Eco. Env. & Cons. 27 (August Suppl. Issue) : 2021; pp. (S203-S212)

ISSN 0971–765X

Conceptual framework of climate risk assessment for Industries

Hrishikesh Mahadev Rayadurgam[1] and Prakash Rao[2]

Symbiosis Institute of International Business, Symbiosis International (Deemed University), Pune, India

(Received 10 March, 2021; Accepted 28 April, 2021)

ABSTRACT

Managing risk is a key component of industries to cope with extreme weather events (EWEs). In this research, we develop a comprehensive conceptual framework of climate risk assessment for industries / businesses. The conceptual framework covers different aspects of industries that may influence the risk towards EWEs. The framework covers ownership aspect, size of industry, location and sector. Further, it details various components of industry that determine the risk component like physical assets, processes, supply chain, logistics, employees, communities, markets, finance, support from the government, adaptation, adaptation barriers and drivers. This study will enable the researcher to use the entire framework or a part of it for assessing climate risk for industries.

Key words : *Climate change, Risk assessment, Vulnerability, Industries, Adaptation*

Introduction

The earth has been experiencing climate change during the past few decades. Climate change is one of the key challenges that inevitably affect our environment, society and economic activities. There has been an increase in frequency and magnitude of extreme weather events (EWE)(Guha-Sapir, 2020; IPCC, 2014) all over the world. The elucidation of climate change includes extreme temperatures, altered rainfalls, frequent droughts, cyclones, heat waves and cold waves. The impact of these EWEs on industries and business plays a substantial impact on the overall economy. Climate risk assessment (CRA) is one of the key methods of analysing risk due to future climate change.

As per International Panel for Climate Change (IPCC), CRA is one of key components of risk assessment (IPCC, 2014). In this framework of assessing the risk, the identification of a system or an area can be addressed by exposure to hazard viz. climate exposure, adaptive capacity and sensitivity or impact of the hazard viz. climate impact (Füssel, 2009), susceptibility, resilience, risk and vulnerability (Mal *et al.*, 2018). Jahn (2015) explains the various components of extreme weather events, which include vulnerability assessments (bio and social vulnerability), adaptive capacity, risk, and damages (direct and indirect losses). Further, in terms of EWEs, the author distinguishes between occurrence and impact extremity and differentiate between absolute extremity and rarity. The author has mentioned that impacts of EWEs depend not only on natural processes but also because of anthropogenic activities. Based on the analysis, risks and damages (direct and indirect losses) are categorised into high, medium or low risk. Jahn (2015) categorises extreme weather events into occurrence and impact extremity and also differentiates between absolute extremity and rarity. To cope with these extreme events, adaptation measures are taken. Roger, (2001) carried out environment risk assessment framework for individual exposure units using the 'bottom-up' approach. The author suggests, including the user-defined threshold in terms of stakeholders-, covering how climate affects the exposure unit being assessed, selection and testing of method and scenarios, carry out sensitivity analysis, assessing bio-physical, socio-economic and autonomous adjustments, evaluate risks and consult stakeholder to evaluate adaptation strategies. Implementation of interventions improves the resilience and ability to deal withEWEs.

Climate change adaptation in industries is a recent concept (Gasbarro and Pinkse, 2016; Linnenluecke *et al.,* 2013). Conceptual frameworks were developed to describe climate risk assessment and climate change adaptation for businesses, firms, industries, SMEs, organisations or corporates. One of the earliest literatures related to climate impact on organisations depicts the threats due to changes in environment and rigidity by the organisation because of these changes, which forms the basis of resilience for future works (Linnenluecke *et al.,* 2013; Staw *et al.,* 1981). During the initial years, the climate events were under the organisations' response to external threats. Meyer, (1982) introduced "resilience" to explain the concept of adaptation in the industries.

The conceptual framework for construction of small and medium enterprises (SMEs) introduces the ability of the company to cope with EWE (Wedawatta and Ingirige, 2016). The novel approach introduced by the author proposes resilience of construction SMEs depending on previous EWE experience, nature of SME, financial resources available, availability of expertise and knowledge of senior management, characteristics, duration, type and timing of EWEs, and other external factors.

The local and small community businesses have relatively smaller profits and less likely to have cash reserves or backup resources. Lo *et al.,* (2019) has carried out the community business resilience considering social capital and place. The study revealed that hazard risk managers should improve the social network and community engagement for preparing EWEs. Similarly, the research conducted by (Canevari-Luzardo *et al.,* 2020) indicated that the exposure and sensitivity is affected by variability of business exchanges, resource interdependency and ability to diversify access to the market. Besides direct impact, the employees are vulnerable to the diseases caused by the aftermath of EWEs. The conceptual framework for resilience of the construction sector to EWEs was developed considering two medium scale industries (Wedawatta and Ingirige, 2016). They have established the vulnerability that depends on the size of the industry, business sector, diversification and location of projects, supply chain and location of the project. It also depends on the coping strategies, coping capacities, experience in dealing with EWE, capacities of senior management and financial resources available.

Bai (2018) has identified six major research areas for mitigating and adapting climate change, which includes expanding observations, understand climatic interactions, studying informal settlements, harnessing disruptive technologies, supporting transformations, recognising global and sustainability context. The need for a study on the above fields in the industrial areas is very critical because the industries are keys to social, economic and development of any region or country.

Though different literature has mentioned different terminologies, an effort has been put to develop a broad CRA framework for industries. Conceptual framework and empirical studies have been carried out by many researchers addressing physical impacts of climate change (Gasbarro and Pinkse, 2016), supply chain (Laura Canevari-Luzardo, 2019), uncertainty, vulnerability, drivers and barriers (Halkos *et al.,* 2018; Moser and Ekstrom, 2010), location (Galbreath, 2014), resilience (Lo *et al.,* 2019), awareness, markets, financials (Capasso *et al.,* 2020) and adaptation (Crick *et al.,* 2018). There is limited research on the integrated approach for assessing risk in industries. This paper attempts to identify key areas of risk within industries and develop a conceptual framework addressing all the aspects of CRA for an industry. The paper begins with an introductory section, followed by CRA terminologies and then developing a conceptual framework for an industry addressing various risk areas.

Climate Risk Assessment Terminologies

CRA is one approach to understand the intensity of vulnerability of the sector or the region. Disaster risk reduction (DRR) and CRA have some relation, which includes likelihood, hazards, risks, and ambiguity. Secondly, CRA may include intensity of

EWE, exposure, vulnerability and equity, societal responses, adaptive capacity and resilience (Solecki *et al.,* 2011). DRR is more working towards the present system, which includes disaster risk assessment, preparedness and management. Climate change is more towards a shift of present disasters into the more frequent and unpredictable future extreme climatic event. Traditionally, the DRR community has been more oriented towards the climate hazards and its negative impacts, whereas the CCA community has more focused on the vulnerability until assessment report 4 (AR4) (Mysiak *et al.,* 2018). However, AR5 addresses the risk as the key component of CRA covering broader scope of exposure and vulnerability, thereby reducing the gap between DRR and CRA (Jurgilevich *et al.,* 2017).

The process of CRA includes assessing various extreme weather events or climate hazards, which are defined as the value of climate parameters, and occur above or below a certain threshold. Climate hazard can be defined as the extreme weather-related hazards causing damages to the resources or injury/loss of life (IPCC, 2014). Disaster is an extreme deviation of the normal conditions of society due to natural or man-made events. Extreme events may not always lead to disasters, it depends on social, physical and geographical conditions of an area. If rainfall is normal but the area has poor infrastructure, then the rainfall will have a significant impact on the social and economic aspects. Disaster risk is a combination of physical hazards and susceptibility or sensitivity of exposed regions, whereas exposure is a spirit of human and physical infrastructure, which are prone to damage.

Vulnerability is the sensitivity of an area or region to be adversely affected due to extreme climatic events. It is a key concept of the climate risk and a function of exposure, sensitivity, and adaptive capacity (Reay *et al.,* 2007). The fifth IPCC assessment report (AR5) (IPCC, 2014), has introduced a new concept which aims to identify and evaluate the risk from climate change. The concept of vulnerability was revised in AR5 and it is different from AR4. According to IPCC AR5, vulnerability is a function of two factors adaptative capacity and sensitivity, whereas the vulnerability in AR4 is defined by exposure, sensitivity and adaptive capacity. In AR5, risk is a function of exposure, hazards, and vulnerability. It is a combination of likelihood and consequence of hazard (IPCC, 2014). Here, in the overall risk framework, the exposure is presented separately from vulnerability and exposure includes the spatial interactions (IPCC, 2014; Sharma and Ravindranath, 2019). Exposure covers, to what extent the system or species could be adversely affected, whereas vulnerability addresses the tendency towards adversely affected system.

The extent to which any species or system is affected beneficially or adversely is the sensitivity (IPCC, 2014). If an industry is located at lower elevation, the industry is more sensitive towards flooding. Such attributes predispose the industry to have an adverse impact on them. However, if the industry increases its adaptive capacity by raising its floor level, the vulnerability of the industry towards flooding decreases. Adaptive Capacity addresses the ability of the system or species to adjust to potential damage. This may include the use of opportunities or respond to consequences (Agard *et al.,* 2014). Availability of water and electricity for industries, or having a robust industrial shed, makes industries resilient from cyclones. This component addresses the ability of a system to cope with extreme weather events known as resilience. The higher the adaptive capacity, the lower the system is vulnerable to extreme weather. The lack of adaptation capacity may be because of the social, environmental or physical aspects of the system.

The higher the resilience, lower will be the risk extreme event. Adaptation is the adjustment to expected or actual climate change and its effects (IPCC, 2014). Adaptation can be categorised into natural and human involvement (Eisenack and Stecker, 2012). Adaptation measures can be broadly categorised into soft and hard measures. Soft measures include awareness raising, education, policy interventions, financial allocations, etc., whereas hard measures include infrastructure interventions, such as raising floor level or better storm water drains to reduce the impact of floods, improved water conservation measures in drought-prone regions, etc. Further, there are different types of adaptation. Direct adaptation is the term used when there is an action to improve the system which is affected by extreme weather, whereas the indirect adaptation is where the action is intended to apply to improve the exposed units of the system (Eisenack and Stecker, 2012). The direct adaptation measures may include strengthening industrial sheds to reduce the impact of cyclones. The industries complying with international standards for improving the quality of the firm is an example of indirect adaptation. Incremental adaptation shows where adaptation actions are aimed at, maintaining the essence and integrity of the system, whereas transformation adaptation aims at changes in fundamental attributes of the system (Agard *et al.,* 2014). Further, the author (Eisenack and Stecker, 2012) has categorised adaptation into facilitating, reflexive, implicit, explicit, and incidental. Autonomous adaptation is the response to the climate and its affect without any planning or conscious effort. This is also called spontaneous adaptation. However, (IPCC, 2014) introduces the concept of adaptation in terms of planned, community-based, ecosystem based, evolutionary, and reactive (Agard *et al.,* 2014). IPCC further discriminates adaptation in terms of technical, institutional, legal, legislative, administrative, organisational, regulatory, research, financial, and market mechanisms (Eisenack and Stecker, 2012). Sometime, certain actions may lead to increased risk and adversely affect the climate change or vulnerability, this is known as maladaptation.

Conceptual elements of climate risk assessment for industries or businesses

The industrial sector is considered being less vulnerable and more resilient to climate change than other sectors like agriculture and water (Wibanks *et al.,* 2007). However, the MSME sector is still struggling to cope with extreme events because of inadequate infrastructure at the industry and industrial park level, especially in developing countries.

MSMEs across the world faces many challenges such as unavailability of liquid and working capital (Song *et al.,* 2016), high cost of credit as commercial banks charge on the loans, lack of basic infrastructure in industrial areas or parks such as energy and water with frequent power cuts, lack of skilled human resources and innovation, high competition within domestic markets, high-quality checks for international markets, which again require capital to invest, sensitive financial markets, changes in government policies, and more recently the impact of extreme weather events (EWE). Extreme climate event is defined as the value of climate parameters that occur above or below a certain threshold. Although extreme events may not always lead to disasters, it depends on social, physical and geographical conditions of an area (Lavell *et al.,* 2012).

The extreme weather can affect various components of industries, like physical assets, location, processes, employees, markets, supply chain, storage and finance aspects. EWEs may disturb the effectiveness of the supply chain in which the SMEs are related and incur losses to the physical assets and processes impacting the inventory cost and downtime loss. The impact depends on the type, intensity, frequency, timing and duration of EWE (Wedawatta and Ingirige, 2016). Figure 1 summarises the conceptual framework for climate risk assessment of industries / businesses.

Ownership Aspects

The general aspects of industries includes the owner / management willingness to commit towards CRA and CCA measures, their educational background and awareness level and past EWE, experience. Gender of the management / owner plays a key role in determining the adaptation measures. Further, certain factors like race, marital status, number of employees, age of industries, own or rented (Josephson *et al.,* 2017), type of ownership and having children or not also determine the industry's wiliness to CRA and CCA.

Size of the Industry

The size of the industry plays an influential role in the industry's vulnerability or business (Wedawatta & Ingirige, 2016). Vulnerability is often related with size of the industry; micro- and small-scale industries are comparatively more vulnerable to EWEs than medium or large-scale industries. Majority of small-scale industries lack planning, delay in recovery and sensitive to cash flows, makes them more vulnerable to EWEs (Runyan, 2006).

Industry Sector

Industries based on primary economic activities such as agriculture, forestry, mining and fishing are most vulnerable to extreme events. The vulnerability of secondary economic activities such as manufacturing units depends on three aspects, first, if the raw materials are primary sources, then price and quality of the secondary product may hamper. Second, the supply chain may get affected and the impact of energy, labour and water may significantly affect. Third, climate change can affect the demand for products (Arent *et al.,* 2014; Arent and Tol, 2014).

In addition, risk also depends on usage of water and energy. Water intensive sectors like tanneries, pulp and paper, textile, breweries and beverages, power plants, pharmaceuticals, etc., are vulnerable to extreme weather events like low rainfall or high temperatures. Some key energy-intensive sectors may include fertilisers, petrochemical, iron, paper, aluminium, textiles, etc. Some of these are both energy and water intensive sectors.

Geographical location

The location of industry is a component of exposure in CRA. Location can be broadly categorised into regional or local. Regional location depends on climatic zones and represents a large area EWE affects, such as cyclones and droughts. Industries in coastal areas are more exposed to EWEs like cyclones, sea-level rise than interior regions. Similarly, industries near large rivers or poorly planned dense areas are prone to floods. Within region, exposure of industry also varies from one place to another based on localised infrastructure and topography. Industries in higher elevated areas are less exposed to flooding than industries in lower elevation region. If the surrounding industries are using boilers for energy usage, then industry is exposed to higher temperature because of heat-wave during summer seasons.

Physical assets

Damages to external and internal infrastructure can make an industry vulnerable to EWEs. External infrastructure covers road, electricity, water, communication systems, storm-water drains, etc. The electric poles, mobile towers and trees are highly vulnerable to cyclonic events (Press Trust of India, 2014; Shanmugasundaram *et al.,* 2000). An increase in number of hot days can affect rail and road infrastructure, disrupting the transportation and increasing the repair cost (Pappis, 2010). The internal damages include physical assets like buildings, sheds, foundations, shutters, etc., depending on the area of impact to the industry. The industrial sheds and walls are vulnerable to cyclonic winds and heavy rains, whereas foundations are vulnerable to heavy rains and flooding. Most recent work by (Kim *et al.,* 2020), used Catastrophic (CAT) model to assess the risk associated with buildings because of typhoons and they concluded that risk from typhoons gradually increased. The risk to industrial buildings has accumulated to 307% and commercial buildings to 455%. Sometimes, the damages are so high that the industry will go defunct or forced to move.

Processing / Manufacturing

Processing is the core component of any manufacturing industry. The key risk areas of processing can be categorised into core processing and non-core processing components. Any damage to the core processing machines may delay the production process. Many times, in MSME sector, a single processing machine is the core component of processing unit. However, large-scale industries will have many units and materials transported through conveyor belts, which may be internal or external (exposed to EWEs). The non-core processing part of industry depends on the internal and external infrastructure, industrial sector, supply chains from raw materials, availability of employees, financial and market risks and demands. The power outages during heavy rains or extreme temperatures can cause an abrupt end to a manufacturing good, leading towards production losses.

Supply chain and logistics

Supply chain covers a wide range of activities from sourcing the raw materials for industrial production from suppliers to the supply of finished goods from industries to the market. Supply chain is a complex process involving people, organisation, technology, resources (Pappis, 2010), and infrastructure. Supply chain management is an industry by itself, however, it forms a vulnerable component of an individual industry. The vulnerability of supply chain may occur at three locations: 1) at the industry, 2) during the transport, 3) at the customer or supplier. Raw materials can be sourced locally, regionally, nationally or from the international market. Similarly, the final products are sold into different markets and consumers. Any disruption of value chain because of extreme weather event, will have a ripple effect downstream, which may be global, regional or at a local level. This disruption may lead towards return of stocks, loss of sale, shareholders wealth, customer goodwill and overall trust (Wedawatta *et al.,* 2010). This impact may be an opportunity as well as a challenge. Canevari-Luzardo *et al.* (2020) has carried out business network dynamics in Jamaica and concluded business inter-dependencies and interim relationships which influences exposure, sensitivity and adaptive capacities of the supply chain. There are internal factors such as production, transportation, which contribute towards climate change and external factors such as EWEs, diseases that impact the industry, indicating that climate change and supply chain management are closely linked to oneother (Ghadge *et al.,* 2020).

Employees and Communities

Several studies have explored the effects of EWEs on employees and communities (Balakrishnan *et al.,* 2010; DiBella, 2020). Because of rapid urbanisation, the industrial areas once planned outskirts of city limits have now become an integral part of the city. Hence, the impact on industries may significantly affect the surrounding community. The risk associated with employees and communities can be categorised into "during the EWEs" and "aftermath of EWEs". The impact of EWEs can be a sudden affect destroying their livelihood such as during cyclones and floods or a slow process like heat waves which reduces their productivity, such as during heat waves or drought. However, in both cases, an increase in the number of hot days can have a significant impact on the productivity and health of the worker leading towards heat strokes, exhaustion, cramps, dehydration, or heat syncope (Balakrishnan *et al.,* 2010). Workers working near furnaces and boilers are more exposed to hot conditions affecting the health. The lack of accessibility and availability of health systems during the hazard is the key to risk associated with the community.

The "aftermath of EWEs" component addresses mainly the health-related infectious and vector-diseases arising because of the damaged vegetation and infrastructure, stagnation of water, delayed health responses, etc. There is an extensive literature on climate change and relationship to health (Daggu and Rukkumani, 2020; Ebi, 2011; Robine *et al.,* 2008). The study conducted by (Nakano, 2018) shows that by 2030, industries are most vulnerable to dengue fever. This will have a significant impact on the supply chain, especially in countries like India, Brazil, China, and even in US and Germany. Further, the impact of EWEs as floods and cyclones may further aggravate the COVID-19 pandemic (Rahman *et al.,* 2021).

Markets

The market risk associated with climate can be broadly categorised into stock market responses to EWEs, risk disclosures, and the response from local market through demands and supplies. Voluntary release of carbon disclosure project (CDP) influences capital and shareholder value of the industry. The existing literature shows a mixed result related to CDP. The study conducted by (DiSalvio and Dorata, 2014) shows stock market responses to be significantly positive to the release of Securities and Exchange Commission (SEC) documents. Research carried out by (Alsaifi *et al.,* 2020; Lee *et al.,* 2015) shows the market responses, especially smaller industries, respond negatively to the release of CDPs as investors perceive its liability and industries have to invest more money to cope with climate change.

The local markets also respond immediately after the EWEs, the demand and supply of certain product and services significantly changes. There may be an increase in demand for robust industrial sheds immediately after cyclones, and power backups during extreme temperature events. The local markets are driven by the demand because of the type and impact of EWEs. If the industry is affected because of EWEs, their production falls, leading towards less supply of goods and cost of the product will increase. This will lead to less consumption of the goods. Further, this will lead to less demand of the product, and industries may have to change their production capacity or shift the product.

Finances

Risk associated with low-frequency and high-severity can jeopardise the industry, hence the access to finance aftermath of EWEs are key for industries to bounce back to business-as-usual. Access to finances can be broadly categorised into credit and insurance. The availability of short-term or long-term finances during EWEs with credit and low interest rates will enable industries to cope with losses and gain time to bounce back. Insurance is a hedge against any losses due to EWEs and serves as the primary form of risk management (West and Brereton, 2013). However, many micro- and small-scale industries do not opt for insurance as they do not perceive EWEs as a threat to their industry or they are not aware of it.

Government Support

Government support during an extreme event especially for MSME sector reduces vulnerability of industries. Government can support by introducing policies for industries, especially MSME sector, by providing incentives to implement adaptation measures as an adaptation incentive. Government may also provide a onetime amount for the loss experienced by the industries, which may happen immediately after an EWE. Promoting CCA measures for industries through policies may encourage industries to implement adaptation measures. This will reduce the vulnerability of industries and increase the ability to cope with EWEs.

Adaptation

The SMEs can reduce the vulnerability posed by EWEs by implementing adaptation measures. The coping strategies and capacities play an important role in developing adaptation for an organisation. Several studies have been conducted addressing firms' behaviour and preparedness towards adaptation (Crick *et al.,* 2018; Gasbarro and Pinkse, 2016). Gasbarro and Pinkse, (2016) explored how the key corporate adaptation behaviour relates to the type of adaptation measures the firm implements in terms of awareness, past experience and vulnerability. The authors broadly classified adaptation into the pre-emptive, reactive, continuous and deferred adaptation.

At the first level, adaptation can be broadly categorised into soft and hard measures. Soft measures involve changes that can be implemented through planning, knowledge, standards, financial planning, and policy. This may include extreme weather planning, assessing risk, developing early warning systems, factoring climate into investments, training and awareness, community engagement, advocating policies, changing new product, etc. Hard infrastructure cover changes the infrastructure or relocation of the industry. Some examples from hard infrastructure are improving water or energy efficiency, strengthening of buildings, construction of emergency shelters, power backups, relocation of industry, etc (Goldstein *et al.,* 2019).

Barriers and Drivers in Adaptation

EWE poses threat to existing business-as-usual approaches as they are deemed to be insufficient (Halkos *et al.,* 2018). The drivers and barriers of climate risk for an industry are a combination of internal and external factors (Surminski *et al.,* 2018). The internal factors like management's priorities, awareness, commitment, culture, resourcesand experiences are few of the key indicators towards adaptation measures. The external factors may include

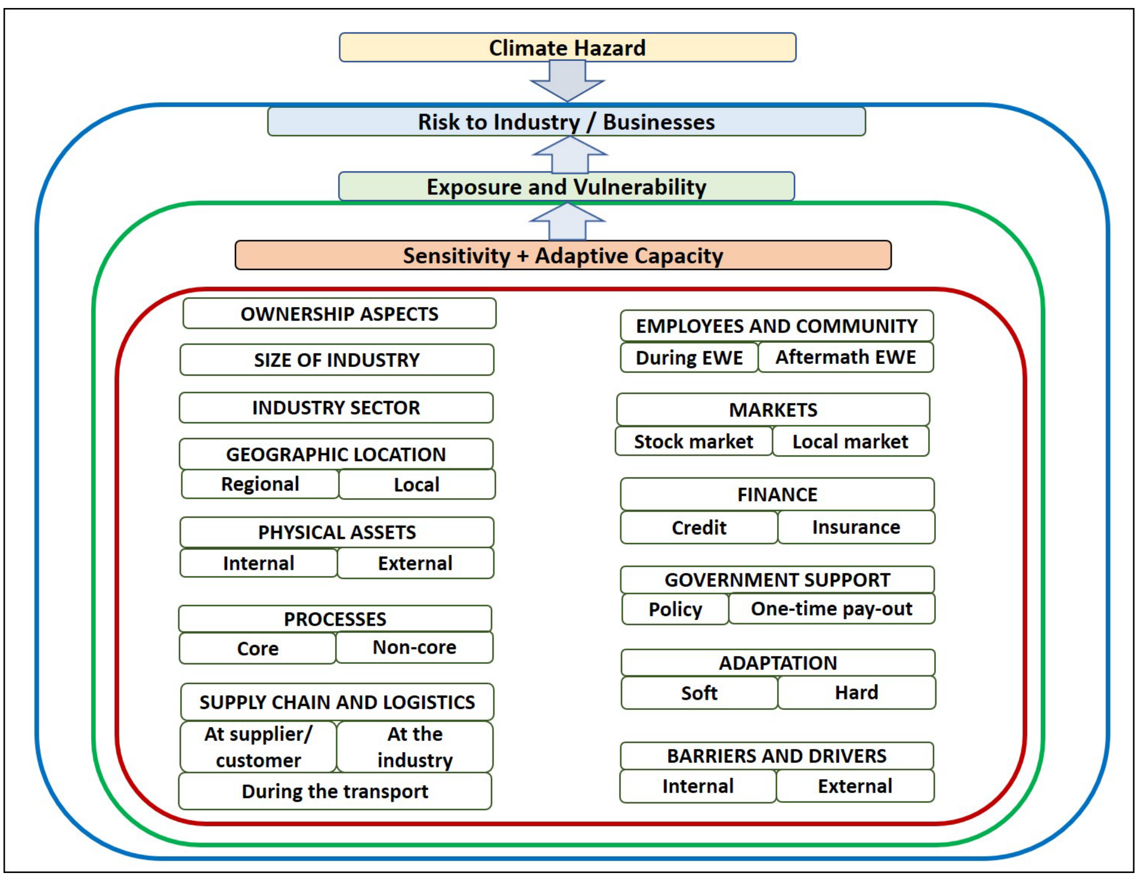

Fig. 1. Conceptual framework of climate risk assessment for industries / businesses

government policy and incentives, responses of insurance and banking sectors, markets, impact on neighbouring industries, community, external knowledge, information and support, etc. Authors have found that the key internal barrier is the awareness among management level that enables industries to implement adaptation measures. External factor may also include institutional conditions and external support (Halkos *et al.,* 2018).

Conclusion

The present research makes an attempt towards developing a conceptual framework of climate risk assessment for industries. The framework covers different aspects of industries that are vulnerable to EWEs. These aspects are physical assets, location, supply chain and logistics, employees and communities, markets, processes, finance, government support, adaptation measures, barriers and drivers. In addition, the general aspects like size of industry and business sector also play a key role in determining the risk. For each aspect, framework explains broad categories that may influence the risk. Within each category, there are indicators which can measure to analyse CRA. Such frameworks will analyse CRA for industries / businesses. Majority of past research relied on one or two specific aspects of CRA component. Hence, this framework will enable future researchers to analyse risk for an industry as a whole or a part of it.

Acknowledgments

This is a part of ongoing doctoral research. The authors are very grateful to anonymous reviewers for providing constructive comments which contributed to improving the final version of this paper.

References

Agard, J., Lisa Schipper, E. F., Mach, K. J., Mastrandrea, M. D. and Eren Bilir, T. 2014. *II Glossary Editorial Board Co-Chairs: TSU Facilitation*.

Alsaifi, K., Elnahass, M. and Salama, A. 2020. Market responses to firms' voluntary carbon disclosure: Empirical evidence from the United Kingdom. *Journal of Cleaner Production*. 262. https://doi.org/10.1016/j.jclepro.2020.121377

Arent, D. J. and Tol, R. S. J. 2014. *Key Economic Sectors and Services (IPPC Chapter 10)*. 659–708.

Arent, D. J., Tol, R. S. J., Faust, E., Hella, J. P., Kumar, S., Strzepek, K. M. and Ngeh, J. 2015. Key economic sectors and services. In *Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects* (pp. 659–708). https://doi.org/10.1017/CBO9781107415379.015

Bai, Y., Wei, X. and Li, X. 2018. Distributional dynamics of a vulnerable species in response to past and future climate change: A window for conservation prospects. *PeerJ*. 2018(1). https://doi.org/10.7717/peerj.4287

Balakrishnan, K., Ramalingam, A., Dasu, V., Chinnadurai Stephen, J., Raj Sivaperumal, M., Kumarasamy, D. and Sambandam, S. 2010. Case studies on heat stress related perceptions in different industrial sectors in southern India. *Global Health Action*. 3(1) : 5635. https://doi.org/10.3402/gha.v3i0.5635

Canevari-Luzardo, L. M., Berkhout, F. and Pelling, M. 2020. A relational view of climate adaptation in the private sector: How do value chain interactions shape business perceptions of climate risk and adaptive behaviours? *Business Strategy and the Environment*. 29(2) : 432–444. https://doi.org/10.1002/bse.2375

Canevari-Luzardo, Laura M. 2019. Value chain climate resilience and adaptive capacity in micro, small and medium agribusiness in Jamaica: a network approach. *Regional Environmental Change*. https://doi.org/10.1007/s10113-019-01561-0

Capasso, G., Gianfrate, G. and Spinelli, M. 2020. Climate change and credit risk. *Journal of Cleaner Production*. 266: 121634. https://doi.org/10.1016/j.jclepro.2020.121634

Crick, F., Gannon, K. E., Diop, M. and Sow, M. 2018. Enabling private sector adaptation to climate change in sub-Saharan Africa. *Wiley Interdisciplinary Reviews: Climate Change*. 9(2). https://doi.org/10.1002/wcc.505

Daggu, N. R. and Rukkumani, S. 2020. An analysis of human resources (Hr) practices of recruitement and selection in higher education with special reference to hyderabad India. *International Journal of Advanced Science and Technology*. 29(3 Special Issue), 537–541. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85081588220&partnerID=40&md5=dab3496decea8f2ec54a5bdb5dae2640

DiBella, J. 2020. The spatial representation of business models for climate adaptation: An approach for business model innovation and adaptation strategies in the private sector. *Business Strategy and Development*. 3(2) : 245–260. https://doi.org/10.1002/bsd2.92

DiSalvio, J. and Dorata, N. T. 2014. SEC guidance on climate change risk disclosures: An assessment of firm and market responses. *Advances in Environmental Accounting and Management*. 5 : 115–130. https://doi.org/10.1108/S1479-359820140000005013

Ebi, K. 2011. Climate change and health risks: Assessing and responding to them through "adaptive management. *Health Affairs*. 30(5) : 924–930. https://doi.org/10.1377/hlthaff.2011.0071

Eisenack, K. and Stecker, R. 2012. A framework for analyzing climate change adaptations as actions. *Mitigation and Adaptation Strategies for Global Change*. 17(3) : 243–260. https://doi.org/10.1007/s11027-011-9323-9

Füssel, H.M. 2009. Ranking of national-level adaptation options. An editorial comment. *Climatic Change*. 95(1–2): 47–51. https://doi.org/10.1007/s10584-009-9609-z

Galbreath, J. 2014. Climate change response: Evidence from the margaret river wine region of Australia. *Business Strategy and the Environment*. 23(2) : 89–104. https://doi.org/10.1002/bse.1762

Gasbarro, F. and Pinkse, J. 2016. Corporate Adaptation Behaviour to Deal With Climate Change: The Influence of Firm-Specific Interpretations of Physical Climate Impacts. *Corporate Social Responsibility and Environmental Management*. 23(3) : 179–192. https://doi.org/10.1002/csr.1374

Ghadge, A., Wurtmann, H. and Seuring, S. 2020. Managing climate change risks in global supply chains: a review and research agenda. *International Journal of Production Research.* 58(1): 44–64. https://doi.org/10.1080/00207543.2019.1629670

Goldstein, A., Turner, W. R., Gladstone, J. and Hole, D. G. 2019. The private sector's climate change risk and adaptation blind spots. *Nature Climate Change*. 9(1) : 18–25. https://doi.org/10.1038/s41558-018-0340-5

Guha-Sapir, D. 2020. EM-DAT: The OFDA/CRED International Disaster Database. Retrieved September 25, 2020, from http://emdat.be

Halkos, G., Skouloudis, A., Malesios, C. and Evangelinos, K. 2018. Bouncing Back from Extreme Weather Events: Some Preliminary Findings on Resilience Barriers Facing Small and Medium-Sized Enterprises. *Business Strategy and the Environment*. 27(4): 547–559. https://doi.org/10.1002/bse.2019

P. 2014. Uprooted trees, electric poles tell tale of Cyclone Hudhud's impact -. Retrieved December 25, 2020, from The Economic Times website: https://economictimes.indiatimes.com/news/politics-and-nation/uprooted-trees-electric-poles-tell-tale-of-cyclone-hudhuds-impact/articleshow/44790921.cms?from=mdr

IPCC. 2014. Climate Change 2014 Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects. In *Cambridge University Press* (Vol. 1). https://doi.org/10.1017/CBO9781107415324.004

Jahn, M. 2015. Economics of extreme weather events: Terminology and regional impact models. *Weather and Climate Extremes*. 10 : 29–39. https://doi.org/10.1016/j.wace.2015.08.005

Josephson, A., Schrank, H. and Marshall, M. 2017. Assessing preparedness of small businesses for hurricane disasters: Analysis of pre-disaster owner, business and location characteristics. *International Journal of Disaster Risk Reduction*. 23 : 25–35. https://doi.org/10.1016/j.ijdrr.2017.03.013

Jurgilevich, A., Räsänen, A., Groundstroem, F. and Juhola, S. 2017. A systematic review of dynamics in climate risk and vulnerability assessments. *Environmental Research Letters*. 12(1): 013002. https://doi.org/10.1088/1748-9326/aa5508

Kim, J.-M., Son, S., Lee, S. and Son, K. 2020. Cost of climate change: Risk of building loss from typhoon in South Korea. *Sustainability (Switzerland)*. 12(17). https://doi.org/10.3390/su12177107

Lavell, A., Oppenheimer, M., Diop, C., Hess, J., Lempert, R., Li, J. and Weber, E. 2012. Climate change: New dimensions in disaster risk, exposure, vulnerability, and resilience. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. *9781107025*, 25–64. https://doi.org/10.1017/CBO9781139177245.004

Lee, S. Y., Park, Y. S. and Klassen, R. D. 2015. Market responses to firms' voluntary climate change information disclosure and carbon communication. *Corporate Social Responsibility and Environmental Management*. 22(1) : 1–12. https://doi.org/10.1002/csr.1321

Linnenluecke, M. K., Griffiths, A. and Winn, M. I. 2013. Firm and industry adaptation to climate change: A review of climate adaptation studies in the business and management field. *Wiley Interdisciplinary Reviews: Climate Change*. 4(5) : 397–416. https://doi.org/10.1002/wcc.214

Lo, A. Y., Chow, A. S. Y., Liu, S. and Cheung, L. T. O. 2019. Community business resilience: adaptation practice of micro- and small enterprises around the Pearl River Estuary. *Climatic Change*. https://doi.org/10.1007/s10584-019-02562-y

Mal, S., Singh, R. B. and Huggel, C. 2018. *Climate Change, Extreme Events and Disaster Risk Reduction. [electronic resource]/: Towards Sustainable Development Goals*. Retrieved from https://www.springer.com/gp/book/9783319564685

Meyer, A. D. 1982. Adapting to environmental jolts. *Administrative Science Quarterly*. 27(4) : 515–537. https://doi.org/10.2307/2392528

Moser, S. C. and Ekstrom, J. A. 2010. A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences*. 107(51): 22026–22031. https://doi.org/10.1073/pnas.1007887107

Mysiak, J., Torresan, S., Bosello, F., Mistry, M., Amadio, M., Marzi, S. and Sperotto, A. 2018. Climate risk index for Italy. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. 376(2121). https://doi.org/10.1098/rsta.2017.0305

Nakano, K. 2018. Future risk of dengue fever to workforce and industry through global supply chain. *Mitigation and Adaptation Strategies for Global Change*. 23(3): 433–449. https://doi.org/10.1007/s11027-017-9741-4

Pappis, C. P. 2010. Climate change, supply chain management and enterprise adaptation: Implications of global warming on the economy. In: *Climate Change, Supply Chain Management and Enterprise Adaptation: Implications of Global Warming on the Economy*. https://doi.org/10.4018/978-1-61692-800-1

Rahman, M. M., Bodrud-Doza, M., Shammi, M., Md Towfiqul Islam, A. R. and Moniruzzaman Khan, A. S. 2021. COVID-19 pandemic, dengue epidemic, and climate change vulnerability in Bangladesh: Scenario assessment for strategic management and policy implications. *Environmental Research*. 192. https://doi.org/10.1016/j.envres.2020.110303

Reay, D., Sabine, C., Smith, P. and Hymus, G. 2007. Intergovernmental Panel on Climate Change. Fourth Assessment Report. Geneva, Switzerland: Inter-governmental Panel on Climate Change. Cambridge; UK: Cambridge University Press; 2007. Available from: www. ipcc.ch. In *Intergovernmental Panel on Climate Change.* https://doi.org/10.1038/446727a

Robine, J. M., Cheung, S. L. K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J. P. and Herrmann, F. R. 2008. Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendus - Biologies*. 331(2): 171–178. https://doi.org/10.1016/j.crvi.2007.12.001

Roger, N. J. 2001. An Environmental Risk Assessment/ Management Framework for Climate Change Impact Assessments. *Natural Hazards*. 23(2–3) : 197–230. https://doi.org/10.1111/j.1523-1739.2007.00752.x

Runyan, R. C. 2006. Small business in the face of crisis. *Journal of Contingencies and Crisis Management*. 14(1): 12–26. https://doi.org/http://dx.doi.org/10.1111/j.1468-5973.2006.00477.x

Shanmugasundaram, J., Arunachalam, S., Gomathinayagam, S., Lakshmanan, N. and Harikrishna, P. 2000. Cyclone damage to buildings and structures - a case study. *Journal of Wind Engineering and Industrial Aerodynamics*. 84(3) : 369–380. https://doi.org/10.1016/S0167-6105(99)00114-2

Sharma, J. and Ravindranath, N. H. 2019. Applying IPCC 2014 framework for hazard-specific vulnerability assessment under climate change. *Environmental Research Communications*, *1*(5), 051004. https://doi.org/10.1088/2515-7620/ab24ed

Solecki, W., Leichenko, R. and Brien, K. O. 2011. *Climate change adaptation strategies and disaster risk reduction in cities/: connections, contentions, and synergies* §. https://doi.org/10.1016/j.cosust.2011.03.001

Song, H., Yu, K., Ganguly, A. and Turson, R. 2016. Supply chain network, information sharing and SME credit quality. *Industrial Management and Data Systems*. 116(4): 740–758. https://doi.org/10.1108/IMDS-09-2015-0375

Staw, B. M., Sandelands, L. E. and Dutton, J. E. 1981. Threat Rigidity Effects in Organizational Behavior: A Multilevel Analysis. In *Quarterly* (Vol. 26).

Surminski, S., Di Mauro, M., Baglee, J. A. R., Connell, R. K., Hankinson, J., Haworth, A. R. and Proverbs, D. 2018. Assessing climate risks across different business sectors and industries: An investigation of methodological challenges at national scale for the UK. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. 376(2121). https://doi.org/10.1098/rsta.2017.0307

Wedawatta, G. and Ingirige, B. 2016. A conceptual framework for understanding resilience of construction SMEs to extreme weather events. *Built Environment Project and Asset Management*. 6(4) : 428–443. https://doi.org/10.1108/BEPAM-06-2015-0023

Wedawatta, G., Ingirige, B. and Amaratunga, D. 2010. Building up resilienc e of construction sector SMEs and their supply chains to extreme weather events. *International Journal of Strategic Property Management*. 14(4) : 362–375. https://doi.org/10.3846/ijspm.2010.27

West, J. and Brereton, D. 2013. *Climate change adaptation in industry and business: A framework for best practice in financial risk assessment, governance, and disclosure*.

Wibanks, T., Romero Lanka, P., Bao, M., Berkhout, F., Cairncross, S., Ceron, J. P. and Zapata-Marti, R. 2007. Industry, settlement and society. Climate Change 2007: Impacts, Adaptation and Vulnerability. *Cambridge University Press*. 357–390. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter7.pdf