [30]; some studies only considered impact on residential property [31-33]; some studies only considered infrastructural losses [34].

Besides that, two studies provided methodological frameworks, such as Aznar-Crespo et al. [8] offered complete guidelines for incorporating SIA into FRM, and Aqilah et al. [23] proposed a comprehensive framework for that includes social, economic, and environmental impact assessments based on United States' Federal Emergency Management Agency (FEMA) damage factors which might not be fit to the countries with different socio-economic and environmental conditions. Among the literature, only two studies are related to dam disaster flood consequence assessment [22, 23]. The following Figure 2 shows the number of studies based on publication year and Figure 3 shows the countries of included studies.

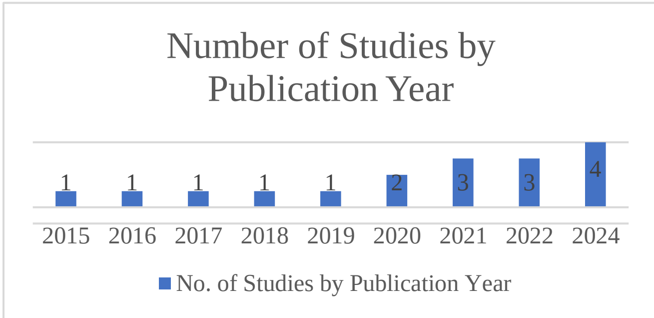

Figure 2. The number of studies based on publication year

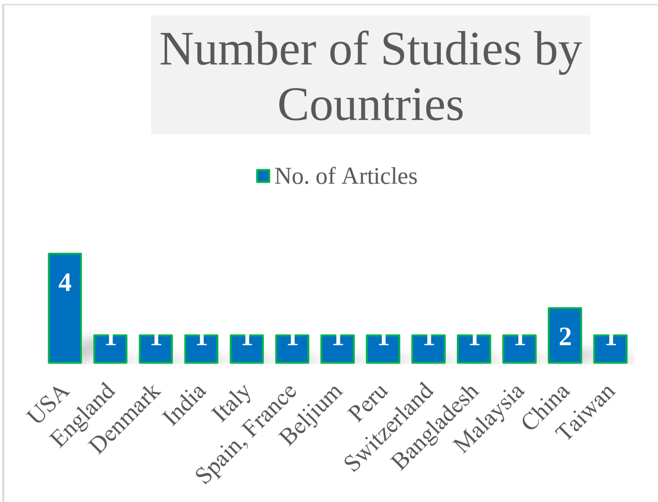

Figure 3. The countries of included studies

Table 3. Table showing review of included studies

No.	Title	Source	Methodology	SIA Content	Element Studied
1.	A novel and comprehensive approach for understanding the social impacts of flooding: assessing social Food vulnerability and social flood Risk in Denmark	[9]	-social risk (probabilistic method) -indicator selection	-predict SIA through SVI	-constructs national SVI for Denmark, combining it with social exposure and coastal flood hazard data to create a national Social Flood Risk Index (SFRI).
2.	Integrated Flood Impact and Vulnerability Assessment Using a Multi-Sensor Earth Observation Mission with the Perspective of an	[27]	-multi sensor earth observation data -hazard estimation (flood extent and depth), -SVI, SII	-yes	population and asset exposed (building)

	Operational Service in Lombardy, Italy				
3.	Probabilistic disaster social impact assessment of infrastructure system nodes	[30]	-probabilistic methodology -Monte Carlo simulation	-partial, only one element	social impact of post disaster infrastructure outrage
4.	Assessing socio-economic and environmental losses of dam failure flood risk: a review on sustainable framework	[23]	-FEMA -scenario building -primary and secondary data	socio-economic and environmental impact	(1) social- community well-being and loss of life, (2) economic losses, and (3) environmental impact- water quality and biodiversity.
5.	Extreme Flood Disasters: Comprehensive Impact and Assessment	[2]	-indicator system - flood simulation method -field study -depth damage rate	-yes	-social Impact (population) -economic Impact (residential, agricultural, industrial, dam, dike loss, traffic and road loss -environmental Impact (nature reserves and environmental sensitive areas)
6.	A Comprehensive Methodology for Evaluating the Economic Impacts of Floods: An Application to Canada, Mexico, and the United States	[35]	-based on proposed method adapted from Economic Commission for Latin America and the Caribbean (ECLAC)	losses in social sector under economic loss	losses in social sector: housing, education, health, water and sanitation, cultural resources, legal government, community
7.	Spatial dimension of impact, relief, and rescue of the 2014 food in Kashmir Valley	[10]	-primary and secondary data -geographic information system (GIS)	partial	-infrastructure and settlements, house, death, poverty, health problems, political crisis, agriculture, trade, tourism,, handloom, environment
8.	Adapting Social Impact Assessment to Flood Risk Management	[8]	-adapted the IAIA's SIA framework for flood disasters and identified key concepts and methods	methodological proposal for initiating SIA in FRM	loss of life and property, psychological effect, migration, political consequence, impact on economic growth and development
9.	Multi-dimensional damage assessment (MDDA): A case study of El Nino ˜ flood disasters in Peru	[26]	-Life Cycle Assessment - disability-adjusted life year (DALY) index.	-yes	-social damage (deaths, injuries, disease outbreaks), -economic damage (loss of assets, infrastructure disruption), -environmental damage (biodiversity loss, habitat degradation).
10.	Community Flood Impacts and Infrastructure: Examining National Flood Impacts Using a High Precision Assessment Tool in the United States	[34]	First Street Foundation Flood Model (FSF-FM)	partial	properties, critical infrastructure, and social facilities, residential, commercial, airport, fire stations, hospitals, police stations, ports, power stations, water outfalls, and wastewater treatment plants.
11.	Rapid Multi-Dimensional Impact Assessment of Floods	[11]	-environment sensor data, social media, remote sensing, digital topography, and mobile phone data.	partial	physical impact, population dynamics as long-term effect.
12.	Evaluation of Dam Break Social Impact Assessments Based on an Improved Variable Fuzzy Set Model	[22]	-Grey system theory (GST) -analyzes the RMD characteristics -improved traditional VFSs	-yes - SVI	loss of life and property, damage to residential and basic security facilities, social unrest and turmoil, damage to cultural landscape
13.	Residential Flood Loss Assessment and Risk Mapping from High-Resolution Simulation	[33]	-GIS-based flood model -flood simulation model (3Di) -field surveys via a questionnaire to develop depth-damage table - The Analytic Hierarchy Process (AHP) for vulnerability weighting.	partial	-losses such as furniture, clothes, electronic devices, and domestic appliances.
14.	The impact of flood risk on the price of residential properties: the case of England	[31]	-sample properties transactions across neighborhoods	partial	residential property price
15.	Flood loss models for residential buildings, based on the 2013 Colorado flood	[32]	-empirical data - FEMA	partial	residential losses based on house type and building components
16.	A global assessment of the societal impacts of glacier outburst floods	[28]	-a relative damage index -public hazard database	societal damage index	farmland, residential. road, railway and service networks, infrastructure, human impacts
17.	An integrated approach of flood risk assessment in the eastern part of Dhaka City	[29]	-risk framework, hazard map, vulnerability map, exposure map; statistical data	social and economic impact	-tangible - intangible impact (health).

As mentioned earlier, most reviewed studies assessed social impact elements partially considering only a few elements; some considered social loss elements under comprehensive or integrated impact assessments and economic and environmental elements. Some offered methodological or framework-based guidelines without practical assessment of SIA.

However, one review article provided a structured SIA assessment in the disaster management cycle beyond traditional post-disaster evaluations [8]. By adapting the IAIA's framework and reviewed concepts and methods from existing literature developed and proposed an SIA framework for management [8]. According to them, the adaptation of SIA in FRM may involve four key phases, shown in Figure 4.

1). Baseline study: To analyze the natural hazard characteristics, adaptive capacities of the potential exposure unit, and the social context;
2). Stakeholder analysis: To identify the prominent individuals and groups related to governance who have any interest in flood risk impacts and can facilitate effective communication and decision-making.
3). Impact identification and assessment: To identify the potential impacts and evaluate them, and
4). Impact management measures: After assessing the impacts, it is necessary to develop a strategic tool for policymakers and flood managers to enhance effective mitigation impact based on the significant of each loss.

Different studies used different processes for impact identification and assessment. For example, Yu et al. [2] applied a five-step process to evaluate socio-economic and environmental damage. First, they assessed flood risk using simulation models and remote sensing to analyze inundation, depth, and duration. Next, they gathered socio-economic and land-use data into a spatial database, followed by GIS overlay analysis to assess asset values across flood depths. In the fourth step, depth-damage rates were developed from historical data to estimate losses, which were then calculated using depth-to-loss ratios in the final step.

Besides that, other authors who mentioned the assessment framework, such as Righini et al. [27], also followed the key steps of assessment of hazard, understanding the flood exposure area, assessment of vulnerability, and finally assessing the impact index [23] also demonstrated assessment flow such as identifying flood characteristics variables, assessment of data and calculation of flood impact through scenario building analysis. However, upon reviewing the included studies we identified the commonly observed steps and stated in the Sections 3.1 to 3.5.

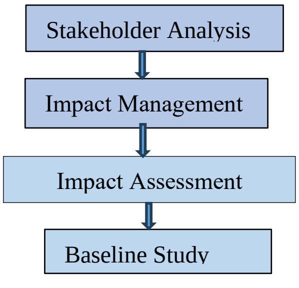

Figure 4. Suggested phases of SIA in flood risk management (FRM) process [8]

3.1 Step one: Understanding the flood risk variables

Understanding key flood risk variables that are responsible for the degree of flood impact severity is the first step in any flood impact assessment study. Table 4 below depicts the list of flood characteristics variables discussed in the reviewed studies.

Table 4. Key flood risk variables

No.	Flood Risk Variables	Refs.
1	Depth	[2, 11, 23, 27, 33, 34, 36]
2	Duration	[2, 23]
3	Inundation area/mapping	[2, 23, 36, 37]
4	Flood extent	[9, 27, 36]
5	Flood volume	[2, 27, 36]

Most of the reviewed studies addressed flood depth, duration, inundation mapping, flood extent, and volume as significant variables in assessing flood risk impact. 'Depth' has been addressed as a flood risk variable in numerous research works [2, 23, 27, 33, 36]. Another important flood characteristic variable is the 'duration' of flooding [2, 23]. Flood inundation mapping, a term that defines the coverage of the flooded area, is also one of the predictive components of flood risk impact [2, 23, 36, 37]. Some other researchers [9, 36] addressed another important flood risk variable, "flood extent", which is a combination of flood depth and volume.

However, past studies mainly utilized flood simulation and numeric modelling to understand the nature of flood risks. For instance, Yu et al. [2] modelled flood hazards, including depths, durations and velocities through 2D hydro-hydraulic simulation models, remote sensing analysis, and field study. Pastor-Escuredo et al. [11] and used the Shuttle Radar Topography Mission (SRTM), Digital Elevation Model (DEM) to estimate the depth, and Afifi et al. [33], Gabriels et al. [36] also utilized DEM to determine flood extent. Righini et al. [27] applied Floodwater Depth Estimation Tool (FwDET-GEE) with multitemporal satellite imagery using Google Earth Engine along with high-resolution Digital Terrain Models (DTM) to map floodwater depth and forecast the inundation extents. Aqilah et al. [23] proposed analyzing flood risk variables- depth, duration, and area of inundation a scenario-building process to measure flood damage across high, medium, and low-risk scenarios. Also, Porter et al. [34] simulated the depth of flooding by a probabilistic method, calculating the expected depth level for each point of interest or asset. Whereas, Beck and Cha [30] used the Monte Carlo simulation technique.

3.2 Step two: Assessing socio-economic data of the exposure area

The second important phase of the study of flood risk impact is the socio-economic evaluation of the potential flood affected areas. This phase lays the foundation for understanding the potential impacts. This step includes assessment of socio-economic determinants such as demographic information [27, 37] and economic activities, income levels, employment status, and educational attainment of the occupants [2, 8, 36]. It also considers real estate values [2, 27], geographic features involving precipitation and topography [8, 11], and land use classes ranging from residential to commercial and industrial zones

[2, 27, 33, 36]. The protected areas and suspected sources of contaminants [2] are also needed to assess to know the potential environmental impacts. The previous study mainly gathered these data from statistical yearbooks, field surveys with questionnaires, national and international databases, and GIS analysis. Table 5 presents an overview of the socio-economic and geographic factors to be considered in flood risk assessment, including probable sources of data collection.

Beyond assessment of socioeconomic conditions, previous studies also addressed some of the social vulnerability factors as contributing factors of flood risk impact severity [8, 9].

Social vulnerability factors include 'demographic characteristics' such as gender, age, the background of the family, race, ethnic background, and languages spoken [2, 8, 9]; 'population density' [9, 33]; and 'socioeconomic status,' which encompasses income, purchasing power, employment, education, and social capital [8, 9]. Additionally, 'access to health services' is also critical factor [8]. 'Land tenure issues,' including property structure, settlement regulation, housing quality, property markets, and insurance systems, further influence vulnerability [8]. Factors such as 'proximity to rivers' [33], 'distance from emergency services' like police and fire stations, and 'neighborhood characteristics' are also significant [8]. 'Risk perception,' or awareness of flood risks, past experiences, knowledge of self-protection measures, and trust in public institutions, also impacts the effectiveness of community responses against flood [8]. Finally, inadequate infrastructure and poorly maintained drainage systems, worsen flooding, particularly during heavy rainfall [9, 37]. The potential social vulnerability factors are depicted in Table 6.

Table 5. Socio-economic factors needed to assess before flood impact assessment

No.	Factors	Elements	Method/Sources of Data	Refs.
1	Population Data	number of populations	statistical yearbook, geoportals, national statistics institutions, and global or federal repositories, GIS	[27, 37]
2	Socio-economic data	number of populations, economic activities, income, purchasing power, employment situation, education	statistical yearbook, field investigations, geoportals, national statistics institutions, and global or federal repositories.	[2, 8, 36]
3	Property value	value of each property (commercial, industrial, agricultural and any other relevant data in the inundation area)	statistical yearbook field study	[2, 27]
4	Geographic and topography	rainfall, elevation, slope, probability of flooding, proximity to river, time of flooding, type of soil	historical rainfall data, climate data, satellite imaginary data, GIS data	[8, 11]
5	Land use data	structure and quality of housing, property markets for renting and purchasing, housing and goods insurance systems, land use types: residential, commercial, and industrial areas; institutional zones like government offices, hospitals, banks, schools, and universities; public utilities and critical facilities (including power, water, roads, and railways; and agricultural land).	statistical yearbook field study	[2, 27, 36, 33]
6	Protected areas	name, area and sensitivity level	federal repositories, GIS	[2]
7	Potential pollutant sources	chemical plants, metal plants, factories pollutants	federal repositories, GIS	[2]

Table 6. Social vulnerability factors

No.	Factors	Elements	Refs.
1	Demographic characteristics	Age, race, ethnicity, gender and language	[2, 8, 9]
2	Population density	Density of people in the potential inundation area.	[9, 33]
3	Socioeconomic status	Income and purchasing power, employment, education and social capital.	[8, 9]
4	Health	Access to health services and health conditions of the population.	[8]
5	Land tenure	Property structure, regulation of human settlements, housing quality, property markets (renting and purchasing) and insurance systems for housing	[8]
6	Distance from river	Distance from river for each affected area	[33]
7	Neighborhood characteristics	Essential urban services and transport infrastructures	[8]
8	Risk perception	Resident's awareness, past flood experiences, knowledge of self-protection measures, and trust in public institutions shape their preparedness and response efficacy	[8]
9	Infrastructure & Drainage Sensify	Inadequate or poorly maintained drainage and infrastructure can worsen flooding	[9]

3.3 Step three: Identifying loss elements

a) Prelisting of impacts (based on literature review and historical data).

The findings of the content analysis shows, loss elements considered in past studies are under social, economic and environmental loss categories. However, it is revealed that there is divergence among literature in categorizing the losses as socio, economic and environmental. For example, Porter et al. [34] evaluated aspects of social loss regarding community infrastructures, including wastewater treatment facilities, governmental institutions, historical buildings, places of worship, museums, and educational institutions. In contrast, Deniz et al. [32] confine their evaluation to only residential losses as social losses. Carrivick and Tweed [28] considered impacts on residential property values. Meanwhile, Wen et al. [35] addressed social losses under economic loss. Another study considered only the affected population as social loss [2]. The only study that presented complete methodological guidelines to incorporate SIA into FRM, by Aznar-Crespo et al. [8], also did not consider the crucial elements of loss such as health impacts, household impacts, or educational impacts as social losses. On the contrary, various researches have assessed the social impacts of flooding based on an overall assessment [2, 23, 26, 28, 29]. Table 7 highlights that previous works have segregated different loss components into social, economic, and environmental heads.

Although there is a discrepancy in the categorization of impact elements as social, economic and environmental, one thing is evident in the literature on how to define social, economic and environmental losses. Anything which is directly or indirectly related to the population or residents belongs to society. For example, Carrivick and Tweed [28] considered the overall impacts of the floods as societal impacts. However, most studies considered economic impact as monetarily measurable in the short or long term. In contrast, social and environmental impacts [2] seem to be a mixture of quantitative and qualitative. Yu et al. [2] assessed environmental impact semi-quantitatively in such a case. However, the key impact elements that were assessed in past studies as social impact elements are categorized under the following six (six) categories.

1). Household impact: Impact on residential building /housing, and residential property such as furniture, clothes, electronic devices, and domestic appliances [27, 31, 35].

2). Health impact: Loss of life, physical damage/injury-disease outbreak (cholera, malaria), treatment cost, workdays lost due to injury, psychological effect [8, 22, 23, 26, 35].

3). Impact on social well-being: Social unrest and turmoil due to panic, loss of livelihood [8, 22].

4). Impact on Education: Building damage, cleaning cost, missing school days, temporary classroom and reset service cost [23, 35].

5). Infrastructural losses: Damage to public and social infrastructure and service network and post disaster infrastructure outrage can interrupt social wellbeing of impacted areas community [2, 28, 34].

i) Public infrastructures: damage to water infrastructure such as dam, dike, sluice gate losses, damage to road and railway network (damage and traffic disruptions) also causes social impact.

ii) Social Infrastructure: damage to government building, historic building, house of worship, museum, school.

iii) Service network: disruption to irrigation, drainage, electricity, mobile and telephone network.

iv) Cultural Resources: damage to worship places, recreational places, graveyard.

6). Other Impacts: Population Dynamics/ migratory process due to flood, post flood political consequences due to lack of efficiency in management of flood damage [2, 8, 22, 35].

Table 7. Impact elements of flood risk

No.	Loss Elements	Social	Economic	Socio-Economic	Environmental
1	**Population/Human/People**				
	Population evacuation, homeless, injury	[2, 22]		[10]	
	Loss of life	[8, 22, 26, 28]			
	Human casualties	[2]			
	Loss of livelihoods	[8]			
2	**Population dynamics/migratory process**	[8]		[11]	
3	**Water and Sanitation**	[35]			
4	**Health Impact**				
	-Physical damage/injury -Disease outbreak (cholera, malaria) -Treatment cost, workdays lost, psychological effect	[8, 22, 23, 26 35]		[10]	
5	**Social unrest and Turmoil**	[22]			
6	**Agricultural/Fisheries/Livestock**	[28]	[2, 35]	[10]	
7	**Cultural Resources** -Worship places, Recreational places, Graveyard	[35]			
8	**Local government/ Community**	[35]			
9	**Additional cost** Emergency assistance				
10	**Political consequence**	[8]		[10]	
11	**Economic Growth and development** -poverty	[8]		[10]	
12	**Education** (Building damage, cleaning, missing school days, temporary classroom and reset service cost)	[35]		[23]	
13	**Residential Property/Household**				
	Residential building /housing	[27, 35]	[2]	[10]	
	Residential property (furniture, clothes, electronic devices, and domestic appliances)	[28]	[2]	[10]	
	Residential property price	[31]			
14	**Property**	[8]	[26]		
15	**Industrial property**		[2]		
16	**Manufacturing**		[35]		
17	**Commercial assets**		[35]		
18	**Indirect effects**				
	Disruption of industrial and commercial chains		[2]		
19	**Trade**			[10]	

20	**Tourism/tourist facilities**		[2, 26, 35]	[10]	
21	**Infrastructural Losses**	[2]			
	Water infrastructure- -dam, dike, sluice gate losses	[28]	[2, 26]		
	Transportation Road and railway network (damage and traffic disruptions)	[28]	[2, 26, 35]	[10]	
	Energy and utilities		[35]		
	Technology & communications		[35]		
22	**Public Infrastructures** -Fire station, hospital, police station, port, airport, power station,, superfund site, water outfalls, wastewater treatment plant, school, bus stop	[28]			
23	**Social Infrastructure:** -Government building, historic building, house of worship, museum, school	[34]			
24	**Commercial Infrastructure**				
25	**Service network (**disruption to irrigation, drainage, electricity, telephone)	[28]			
26	**Environment**				
	Nature reserve and environmental sensitive areas			[2]	
	Scouring and polluting ecological and environmental sensitive areas				[2]
	Public forests		[35]		
	Biodiversity losses			[23]	[26]
	Habitat degradation				[26]
	River morphology and water quality			[23]	

b) Finalizing Socio-Economic Loss Indicators Through Integration of Diverse and Spatial Data

After collecting socio-economic, demographic, and land use datasets, and prelisting of potential loss elements, the next step is the integration of these data. At this stage, it is necessary to develop a database with a spatial distribution that appropriately represents the social, economic, and environmental assets of the potential flood exposure which will be considered for finalization of loss indicators. Most of the past studies used GIS-enabled socio-economic and environmental database integrates key loss indicators in a geographically informed perspective to allow the visualization and analysis of spatial variations and regional disparities [2, 10, 33]. Pastor-Escuredo et al. [11] presented a fast impact assessment model that used clear geographical and temporal markers by integrating diverse data sources such as environmental sensors, social media, remote sensing, and digital topography. Hence, integration of collected data will help to assess the relevant loss indicators correctly and will also help the researchers to finalize the key loss indicators based on data availability.

3.4 Step-four: Superimposing flood inundation layers onto socio-economic and environmental layers

Following the assessment of flood hazard characteristics through simulation methods, the collection of socio-economic and environmental data, and the prelisting and finalization of the relevant socio-economic and environmental indicators, the next critical step in flood impact assessment involves superimposing flood inundation layers onto socio-economic and environmental data [2]. This step suggested overlapping or mapping flood inundation layers, based on variations in flood risk levels-depths, durations, and volumes, onto the socio-economic and environmental layers. This step will enable to understand how variation in flood risk levels can impact society, the economy, and the environment differently. Studies have assessed the spatial impacts of floods by combining ethnographic methods with GIS analysis [10, 33]. Similarly, Pastor-Escuredo et al. [11] proposed a rapid impact evaluation framework that integrates specific geographical and temporal markers to assess the socio-economic scale of disasters. Hence, this overlaying can be achieved using GIS tools and flood damage assessment models [36].

3.5 Assessment of impacts

The final steps of flood impact assessment is conducting impact assessment. The key method of estimating or projecting pre-hazard impact, past studies commonly calculated the depth to damage ratio for socio-economic and environmental assets of the vulnerable area, developing the social vulnerability index (SVI) and finally developing the social impact index (SII).

a) Calculation of flood damage through depth to damage rate

One of the common approaches for calculating flood risk impacts observed in past studies is to develop a depth-to-damage ratio or a depth-damage table for the flood exposure area. Such flood loss rate will indicate the vulnerability of different properties at various levels of flood risk. To calculate such depth to damage rate previous studies used historical flood loss data [2], field surveys, and empirical studies [33]. Additionally, damage factors can also be derived from a well-established flood damage assessment framework, such as provided by FEMA [23, 32] or past literature [36]. Alternatively, some studies employed flood damage models that estimate economic losses using depth-damage curves, which relate floodwater depth to damage factors based on prior research [36]. Once depth-to-damage rates are determined for various flood risk levels, the next step is to estimate the potential impacts at different flood inundation scenarios.

b) Developing Social Vulnerability Index (SVI) and Social Impact Index (SII)

After calculation of flood impact using a depth to damage rate, past studies used SVI, to show the susceptibility or vulnerability of populations of a particular exposure area, derived from socio-economic and demographic as well as environmental factors. To develop SVI, the first thing is to identify socio-economic indicators of income levels, education, employment status, housing conditions, age distribution, racial and ethnic composition, access to health care [9], of the potential inundation area at particular risk level. The weighting of these indicators under the various risk scenarios used in constructing the SVI is done after the identification of the relevant indicators. Aggregating these indicators into a single index, the SVI provides an integrated measure of relative vulnerability for different areas or social groups within the exposure area [9]. The SVI is particularly useful for showing the inequality of the levels of vulnerability between areas and between various social groups. An example of using SVI can be derived from Righini et al. [27], who apply the development of SVI using AHP.

Beside demonstrating the potential vulnerability of populations and communities through the SVI, some studies have assessed or recommended to assess the SII to predict or estimate SIA. For instance, Aznar-Crespo [8] emphasized the importance of assessing SIA while providing guidelines for SIA within FRM. Similarly, Righini et al. [27] advocated for assessing both SVI and SII, proposing a classification of SII into five risk categories ranging from very high to very low. Carrivick and Tweed [28] developed a relative damage index.

4. RECOMMENDATIONS FOR INCORPORATING SOCIAL IMPACT ASSESSMENT (SIA) IN MANAGEMENT OF DAM FAILURE FLOOD

From the review of methods and frameworks in the included literature, only two studies specifically addressed dam failure floods [22, 23]. He et al. [22] proposed a SIA based on the development of SVI using a mathematical model but considered few elements. In contrast, Aqilah et al. [23] included most social, economic, and environmental loss elements, focusing on the monetary evaluation of impacts utilizing the FEMA model to derive damage factors for high, medium and low risk level. Such damage factors may not be suitable for countries with different socio-economic and geographical contexts. Depth-damage ratio relevant to particular areas socio-economy, geographical and topographical condition may result in more accurate impact assessment. Given this, based on findings of SLR, the study proposes a step by step-by-step guidelines as well as probable methods to assess SIA for pre-hazard dam failure FRM, based on the review of the frameworks and models utilized in these studies, as depicted in Figure 5.

4.1 Flood hazard evaluation or assessing flood hazard map

The first step will include assessment of potential flood hazard maps at various simulated dam failure flood scenarios. This step includes understanding dam failure flood risk or flood characteristics variables depth, and duration and flood extent using flood numeric flood simulation model at different probability. The potential flood risk variables are depicted in Table 4 from literature review.

4.2 Data collection

i) Identification of potential dam failure flood exposure

Collection of socioeconomic data such as population data, economic value of each asset, geographic data, rainfall data; land use; protected area; and sources of potential pollutants. The potentially useful elements identified from the literature review are shown in Table 5 of the Literature Review.

ii) Considering Social vulnerability factors

Social vulnerability to flooding is shaped by a range of factors, including demographic characteristics, socioeconomic status, health access, land tenure, property structures, housing quality, and property markets. The proximity to rivers, neighborhood characteristics, and infrastructure quality, and drainage systems. Additionally, risk perception, awareness of flood risks, past experiences with floods, knowledge of self-protection measures, and trust in public institutions influence how respond to flooding. Poor infrastructure and inadequate drainage can exacerbate flooding. The key social vulnerability factors that can be considered are shown in Table 6.

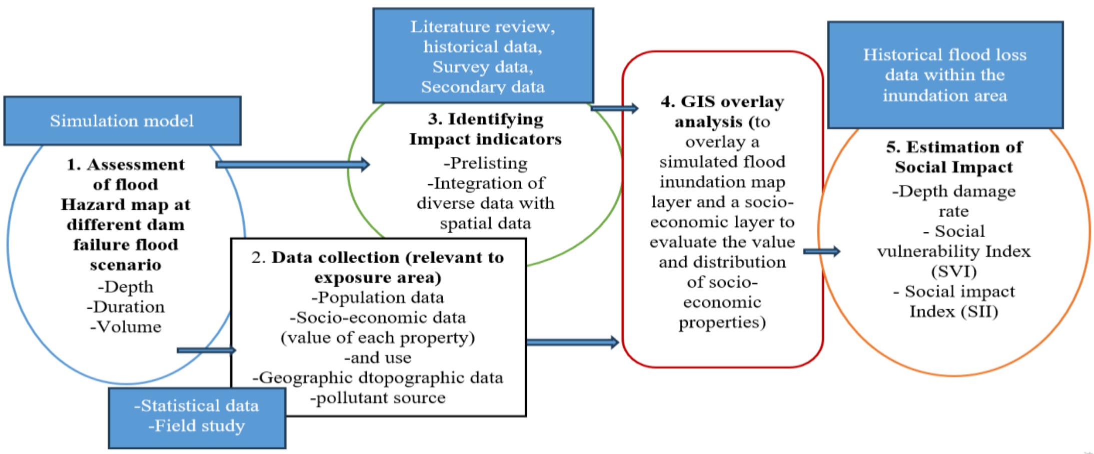

Figure 5. The proposed flowchart of SIA for dam failure flood risk
Source: based on the findings of study

4.3 Identifying Impact indicators

The relevant set of loss indicators should be gathered for an individual dam surrounding potential inundation areas from historical flood loss data, field study, literature review. During the selection of potential impact elements related to the areas affected by flood and considered around a dam, a set of criteria [9, 38] have to be considered to make sure that the data is relevant at a local scale. The most recent data are needed, from dependable institutions. The potential list of elements of flood loss derived from the literature review is depicted in Table 7 above.

4.4 GIS overlay analysis with socio-economic and land use data

The next step would be the use of GIS tools to overlay the inundation map layer of dam failure flood with the socio-economic layer, population data, and land use data to check the spatial relationship and distribution of socio-economic properties in various levels of flood hazards. Finally, the probable impacts of the dam failure flood in various risk scenarios is needed to be predicted. These may include any or all of the following phases.

i) Development of depth-damage rates

It shall be done through the support of a GIS-based spatial analysis and historic depth to damage data in order to generate the depth-to-damage rates for the various kinds of property in the land that is most prone to flooding. The data would include historical flood loss data [2], field study/ survey data or a questionnaire [33] relating to the potential area of flooding at various dam failure flood scenarios.

ii) Social vulnerability index (SVI)

To assess the vulnerability of communities to dam failure flood, SVI can help to identify population groups and areas which are comparatively at higher risk. After calculating the depth damage ratio or depth-to-damage rate, some previous studies assessed SVI. Hence, it is recommended to assess SVI as a part of SIA for dam failure floods. Identifying vulnerable groups through SVI will increase the effectiveness of flood risk management in adopting targeted and prioritized interventions.

iii) Developing Social Impact Index (SII)

After calculating the depth-damage table rate and SVI, the suggested next step is to develop the Integrated Social Impact Index (SII). The SII is a composite measure which is designed to quantify the overall social effects of the flood event on a group of people, area or society. It consolidates various social indicators into a single score or index to provide a comprehensive overview of the social changes or disruptions caused by the disaster event. Hence, besides developing SII, the estimation of integrated impact will demonstrate the total scenario of predicted impact. This may enable dam disaster managers and policymakers to adopt proper policy-making and other interventions.

5. CONCLUSION

This study reviewed the literature on SIA and flood risk to reveal how SIA can be effectively integrated into dam failure flood risk impact assessments. Through SLR and content analysis, the study identified the key flood hazard variables, essential methodologies, and the data that needs to be collected to measure such variables. It also pointed out the socio-economic and social vulnerability factors that were considered as a predictive factors of flood risk impact assessment. This study has also demonstrated how past studies categorized these impact elements into social, economic, and environmental. It also identified one of the major knowledge gaps as the inconsistency in the categorizing social, economic and environmental loss indicators. This study also presented a typical flow of flood impact analysis observed from past studies. Since only a few studies are found in the literature regarding assessments of dam failure flood impact, the authors suggested a new flowchart for SIA application in this specific field based on the content analysis. This flowchart presents the potential steps to follow and key data needed to collect to conduct SIA for pre-hazard dam disasters. The study is expected to contribute to the existing literature on FRM by providing useful information and pragmatic recommendations that might be helpful for policymakers and other relevant stakeholders in their effort to reduce the potential negative impacts of dam failures.

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