RESILIENT INDUSTRIES

Competitiveness in the Face of Disasters

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Global Facility for Disaster Reduction and Recovery

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Acronyms

ADPC	Asian Disaster Preparedness Center
AI	artificial intelligence
APEC	Asia-Pacific Economic Cooperation).
BCP	business continuity plan/business continuity planning
BCM	business continuity management
BEZA	Bangladesh Economic Zone Authority
BFE	Basic Flood Elevation
BCM	Business Continuity Management
BSMSN	Bangabandhu Sheikh Mujib Shilpa Nagar
CCRA	Climate Change Risk Assessment (The United Kingdom)
CCTV	Closed-circuit television
CEMS	Community Energy Management System
CGC	Credit Guarantee Corporation
CMS	Critical Manufacturing Sector
DBJ	Development Bank of Japan
DFE	Design Flood Elevation
DHS	Department of Homeland Security
DRM	disaster risk management
EPA	U.S. Environmental Protection Agency
EP&R	Emergency Preparedness and Response Plan
FDI	foreign direct investment
FEMA	Federal Emergency Management Agency (The United States)
FIRM	Flood Insurance Rate Map
GDP	gross domestic product
GEJE	Great East Japan Earthquake
GFC	global financial crisis
GHG	greenhouse gas
GVC	global value chain
HOPE II	Haitian Hemispheric Opportunity through Partnership Encouragement Act II
ICT	information communication technology
IFC	International Finance Corporation
IEAT	Industrial Estate Authority of Thailand
IMF	International Monetary Fund
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard Industrial Classification of All Economic Activities
IT	information technology
ITOIZ	Istanbul Tuzla Organized Industrial Zone

JICA	Japan International Cooperation Agency
kWh	kilowatt-hour
LCCA	Life Cycle Cost Analysis
LLP	Limited Liability Partnership
MCA	multi-criteria analysis
METI	Ministry of Economy, Trade and Industry (Japan)
MiCRO	Microinsurance Catastrophe Risk Organization
MINUSTAH	United Nations Stabilization Mission in Haiti
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
MoU	Memorandum of Understanding
MW	megawatt
MWBE	Minority- and Women-owned Business Enterprises
NCIF	National Catastrophe Insurance Fund (Thailand)
NIPP	National Infrastructure Protection Plan
NFIP	National Flood Insurance Program (The United States)
NYCEDC	New York City Economic Development Corporation
OECD	Organisation for Economic Co-operation and Development
OIC	Office of Insurance Commission
OIZ	Organized Industrial Zone
PCGP	partial credit guarantee program
PDNA	Post-Disaster Needs Assessment
PIM	Parc Industriel Metropolitan
PMI	purchasing managers' index
PPD	public-private dialogue
PPE	Personal Protective Equipment
PPP	public-private partnership
PRIDCO	Puerto Rico Industrial Development Company
RESAS	Regional Economy Society Analyzing System
RESCUE	REinforce Supply Chain Under Emergency
SEZ	Special Economic Zone
SME	small and medium enterprise
STP	sewage treatment plants
UAV	unmanned aerial vehicle
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
US DHS	US Department of Homeland Security
WTO	World Trade Organization

All dollar amounts are in US dollars unless otherwise indicated.

Executive Summary

Industrial activity creates jobs, catalyzes investments and innovation, and raises standards of living in many countries. As climate change, and disasters intensify, so too does the risk environment for industry activity. More recently, a viral pandemic has threatened industries and national economies, and the imperative to secure business continuity and competitiveness in the midst of growing instability has thrust resilience into the spotlight. The suite of risks posed by climate change and disasters threatens industry's potential to grow, generate jobs, and compete. For many developing countries, disaster-related liabilities may exceed the capacity of governments to respond, and even national economies may be threatened. The emergence of industry resilience as a global discourse is timely; however, industry resilience is a nascent discipline, and frameworks for its application and operation remain limited even as threats intensify. Disasters offer the opportunity, with the right frameworks in place, to strengthen competitiveness through build-back-better initiatives, and to adapt to long-term climate change and disaster risks. Despite these insights, and the urgency to act, however, the evidential basis for policy intervention and conceptual frameworks for industry resilience are far from definitive, and gaps in knowledge remain. As a result, industry resilience policy and action remain low in both the public and private sectors, and firms and economies still face significant costs of inaction.

Based on the studies of global cases, this report calls for proactive approaches to industry resilience, provides policy makers with ways to boost industry competitiveness in the face of disasters and considers the roles of various stakeholders in advancing these goals. The report defines industry resilience as the ability of firms, industrial parks, and manufacturing sectors to increase competitiveness by minimizing losses and damages, and by achieving continuity and growth in the face of more frequent and intensifying disasters. Types of sectors, hazards, and solutions featured in this report are summarized in table ES.1.

Table ES.1 Types of Sectors, Hazards, and Solutions

Types	Description
Types of sectors	Manufacturing sector, and other sectors critical to manufacturing sector competitiveness, including energy, water, transport, trade, industry, construction and finance.
Types of natural hazards	Geological: earthquakes, volcanoes, and tsunamis. Hydrometeorological: floods, including flash floods; tropical cyclones (also known as typhoons and hurricanes); droughts, heatwaves, and coastal storm surges.
Types of solutions	**Policy** measures including national strategies, policies, regulations, and institutional arrangements that mainstream industry resilience in advance of disasters; **Infrastructure** solutions that minimize physical damage and disruption of services critical to industries; **Financial** mechanisms available before, during and after disasters to secure financial protection of firms and channel investment in resilient infrastructure; **Gender-aware** approaches addressing challenges women in manufacturing sectors face during and after disasters; and **Technology** measures that harness digital technologies to improve data quality, offer predictive analytics, enhance monitoring and communication, and provide real-time information.

Figure ES.1 Competitiveness Benefits of Risk-Informed Industry Resilience Planning and Investments

Industry Resilience Actions and Investments

Policy actions and investments related to infrastructure, policy and finance measures to help industries avoid or reduce damage and losses and prepare for, and respond to, the impacts of disasters.

Investment Cost

- Life-cycle costs of resilient infrastructure investments
- Firms' implementation of BCPs
- Firms' purchase of insurance
- Potential environmental and social cost

Maintain competitiveness when disaster strikes

Avoided Damage and Losses

- Avoid direct damage to industry assets (buildings, facilities, equipment, machinery, and inventories) and contain repair costs
- Avoid losses in production and sales
- Avoid losses due to infrastructure and service disruption
- Avoid disaster-induced coping cost (e.g. increased transportation costs, or investments in alternative means to continue business operations such as operation costs of back-up generators)
- Avoid job losses

Enhance competitiveness benefits regardless of disaster

Unlocking Development Potential

- Encourage firms save operational costs and build assets
- Increase usability and value of serviced industrial land
- Stimulate firms to invest and innovate
- Increase reputation and competitiveness of firms, manufacturing sectors and industrial parks

Generating Co-Benefits

A wide range of additional benefits across society, income groups, and industry sectors, including:

- mitigation of environmental pollution and greenhouse gas emissions
- increase workforce productivity and safety
- increase resilience of local communities

Source: Adapted from Tanner et al. 2018.

Industry Competitiveness and Disasters

Disasters, especially large-scale natural disasters, can affect industry competitiveness if no action is taken to build industry resilience. The physical and non-physical impacts of disasters disrupt flows of people, goods, infrastructure services, capital and information. These impacts occur through physical damage to firm's assets and to on-site and off-site infrastructure, which incurs repair and reconstruction costs; disruption to supply chains and production networks due to impacts on suppliers and availability of input materials; or disruptions to infrastructure and services such as power, water, transportation networks, and telecommunication systems that service firms, industrial parks, and people. Indirect impacts often relate to the loss of production capacity and market demand, reputational risk, and loss of investors, which consequently reduces sales and export performance, and increases the bankruptcy risk of firms. In addition, indirect impacts include job losses, and potentially gender-differentiated impacts on employment continuity. Collectively, such impacts may affect competitiveness for long periods through reduced contracts, revenues and investments. With increasingly globalized manufacturing, the effects of disasters can rapidly cascade through global value chains.

Elements and Steps for Promoting Resilient Industries

The case studies and lessons learned in this report highlight that resilience is an essential element for enhancing the competitiveness of industries. Proactive industry resilience planning and actions incur start-up costs but generate competitiveness benefits that offset these costs, provided that these actions are supported by well-functioning economic and market structures that allow for innovation and healthy competition between firms. Industry resilience investments limit physical damage to key industry assets, reduce repair costs, business interruption and financial losses, and support the continued operation and productivity of firms. Importantly, they may also yield benefits under normal circumstances by improving water and energy efficiencies, increasing operational cost savings, industry asset values, reputation, and investments from risk-informed global companies looking for sustainable investment opportunities. Resilience investments also support job creation in related sectors, creditworthiness and access to finance for small firms, female leaders and workers in the sector, connectivity to global value chains, and other synergies of social, environmental, reputational and economic benefits (figure ES.1).

Policy makers and manufacturing industries face significant barriers in their efforts to integrate resilience measures at the core of competitiveness agendas (Section 3.2). These include:

- Limited understanding of how present and future impacts of climate change may affect industries;
- Weak economic incentives for individual and collective disaster mitigation and preparedness efforts due to conventional business practices and lack of information on how shocks transmit through complex production networks;
- Policy, regulatory and institutional challenges which constrain cross-sectoral initiatives, public-private partnerships and innovation;
- Lack of life-cycle and cost-benefit analyses to reveal operational cost savings and returns on resilience investments;
- Manufacturing firms' limited access to finance for disaster response and recovery (especially small and medium enterprises [SMEs]);
- Insufficient capacity of financial institutions to absorb shocks;
- Limited uptake of information and communication technology (ICT) and other new technologies;
- Vulnerable groups of the sector, including women entrepreneurs and female workers, who have limited access to financial resources, markets, training and employment during downturns following disasters.

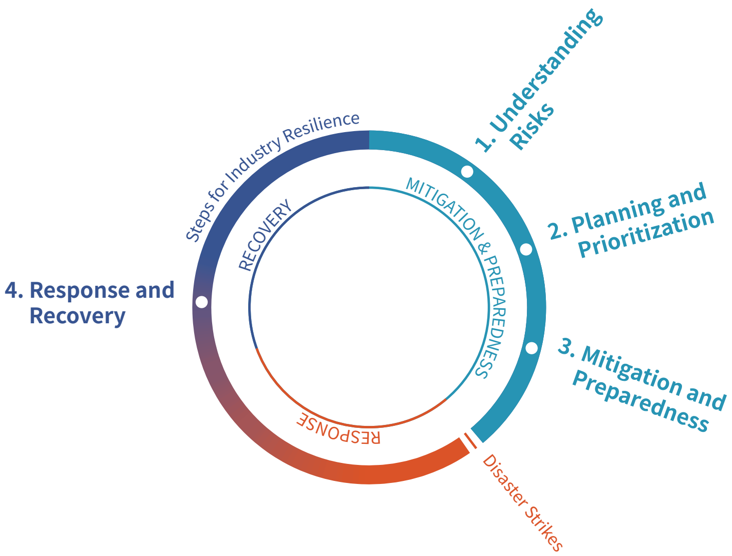
The Resilient Industries Framework: What Actions Can be Taken?

The Resilient Industries Framework suggests ways in which countries can counter these barriers, and mainstream disaster and climate change considerations into industrial development plans and investments (Section 3.3). The Framework is composed of three main levers—policies, industry infrastructure, and financial instruments—and recognizes the ways in which market structure governs the competitiveness of the manufacturing environment. In particular, the Framework highlights that the optimal arena of influence for policy makers is at national and industrial park levels.

The implementation of the Framework may be guided by the following four steps, while mainstreaming gender-sensitive approaches and leveraging new technologies (figure ES.2):

1. Understand the nature of climate change and disaster risks affecting industries;
2. Plan and prioritize national strategies for industry resilience;
3. Mitigation and preparedness investments to reduce impacts, using policy, infrastructure, and financial interventions;
4. Coordinated response and recovery to build-back-better for more competitive industries.

Figure ES.2 Process of Building Resilient Industries



1. Understanding Risks
Understanding the range of disaster and climate risks that can impact and threaten business continuity and competitiveness

2. Planning and Prioritization
Evidence-based planning and prioritization of investments and actions that could address key bottlenecks and strategically avoid or minimize negative impacts

3. Mitigation and Preparedness
Implementing resilience actions and investments in advance for disaster mitigation and preparedness

4. Response and Recovery
Taking good response decisions and actions during and after disaster events to minimize disruptions and losses, and as a result, maintain and enhance competitiveness

Source: Original compilation based on UNDRR 2015.
Note: This diagram is based on the disaster timeline. Note that the distribution of the steps around the cycle does not reflect their weight or importance, and each action will contribute to industry resilience.

Industry resilience requires cross-sectoral planning and actions implemented at multiple levels, considering different types of hazards, types of industry sectors, and the specific characteristics and interdependence of their industries and infrastructure systems. Such multilevel, and multi-sectoral approaches provide for an optimal understanding of both risks and possible mitigation, preparedness and response actions.

Table ES.2 Resilient Industries Framework

Industry resilience timeline		Type of solution	Recommended actions	Examples of measures	Key stakeholders
Actions before disasters	Understanding risks to industries	**Policy:** Data and information	Enhance national understanding of disaster risks to industries.	Collect, analyze and share climate change and disaster risk information specific to the needs of industries.	National and local governments, industry associations, firms, and industrial park operators, infrastructure operators and civil society.
			Develop frameworks and tools to assess risks to firms, value chains and industrial parks.	Climate change/disaster risk assessment tools and hazard maps to assess location- and industry-specific risks to firms, value chains, industrial associations, industrial parks, and regions.	National and local governments, industry associations, industrial park operators, and firms.
			Promote public-private partnerships to enhance sector-and location-specific risk assessments.	An interactive dialogue platform for stakeholders to deepen shared understanding of risks to industries, sectors and/or industrial parks, and facilitate planning and actions.	National and local governments, industry associations, firms, and industrial park operators, infrastructure operators and civil society.
	Planning and prioritization	**Policy:** Institutional arrangements	Identify national priorities for industry resilience.	National Disaster/Climate Risk Assessment documents with ranking of key risk areas and opportunities. Critical analysis for targeted resilience investments.	National and local governments, industry associations, firms, industrial park operators, infrastructure operators and civil society.
		Policy: National strategies for resilient industries	Develop a national resilient industries framework and coordination structures.	Risk-informed national infrastructure development plans, or land use plans. An institution such as the National Resilient Industries Council.	National and local governments, industry associations, firms, industrial park operators, infrastructure operators and civil society.
	Mitigation and preparedness	**Policy:** Economic incentives, supporting programs, and regulations	Promote business continuity planning and management.	National, regional and park level guidelines, manuals or training materials for BCPs and BCMs. Pre-arranged agreements with suppliers. Park-wide BCPs.	National and local governments, industry associations, industrial park developers and operators, and firms (including tenant firms).
			Help industries maintain global value chains.	Risk-informed agreements with trade partners (e.g., cross-border BCPs). These agreements can be either formal or informal.	National and local governments, industry and trade associations, firms, and trading partners.
			Promote resilient industrial park development.	Regulations and guidelines that guide risk-informed industrial park development. National regulations that define acceptable levels of risk for infrastructure development and operation, which also applies to those located in industrial parks. Minimum design standards to account for future risk.	National and local governments, industrial park developers and operators, and firms (including tenant firms).
		Infrastructure: Consideration of natural hazards in the design and (re)construction, operation, and maintenance of industrial park infrastructure and services	Minimize infrastructure disruption in industrial parks.	Structural designs to factor in hazards and climate change (e.g., flood-proofing and seismic-proofing of captive power plants). Increase reliability of infrastructure services through built-in redundancy and resource recovery systems (e.g., backup power and water supply systems, and nature-based solutions, etc.). Rigorous construction inspections, maintenance, operation and monitoring mechanisms. Emergency preparedness and response plans for industrial infrastructures, including response protocols, pre-arranged agreements for restoring infrastructure disruptions, contingency finance for repairs and plans for post-disaster damage assessments.	National/local governments, infrastructure operators, industrial park developers and operators, service providers, tenant firms, and civil society.
			Conduct alternative cost-benefit analyses.	Life-cycle cost analysis of infrastructure system design specifications; multi-criteria analysis.	National/local governments, industrial park operators, service providers, financial institutions, and firms.
		Finance: Financial support and incentives for capital investment in resilient infrastructure, BCP, and pre-arranged disaster risk finance	Analyze financial impacts and needs.	Understanding potential financial impacts of disasters on firms, markets and industry sectors. Financial needs assessment for small firms.	National/local governments, industrial associations, firms, and financial institutions.
			Support up-front resilient infrastructure investment.	Life-cycle cost analysis, reflecting the costs of disaster impacts for industrial parks and infrastructure. Fiscal incentives, resilient infrastructure PPP models, loans, and other financing mechanisms to cover capital and operating costs.	National/local governments, industrial park operators, service providers, and financial institutions including international financial institutions/ development partners.
			Provide financial support for contingency planning and advance disaster risk financing.	Financial measures to incentivize contingency and continuity planning by firms and industrial parks. Pre-arranged financial measures to allow rapid release of funds for responses needed to resume operations and minimize losses.	National/local governments, financial institutions, and firms.

Industry resilience timeline		Type of solution	Recommended actions	Examples of measures	Key stakeholders
Actions during and after disasters	Response and recovery	**Policy:** Institutional arrangements	Activate and refine coordination frameworks for response and recovery.	Activating emergency response plans based on predetermined criteria, establishing an emergency operations center if needed, and adjusting the coordination framework to support and streamline effective response processes.	National/local governments, industrial park operators, service providers, financial institutions, international donors, humanitarian aid, and firms.
		Policy: data and information	Conduct rapid assessment of industrial damage and losses.	Streamline data collection and analysis to inform investment and reconstruction needs. Advanced technologies (e.g., satellite mapping technology) may be used to fast-track assessments.	National/local governments, industrial park operators, service providers, financial institutions, international donors, and firms.
		Policy: Economic incentives, supporting programs, and regulations/de-regulation	Provide support to retain investors and boost market demand.	Increased tax incentives for investors including foreign investors, temporary removal of regulatory barriers to fast-track product certification and facility reconstruction, and investment aftercare programs.	National/local governments, industrial park operators, investment promotion agencies, and financial institutions.
			Support safety and employment continuity.	Security, health, and humanitarian assistance programs. Employee exchange programs with trading partners. These programs may also include working capital loans.	National/local governments, industrial park operators, international donors, trading partners, and firms.
		Infrastructure: Restoration of critical infrastructures and services	Promptly restore critical infrastructures and services.	Pre-arranged agreements and post-disaster emergency contracts to engage private sector stakeholders and mobilize resources to restore infrastructure services critical to business continuity.	National/local governments, industrial park operators, infrastructure providers (including logistics companies), development partners, industry associations and firms.
		Finance: Financial support for post-disaster recovery and reconstruction	Provide financial safety nets targeting SMEs.	Post-disaster emergency loans and credit guarantees for SMEs, group subsidies for firms linked through supply chain networks, and disaster risk financing instruments to cover damage and repair costs.	National/local governments, financial institutions, development partners, and firms.
			Finance investments in building back competitive industries.	Post-disaster financial support programs or existing sustainability initiatives to attract private investments toward resilient infrastructure development. Financing greenfield industrial park development in disaster-affected regions.	National/local governments, financial institutions, industrial park developers and operators, development partners, and firms.
Integrating gender and technology solutions		**Gender-sensitive resilience planning and actions**	Conduct gender-sensitive needs assessment.	Gap analysis to identify gender-differentiated impacts of disasters in manufacturing sector. Post-Disaster Needs Assessment (PDNA) that integrates data analysis to support gender-informed responses in the manufacturing sector.	National and local governments, industry associations (e.g., women entrepreneurs' associations), firms, development partners, and civil society (e.g., employees' associations).
			Finance women-owned SMEs through disaster risk financing.	Disaster risk financing instruments (e.g., insurance) directed to assist women entrepreneurs or businesses with high percentages of female employees. Trade finance that targets women-owned SMEs.	National and local governments, financial institutions, industry associations (e.g., women entrepreneurs' associations), firms, development partners, and civil society (e.g., employees' associations).
			Enhance market access for women-led SMEs during disaster response.	Provide access to contracting opportunities for women-owned SMEs pre- and post- disasters. Training programs to involve women entrepreneurs in post-disaster/emergency restoration work.	National and local governments, and industrial associations, infrastructure operators, and firms.
			Maintain training programs for women entrepreneurs and female employees during and post-disaster.	Skills and awareness-raising programs on digital payments, e-commerce, disaster risk management, BCP, evacuation plans, etc.	National and local governments, and industrial associations, industrial park operators, and firms.
		Improving resilience through technology	Encourage ICT uptake by firms.	Low-interest loans for the purchase of equipment, machinery, computer hardware and software. A program to encourage the use of e-commerce and digital payment/contractual arrangement systems to lower transaction costs during disasters.	National and local governments, industrial associations, industrial park operators, firms, and technology providers (ICT providers).
			Enhance supply chain resilience and visibility utilizing new technologies.	Big data or blockchain technologies tracing and visualizing end-to-end supply chains; big data analysis monitoring complex production networks and mitigating potential supply chain disruption risks.	National and local governments, industrial associations, firms, and technology providers.
			Minimize industrial infrastructure disruption with new technologies.	New technologies that diversify industrial infrastructure services. Digital technologies to embed redundancy into infrastructure system design and operation.	National and local governments, industrial park operators, infrastructure developers and operators, and technology providers.
			Use innovative technologies to fast-track asset damage assessments and insurance claims payouts.	New technologies to collect real-time data and provide early warning and asset monitoring systems, such as sensor data that allow technicians and engineering teams to track the structural integrity of infrastructure.	National and local governments, financial institutions including insurance companies, firms, and technology providers.

Source: Original compilation.

Understanding Risks to Industries

As disasters and climate change intensify globally, national governments should gain a deeper understanding of how these risks affect individual firms and industrial infrastructure, and propagate through complex supply chain networks (Section 4). Climate change and disaster risks should be specifically viewed from the local-level perspectives of firms, industrial parks and key infrastructure assets, taking into consideration industries' dependence on infrastructure services, global value chains, complex production networks and the market structures spanning countries and continents. At all these scales, different hazards, their probabilities of occurrence, and their impacts should be anticipated, and the scope of these risk assessments should be closely tied to stakeholder objectives. This requires policy makers to integrate sectoral needs in national climate change and disaster risk assessments; it also requires stronger institutional frameworks or platforms, enhanced stakeholder skills for data collection, hazard and need assessments; and impact assessment and risk-informed decision-making tools. Specific recommended actions for policy makers include:

- **Enhance national understanding of risks to industries** by integrating industry sector into national climate change and disaster risk assessments.
- **Develop frameworks and tools to assess risks to firms, value chains and industrial parks.**
- **Promote public-private partnerships to enhance sector-and location-specific risk assessments.**

Planning and Prioritization

As understanding of industry specific risks improves, policy makers should partner with industry stakeholders to plan and prioritize strategic investments and actions (Section 5). Effective coordination frameworks will be needed to implement these actions as they require multi-sectoral approaches, and will need to do so at multiple levels, including existing national and sub-national policy documents and planning forums, as well as at industrial parks and between firms. Governments, with support from other industry resilience stakeholders, can:

- **Identify key risks and opportunities, and establish national and regional priorities for industry resilience.**
- **Develop a national resilient industries framework and coordination structure.**

Mitigation and Preparedness

Mitigation and preparedness actions may be the most essential and cost-effective booster of industry resilience (Section 6). These actions span policy, infrastructure investments, and financial instruments, all of which offset impacts and speed post-disaster recovery and responses. These include policies and incentives, and risk-informed construction and strengthening of infrastructure, and can be tied to different hazard types; while non-structural measures entail hazard mapping, contractual arrangements, decision-making, and the ability to cooperate, and apply to multiple disaster contexts. Resilience principles will ideally be integrated into the development of industrial parks, taking a lifecycle management approach to infrastructure services.

Examples of infrastructure solutions include building in redundancy and diversification of resources and infrastructure services. This leads to infrastructure system designs that enhance resource recovery and circulation, provide back-up power and water supply, and integrate nature-based solutions. Infrastructure approaches also include non-structural measures such as strengthening construction inspection and maintenance, and establishing emergency preparedness and response plans. A suite of recommended actions for governments and other public sector entities is provided below:

- **Promote business continuity planning (BCP) and management** through regulations, incentives, guidelines, manuals and training. Business continuity plans (BCPs) can be promoted at the firm, inter-firm, and industrial park levels.
- **Help industries maintain global value chains** through risk-informed trade regimes or cross-border BCP initiatives.
- **Promote resilient industrial park development** through risk-informed guidelines and regulations.
- **Minimize infrastructure disruption in industrial parks** by integrating resilience principles into infrastructure system design and operation.
- **Conduct alternative cost-benefit analyses** to capture full life-cycle costs and benefits of resilience investments.
- **Analyze financial impacts and needs** by assessing how to cost disaster impacts, and considering a range of financial instruments.
- **Support up-front resilient infrastructure investment** using various financing schemes including fiscal incentives, Public-Private Partnership (PPP) models and other instruments.
- **Provide financial support for contingency planning and advance disaster risk financing**.

Response and Recovery

Recovering from disasters may require long periods of implementation which focus initially on rapid restoration of critical functions, while also catering to long-term mitigation and preparedness agendas to support build-back-better approaches based on the lessons of previous disasters (ses Section 7). When disasters strike, planned responses are activated according to predetermined criteria. Fast industry recovery is crucial to the recovery of national and local economies. Therefore, governments should quickly assess impacts on industry sectors, infrastructure, and firms, mitigate further disruptions, and restore critical operations. They should also engage industry practitioners in discussions on longer term recovery processes. Under certain circumstances, existing response plans may need to be adjusted, based on fast-tracked damage assessments, when ad-hoc responses are needed.

Governments in emerging economies may be required to rapidly establish policies and programs to help firms retain investors, boost reconstruction, and maintain market demand. Examples of such policies include tax incentives, relaxation of regulatory requirements for product certification and reconstruction activities, faster border and visa services, and post-disaster trade finance. Firms, in turn, must protect workers, assess and repair damage, and diversify supplier networks. Longer term recovery strategies need to include resilience more fully in overall economic development and market structuring. Thus, disaster response situations offer opportunities to examine existing market challenges for manufacturing firms, implement reforms, and strengthen resilience in order to remain competitive under disaster conditions. Recommended actions are:

- **Activate and refine coordination frameworks for response and recovery.**
- **Conduct rapid assessment of industrial damage and losses** through fast-tracked assessment procedures.
- **Provide support to retain investors and boost market demand** through increased tax incentives, temporary removal of regulatory barriers, and investment aftercare programs.
- **Support safety and employment continuity** leveraging humanitarian assistance programs and employee exchange programs.
- **Promptly restore critical infrastructure and services** through pre-arranged agreements and postdisaster emergency contracts to quickly mobilize additional resources required to restore critical infrastructure.
- **Provide financial safety nets targeting SMEs** through low-interest loans, emergency credit guarantee programs, or group subsidies which help restore affected value chains and regional economies.
- **Finance investments to build back competitive industries** through, for example, financing greenfield industrial park development or establishing financial support programs to attract private investment toward resilient infrastructure development in disaster affected regions.

Promoting Gender-Sensitive and Technological Approaches to Industry Resilience

Policy makers should place gender equality and the inclusion of vulnerable groups at the core of industry resilience planning and actions (Section 8). The Resilient Industries Framework should be used to institutionalize industry-wide gender-awareness and shift corporate culture; this shift is especially important in the resilience context, which often deals with disaster-affected groups which are disproportionately composed of women. Some of the key recommended actions are summarized below:

- **Conduct gender-sensitive needs assessments.**
- **Finance women-owned SMEs through disaster risk financing.**
- **Enhance market access for women-led SMEs during disaster response.**
- **Maintain training programs for women entrepreneurs and female employees during and post-disaster.**
- **Encourage ICT updates by firms.**
- **Enhance supply chain resilience and visibility utilizing new technologies.**
- **Enhance disaster preparedness of industrial infrastructure with new technologies.**
- **Use innovative technologies to fast-track asset damage assessments and insurance claims payouts.**

Key Lessons and Next Steps

Resilient industries are competitive industries that are prepared for various hazards and able to build back better after disasters. The key message of this report is that risk-informed planning and investment can yield both short-term and long-term competitiveness benefits that make sense for a wide range of stakeholders even before disasters strike. The case studies presented in this report highlight that resilient industries are competitive, and that historically, disasters have driven industries to adapt their industries over time to better manage the risks of disasters and climate change. If the right frameworks and market environments are in place, disasters provide opportunities for industries to reflect, learn, and build-back-better to prepare for disasters to come. With support, industries can act to mitigate long-term climate change risks through circular economy practices, sustainable infrastructure investments, nature-based solutions and renewable energy and recycling projects. These practices generate social and environmental benefits, attractive returns on investments, and operational cost-savings. Life-cycle cost-benefit analyses are useful in assessing these savings. To build-back-better is often to build-back-greener, and such approaches may come to define competitiveness.

Industry resilience policy and actions require a whole sector approach and strategic public-private partnerships. Collaboration between national and local governments, public agencies, public infrastructure operators, manufacturing firms along multiple supply chains, industry associations, industrial park operators, and financial institutions can strengthen the competitiveness benefits of industry resilience actions. This report recommends roles and actions for these key stakeholders:

- **National and local governments, public agencies, and public infrastructure operators** guide industry resilience initiatives and provide enabling environments through policies and financial support. They can work at inter-governmental levels, partner with industries to increase understanding of disaster risks, seed resilience principles into policies and plans, advance guidelines and establish institutional arrangements, and implement fiscal incentives and disaster risk financing to improve firms' contingency and continuity planning. They can also drive resilience investments for public infrastructures that service industries through risk-informed industrial park planning guidelines, design standards, tools and other related regulations. During response and recovery stages, public sector entities can also partner with industries to streamline recovery from shocks by supporting firms to better access global value chains boost market demand through fast-tracked damage assessments, streamline product certification and stimulus packages, while maintaining healthy and competitive market structures to build back better.
- **Manufacturing firms** can reduce losses and increase competitiveness by investing in low-cost disaster mitigation and preparedness measures. These measures include investing in risk-informed facility designs, purchasing insurance, developing contingency/emergency preparedness plans, rethinking their business strategies, and re-arranging business operations with suppliers and customers.
- **Industrial associations** can establish strategic partnerships to support governments and their member firms to identify sector-specific or cross-sectoral disruption risks, or develop training programs to facilitate BCP implementation and uptake of innovative technological applications across member firms.
- **Industrial park operators** can use park-wide hazard maps and BCPs to secure their parks against risk, prepare business cases for resilience investments, and explore collective access to finance for these investments.
- **Financial institutions** may provide instruments to incentivize firms, infrastructure providers and other stakeholders to increase preparedness. Some measures include integrating disaster resilience benefits into investment analytics, providing financial incentives such as preferential loans, insurance premiums or guarantees; or innovating disaster risk financing mechanisms using new technologies.
- **Development partners** can support client governments to mainstream resilience into industry development/private sector development projects through policy, institutional, technical, and financial support. Development partners can also pilot emerging finance and industry resilience approaches, plan key resilient infrastructure investments, and help firms improve understanding of the risks they face.

Industrial parks offer opportunities to create synergies to enhance resilience. Industrial park operators can improve resilience of park infrastructure, services, and management, and these improvements may collectively benefit tenant firms and broader communities. Such parks can also attract investments in further improvements of common infrastructures such as back-up power supply or flood protection, as in the Japan and Thailand cases. Common infrastructures with improved resilience collectively benefit park operators, tenant firms and communities that depend on them. Industrial park operators can launch site-specific risk assessment studies, develop risk-informed master plans and park-wide BCPs to guide the mobilization of collective resources from tenant firms when disasters require this, offer managers and employees skills training on BCPs and the use of ICT, and catalyze access to private finance in resilient infrastructure investments. These park-level actions can generate further synergies across different industry sectors and regions if implemented alongside national efforts to improve resilience.

The relationship between market structure and industry resilience, as well as the long-term impacts of climate change on industries, requires investigation. Collective measures to enhance industry resilience, such as park-wide BCPs and pre-arranged agreements, should also support innovation and stabilize market prices, and should guard against imperfect competition among firms, which may negatively affect consumer welfare. Better understanding of how market structure transmits shocks or encourages the private sector to develop resilience measures can provide policy makers key insights to design new and alternative market-based rules that can incentivize improved resilience of manufacturing firms and sectors.

Many of the actions and perspectives in this report are based on the emerging insight that addressing disaster and climate change risks lays the groundwork for attractive investment returns, and social and environmental co-benefits. In the long term, these benefits will moderate the risk environments in which firms operate, and form the basis of competitiveness strategies. The take-home message of this perspective is that industry resilience actions both increase competitiveness and ameliorate risk environments. Thus, industry resilience actions offer a means to do more than simply reacting to risk—they invite policy makers and industry practitioners to reflect existing challenges and future risks in a way that may author a safer and more stable and sustainable future.

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1

INTRODUCTION

Industrial activity creates jobs, catalyzes investments and brings technological advancement into a country. As disasters, including large-scale natural disasters, and, more recently, a viral pandemic, threaten industries and national economies, the imperative to retain business continuity and competitiveness in the midst of instability has thrust resilience into the spotlight. The emergence of industry resilience as a global discourse is timely; industry resilience is a nascent discipline, and frameworks for its application and operation remain limited even as threats intensify. What is known, however, is that industry resilience requires proactive study of risks from industry perspectives; and that risk-informed planning, mitigation, and preparedness investments reap multiple benefits. Even once disasters have struck, they offer the opportunity, with the right frameworks in place, to strengthen competitiveness through build-back-better initiatives, and to adapt to long-term climate change and disaster risks. Despite these insights and urgency of actions, however, investment in these adaptations remains low in both public and private sectors.

1.1 Objectives

This report aims to provide policy makers with key insights to enhance industry competitiveness in the face of disasters. There is growing awareness of the need to protect industries, and to strengthen their capacities to prepare for and mitigate the impacts of disasters, including pandemics. To accomplish this, resilience-aware actions to address climate change and intensifying disaster risks should be mainstreamed into industrial development policies and investments. However, the industry resilience field is young, with few resources, conceptual frameworks, or case studies. This report attempts to fill this gap by highlighting potential areas of intervention, and by drawing on existing knowledge and best practice. It shares lessons from the featured cases, and offers advice for policy makers and other stakeholders to help them plan and prioritize preparedness and disaster-response investments and actions.

The report focuses on approaches introduced in manufacturing sectors, which play critical roles in economic growth and social development in many developing and emerging economies. The report relies on the World Bank's definition of the manufacturing sector.[1] Both risks and remedies for the infrastructure sectors—electricity, gas, water supply, and transportation—are given attention, as these sectors support manufacturing industries. The report also acknowledges the need to increase the resilience of related industry sectors such as agriculture, service and tourism, which are also vulnerable to various types of hazards. However, currently, they are not included in the scope of this report. Solutions to enhance resilience of the tourism sector are given in the World Bank's *Resilient Tourism: Competitiveness in the Face of Disasters* (World Bank 2020a). Terminology used in this report is given in box 1.1 of Section 1 and in the Glossary.

The report highlights approaches strengthening resilience at national, local and industrial park levels. The ways in which governments can increase resilience of industrial parks are emphasized because, in emerging economies, industrial parks often serve as policy tools within overall economic growth strategies to boost industry competitiveness, attract foreign direct investment (FDI), and generate exports and employment. They serve as platforms for governments to enact location-specific industrial policies and offer tailored infrastructure and services to firms. Industrial parks allow for tenant firms' collective access

1 The World Bank's definition of the manufacturing sector follows the International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 3, Divisions 15–37. According to this definition, the manufacturing sector includes, but is not limited to, industrial activities related to manufacturing of automobiles, food products and beverages, textiles and apparel, electronic products, electrical machinery, wood products, refined petroleum products, and chemicals and chemical products.

to facilities and services that would be unaffordable to single companies. They are also a significant source of local employment and exports. They help create linkages with domestic firms and foreign manufacturers or buyers, and generate economic opportunities for women-owned SMEs and female workers (UNIDO, World Bank and GIZ 2017; Farole and Akinci 2011). However, industrial parks are often sited on high-risk areas such as reclaimed land, low-lying areas, or coastlines. These areas offer better access to markets, resources, and supplies, but may also expose tenant firms to a range of hazards. Therefore, industrial park-level solutions, when combined with national and local level efforts, offer opportunities to create powerful synergistic effects in enhancing industry resilience.

This report provides useful insights primarily for governments but also considers the importance of collaboration, and recognizes the roles various stakeholders play in promoting industry resilience, including:

- **National and local governments, public agencies, and public infrastructure operators**
- **Manufacturing firms**, including those operating in industrial parks and/or connected to them through domestic and global value chains
- **Industrial associations**
- **Industrial park developers and operators**
- **Financial institutions**, including commercial banks and insurance companies
- **Development partners**

1.2 Definition of Industry Resilience

Industry resilience refers to the ability of firms, industrial parks and manufacturing sectors to increase competitiveness by minimizing losses and damages, and by achieving continuity and growth in the face of more frequent and intensifying disasters. Industries can enhance resilience through increased and shared understanding of disaster and climate change risks specific to them, risk-informed planning, disaster mitigation and preparedness actions; they can also adopt evidence-based responses and recovery actions. These measures help industries minimize or avoid physical damage and financial losses. They also mitigate indirect productivity losses from disasters by minimizing impacts on workers and local communities, and disruption of supply chains and infrastructure. Disaster preparedness and response measures help businesses minimize shut down times, resume operations quickly (even if not to full capacity), and therefore, mitigate productivity and revenue losses. As a result, industries can maintain business continuity, stay connected to their markets, suppliers and customers in other countries, and avoid bankruptcy. During such a “building back” process, industries address critical challenges and improve capacities to manage disaster risks, thereby boosting their long-term economic viability and competitiveness.

1.3 Methodology

This report has used a case study approach, featuring 16 country-specific examples (figure 1.1). These case examples portray how and why industry resilience solutions were designed and implemented in these countries. This approach highlights what governments have done or are doing, and sheds light on the key elements of resilient industries, potential areas of action, and the roles of other stakeholders. The cases are included on the basis of:

- **Empirical evidence:**
  - Countries, regions or industrial parks are exposed to natural hazards, or have experienced disasters that affected manufacturing sectors and their value chains, as well as their related sectors.
  - Availability of data and information on the design and implementation of industry resilience solutions.
- **Coverage:** Cases cover a range of regions and countries with different socio-economic characteristics, as well as various types of manufacturing sectors, hazards, and solutions.
- **Applicability and scalability:** Solutions have potential applicability to developing countries, and are scalable.

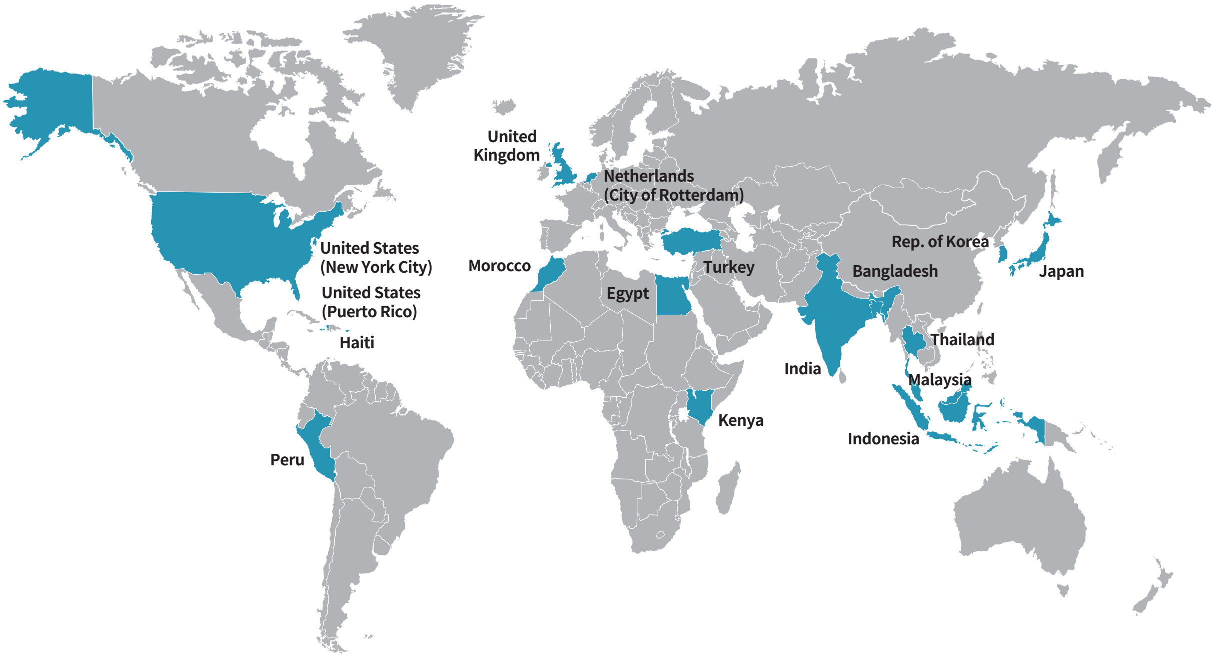
Types of sectors, hazards and solutions featured in this report are summarized in table 1.1. Industry resilience can be maximized when different types of solutions are combined and generate synergistic effects.

Table 1.1 Types of Sectors, Hazards, and Solutions

Types	Description
Types of sectors	Manufacturing sector, and other sectors critical to manufacturing sector competitiveness, including energy, water, transport, trade, industry, construction, and finance.
Types of natural hazards	Geological: earthquakes, volcanoes, and tsunamis. Hydrometeorological: floods, including flash floods; tropical cyclones (also known as typhoons and hurricanes); droughts, heatwaves, and coastal storm surges.
Types of solutions	**Policy** measures including national strategies, policies, regulations, and institutions that mainstream industry resilience in advance of disasters; **Infrastructure** solutions that minimize physical damage and disruption of services critical to industries; **Financial** mechanisms available before, during and after disasters to secure financial protection of firms and channel investment in resilient infrastructure; **Gender-aware** approaches addressing challenges women in manufacturing sectors face during and after disasters; and **Technology** measures that harness digital technologies to improve data quality, offer predictive analytics, enhance monitoring and communication, and provide real-time information.

It is important to note that long-term data that enable quantitative and qualitative analysis of resilience actions are lacking. While some analytical work has been conducted (some examples are provided), data availability and quality challenges remain. Therefore, examples of resilient industry solutions introduced in this report are not prescriptive, or definitive, but rather an attempt to flag the importance of this field, and the need to gather knowledge, case studies and examples of best practice.

Figure 1.1 Resilient Industry Case Examples Featured in this Report



Note: See appendix I for the overview of country-specific examples featured in the report.

1.4 Structure of this Report

Section 1 provides the definition of industrial resilience, and the report's objectives, structure, methods, and case studies.

Section 2 examines the impacts of disasters on the competitiveness of manufacturing sectors, through impacts on industrial parks, and firms including impacts on growth, jobs and the global value chains (GVCs).

Section 3 examines why industry resilience is important from a competitiveness perspective. It also looks at barriers to strengthening industry resilience, and highlights key elements of the Resilient Industries Framework, and recommended planning and actions.

Section 4 examines methods used to understand disaster risks to industries at various levels, including national, local, industrial park, and firm levels. It explores ways in which governments can identify areas with high risk exposure, and considers various tools being used to assess disaster risks to industries at multiple levels. It emphasizes the need to share understanding of such risks among a wide range of stakeholders, including industry practitioners.

Section 5 provides examples of national governments' strategies to plan and prioritize industry resilience investments, and the institutional frameworks that support and coordinate their implementation.

Section 6 covers a wide range of government actions (both structural and non-structural measures) implemented prior to disasters to support firms (either at the individual level or connected through supply chains) and industrial parks to avoid, mitigate and prepare for damages and losses. It also examines actions to secure the continuity of critical business functions and infrastructure/services. These actions are grouped in terms of the following three types of solutions: policy (6.1), infrastructure (6.2), and finance (6.3).

Section 7 provides an overview of government actions implemented during or immediately after disasters. These include strategic actions and investments to accelerate and promote sustainable and informed recovery of firms, industrial parks, key sectors, and people who depend on these sectors. Section 7.1 highlights the importance of disaster response coordination focusing on industry sector recovery. Section 7.2 examines evidence-based approaches to disaster response such as rapid assessment of industries' damages and losses. Sections 7.3 – 7.5, grouped in terms of policy (7.3), infrastructure (7.4), and finance (7.5) solutions, strategic decisions and targeted investments to support business continuity and rapid recovery of industries.

Section 8 introduces a range of gender-sensitive and technology-driven solutions that have been implemented or are being tested.

Section 9 summarizes findings and lessons learned from international practices, and discusses areas for further improvement.

Box 1.1 Key Terms

Business continuity: "ability to continue the delivery of previously agreed products and services within acceptable time frames at predefined capacity during disruption." [2]

Business continuity plan (BCP): documented information that guides an organization to recover from a disruption and resume delivery of products and services (such as manufactured items) consistent with its business continuity objectives. BCPs are often related to management systems and processes.[3]

Critical infrastructure: utilities and public works essential to economic security, productivity, and public health and safety. Critical infrastructures include water, sanitation, electricity, transportation and communication[4] [5] (Hallegatte, Rentschler, and Rozenberg 2019). In industrial parks, critical infrastructure includes internal roads, embankments and dikes, power and water supply networks, wastewater treatment plants, sewer networks, and so on.

Disaster impact: the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or disaster.[6] The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being.

Global value chain (GVC): the "series of stages required to produce a good or service that is sold to consumers, with each stage adding value and with at least two stages conducted in different countries" (World Bank 2020b). The manufacturing eco-system of a bicycle, which is assembled in Finland with parts from Italy, Japan, and Malaysia, and exported to the Arab Republic of Egypt, is an example of a GVC. By this definition, a country, sector, or firm participates in a GVC if it engages in at least one stage in a GVC (World Bank 2020b).

2 ISO 22301:2019 (en) Security and resilience — Business continuity management systems — Requirements (https://www.iso.org/obp/ui/#iso:std:iso:22301:ed-2:v1:en).

3 ISO 22301:2019(en) Security and resilience — Business continuity management systems — Requirements (https://www.iso.org/obp/ui/#iso:std:iso:22301:ed-2:v1:en).

4 https://www.cisa.gov/critical-infrastructure-sectors.

5 https://www.law.cornell.edu/definitions/uscode.php?width=840&height=800&iframe=true&def_id=42-USC-1066716883-1185975015&term_occur=999&term_src=.

6 https://www.undrr.org/terminology/disaster.

Geological or geophysical hazards: natural hazards which originate from internal earth processes. Examples are earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapse and debris or mud flows. Hydrometeorological factors are important contributors to some of these processes. For example, tsunamis are triggered by undersea earthquakes and other geological events, but are oceanic phenomena which manifest as coastal hazards.[7]

Hydrometeorological hazards: hazards of atmospheric, hydrological or oceanographic origin. Examples are tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; droughts; heatwaves and cold spells; and coastal storm surges. Hydrometeorological conditions may also be a factor in landslides, wildland fires, locust plagues, epidemics, and in the transport and dispersal of toxic substances and volcanic eruption material.

Industrial parks: also known as economic zones, industrial areas, industrial zones, industrial investment regions, special economic zones, industrial corridors, etc. Industrial parks are planned, developed and managed for the purposes of industrial and associated commercial, infrastructure, and service activities. Through the grouping of firms in a defined location, industrial parks offer important potential collaborative and efficiency gains.[8]

Industry competitiveness: the ability to compete in national or international markets, and can be measured at firm, sector or country level in terms of net profits, productivity, skills, innovations, reputation, net exports and investment flows, that affect economic performance (Deloitte 2016; Kechichian et al. 2016; UNIDO 2019; McKinsey & Company 2012).

Industry resilience: the ability of industry (including manufacturing sectors and firms) and industrial parks to increase competitiveness by minimizing losses and damages, and achieving continuity and growth in the face of ever more frequent and intensifying disasters.

Manufacturing: the making of goods or wares using manual labor, or with machinery, especially on a large scale.[9] The ***manufacturing sector*** includes industrial activities related to manufacturing of automobiles, food products and beverages, textiles and apparel, electronic products, electrical machinery, wood products, refined petroleum products, and chemicals, chemical products and many others. The scope of manufacturing sector activities varies by country.[10]

On-site infrastructure: infrastructure provided in an industrial park by the park's developer. Such infrastructure and services may vary, but generally include roads, and utilities such as captive power plants that provide a localized source of power to tenant firms, including renewables, common effluent treatment plants (CETP), sewage treatment plants (STP), water supply networks and telecommunication. They also include coastal defenses, common facilities such as warehousing, factory buildings, emergency response facilities such as fire stations and disaster/emergency shelters, and so on. On-site infrastructure also includes social infrastructure, childcare facilities and services, medical facilities, schools, and safety and security systems.

Off-site infrastructure: infrastructure and utilities provided outside an industrial park by the government, including public utilities, transport, and other infrastructure connections to an industrial park. Off-site industrial infrastructure also often provides services to surrounding cities and communities. Ports are often located close to industrial parks, and are also considered part of off-site infrastructure servicing industries.

Supply chain: a network of connected and interdependent firms and business organizations mutually and cooperatively working together to control, manage and improve the flow of products, services, finances, and/or information from suppliers to end customers/users (Sheffi 2005; Christopher 2011; Mentzer et al. 2001). The supply chain includes all production activities, functions and facilities of upstream (firms that are most distant from the end users) and downstream suppliers (firms that are close to customers and end users, including multinational manufacturing firms and global buyers/retailers).

7 https://www.undrr.org/terminology/hazard.

8 For more information, see UNIDO, World Bank and GIZ. 2017. *An international framework for eco-industrial parks.*

9 World Bank. 2016. "Sector Taxonomy and definitions." http://pubdocs.worldbank.org/en/538321490128452070/Sector-Taxonomy-and-definitions.pdf.

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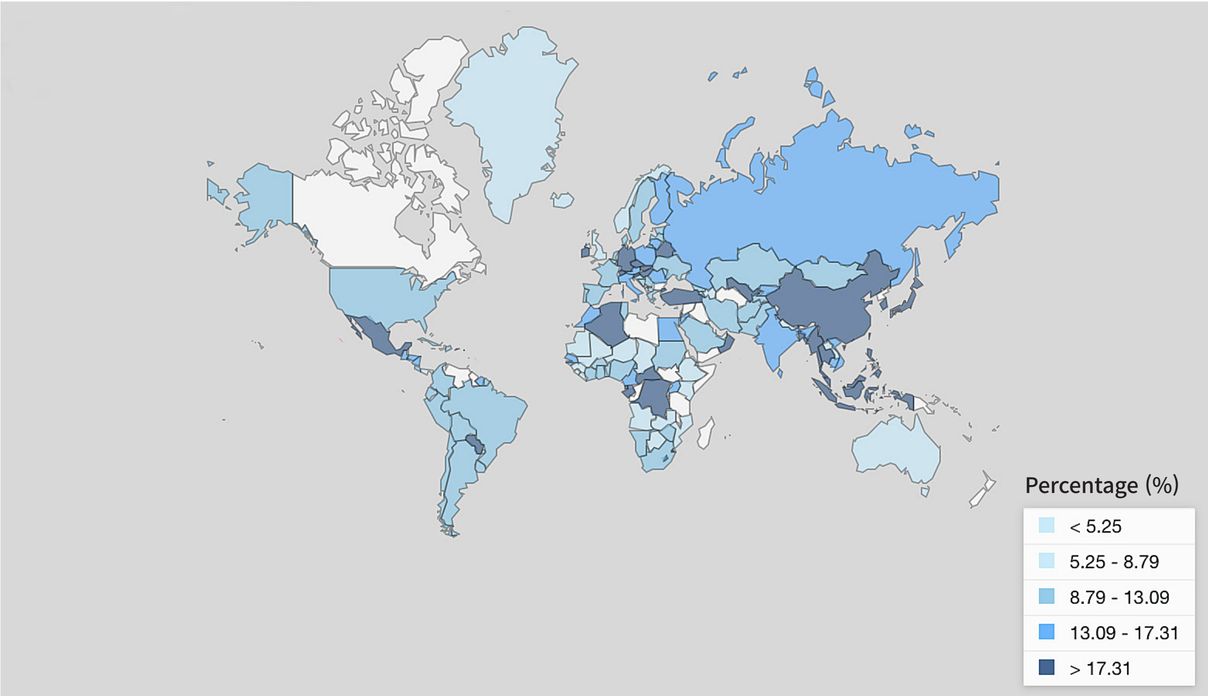
2

Industry Competitiveness and Disasters

Industry[11] is the engine of economic and social development. Historically, industrial growth, particularly in the manufacturing sector, has driven growth in GDP (Cruz and Nayyar 2017; Szirmai and Verspagen 2015). While the contribution made by manufacturing industries as a share (percentage) of nominal gross domestic product (GDP) has declined over the past two decades to 15.6 percent as of 2017, manufacturing remains an important contributor to GDP (figure 2.1). In some countries, including Cambodia, China, Lao People's Democratic Republic, Myanmar, and Vietnam, manufacturing growth rates were high over particular periods of sustained economic growth (Haraguchi, Cheng, and Smeets 2016). In these countries, as of 2018, value-added manufacturing accounted for 20.2 percent on average of GDP (World Bank Open data[12]) (table 2.1).

Figure 2.1 Manufacturing Sector Contribution to GDP



Source: Adapted from World Bank 2019a, World Bank 2018, World Bank 2017, and Cabinet Office 2020.
Note: World Bank (2017) data were used for Afghanistan, Greenland, Iran, Tajikistan, and the United States; World Bank (2018) data were used for Angola, Cameroon, Guinea, Mauritania, Montenegro, Morocco, Mozambique, Myanmar, Oman, Peru, Serbia, Tunisia, and Zambia; and World Bank (2019) data were used for all other countries except Japan. Data from the Cabinet Office (2020) were used for Japan.

Manufacturing industries are also a major contributor to export performance across countries, though variation among countries exists.[13] As of 2019, they accounted for 67 percent of global merchandise exports including textile and garment, chemicals, electronic

11 We use the terms "firms" and "industries" with the following understanding. An industry sector consists of many firms selling similar products (automobile, beverages, machinery, textiles, apparel, etc.). In this sense, an industry sector is not a discrete entity whereas a firm is. Many industry sectors make up a country's economy; in this report, we focus on the manufacturing sector.

12 World Bank Open Data. https://data.worldbank.org/

13 For example, Pakistan has not been part of this trend. The global share of exports from India, Malaysia, and Thailand increased significantly from 1974 to 2005, whereas Pakistan's share has remained relatively stable for the period, or even declined between 1990 and 2008 (Sanchez-Triana et al. 2014).

machinery and transport equipment, etc.[14] While high-income countries perform well in the manufacturing sector (71.1 percent of exports), low- and middle-income, middle-income, and upper-middle-income countries are comparable, accounting for 64.5, 64.7 and 67.2 percent, respectively. Export performance of manufacturing industries is particularly high in some of these countries, such as Bangladesh (96 percent), China (94 percent), the Dominican Republic (69 percent), India (70 percent), Thailand (77 percent), and Turkey (81 percent).

Table 2.1 Industry Sector Contribution to GDP (Percentage of GDP)

	Year	Agriculture	Services [a)]	Industry (including construction sector)	Manufacturing industry (excluding construction sector)
Low-income	2017	25.8	39.3	**24.9**	**8** [b)]
Lower-middle-income	2018	14.9	49	**28.9**	**15**
Low-& middle-income	2018	7.9	53.7	**32.2**	**19**
Middle-income	2018	7.8	53.9	**32.3**	**20**
Upper-middle-income	2018	5.7	55.3	**33.3**	**21**
High-income	2017	1.3	69.8	**22.8**	**14**

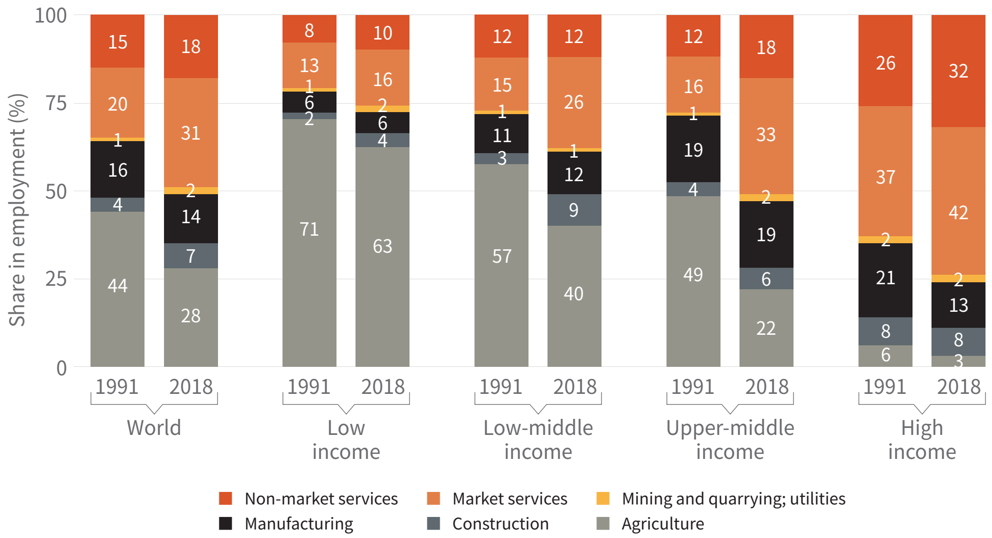
Source: World Bank 2018.
Note: a) Services, as with manufacturing, are becoming an active contributor to industrial policy in many developing countries. The services sector experienced the fastest growth rate among all sectors between 1990 and 2012, and contributed to economic growth and job creation (Ghani and O'Connell 2014). However, this report does not address resilience in this sector.
b) 2016 data.

In addition, manufacturing industries play key roles in job creation, and have potential to scale up skills and technology transfer and innovation, especially for economically and socially vulnerable populations in emerging economies (Hallward-Driemeier and Nayyar 2017). The share of the manufacturing in total employment is decreasing at the global level but this is a trend that is driven by high-income countries; as of 2017, 82.4 percent of global manufacturing employment (389 million out of 472 million jobs) was centered in emerging economies (figure 2.2) (ILO 2019; UNIDO 2019). In developing and emerging economies between 1991 and 2016, employment in manufacturing sectors increased by 29 percent (from 215 million to 279 million jobs) (UNIDO 2017). Manufacturing has also improved women's economic prospects significantly, although the representation of women in the workforce varies by country and subsector. While the representation of women in the manufacturing sector has declined since 1995 due to technological advances, it still accounts for 12.4 percent of female employment in upper-middle-income countries in which manufacturing plays a key role in economic growth (ILO 2016). The global proportion of female workers has been especially high in the textile, apparel and leather sectors, the pharmaceutical sector, and the electronics assembly sector. From 2007–2011, women accounted for 70, 50 and 30 percent of those employed in these sectors,[15] respectively (Hallward-Driemeier and Nayyar 2017).

14 Data are available from the World Bank on manufacturers' exports (https://data.worldbank.org/indicator/TX.VAL.MANF.ZS.UN). World Bank's data on manufacturer's exports are estimated based on the Standard International Trade Classification (SITC) revision 3 available from the United Nations Trade Statistics (https://unstats.un.org/unsd/tradekb/Knowledgebase/50262/Search-SITC-code-description).

15 Gender composition of the workforce varies across manufacturing subsectors. The global share of female workers in other manufacturing sectors during 2007–2011 is approximately as follows: food, beverage, and tobacco sectors (28 percent), electrical machinery and equipment (18 percent), chemical sector (15 percent), rubber and plastics manufacturing sector (10 percent), transport equipment including automobiles (9 percent), and coal and refined petroleum products (2 percent).

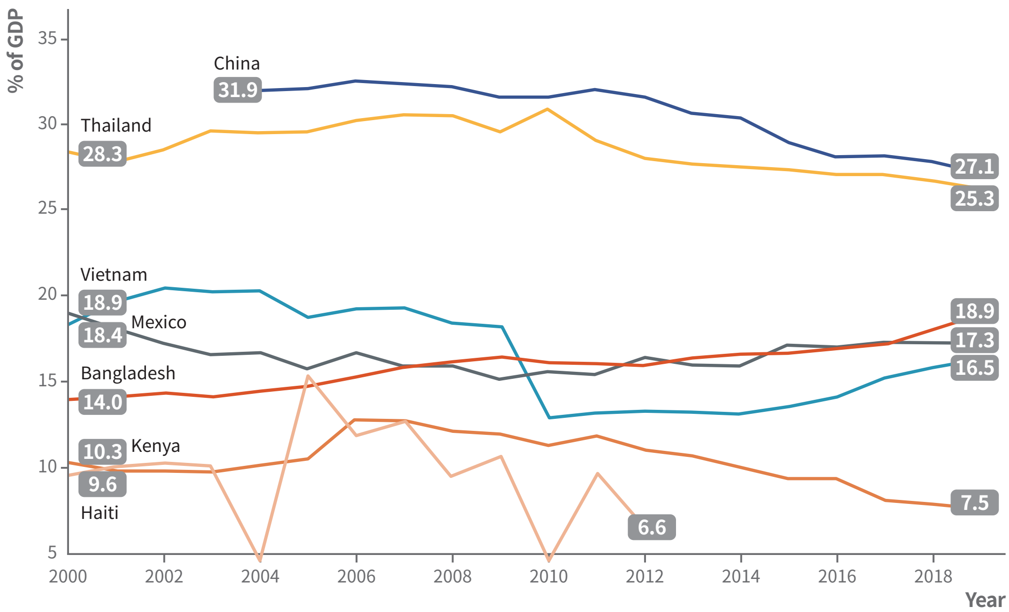
Figure 2.2 Distribution of Employment by Global Aggregate Sectors, and by Country Income Group, 1991 and 2018



Source: ILO 2019.

However, sustaining high growth rates in the manufacturing sector is challenging. Globally, while some countries' manufacturing sectors have grown fast (e.g., Bangladesh), other countries' manufacturing growth rates and industrial production have either declined or stagnated over the past two decades (figure 2.3). Overall, industrial production, world trade volumes, and manufacturing purchasing managers' indexes (PMIs) have declined since 2017 and especially after 2019 (IMF 2019). While there are some exceptions, emerging economies that have historically depended on manufacturing for growth were also experiencing slow growth rates before the pandemic.

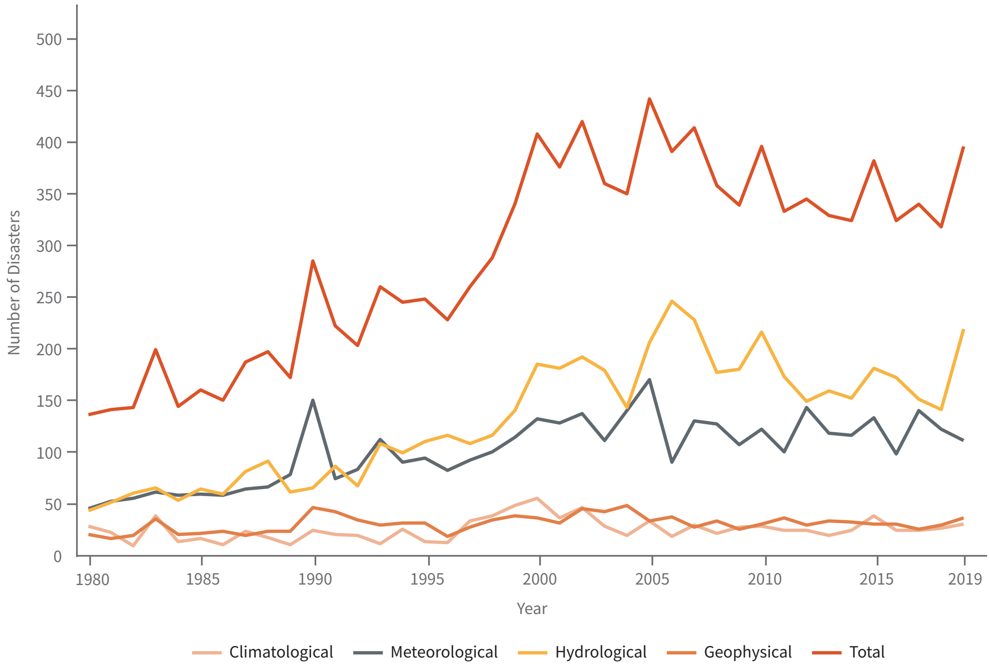
Figure 2.3 Growth of Value-Added Manufacturing in Developing Countries



Source: World Bank 2019a.

The growing frequency and intensity of disasters threatens the manufacturing sector's ability to drive sustainable growth. The number of disasters, many of which were associated with hydrometeorological hazards such as floods and storms, increased from 136 in 1980 to 396 in 2019 (figure 2.4). Globally, the number of disasters including earthquakes and extreme weather events, which caused catastrophic losses between 2013 and 2018 reached 4,328; while losses from tropical cyclones, extreme storms and floods cost approximately US$ 150 billion in 2019 alone (Munich Re 2020).

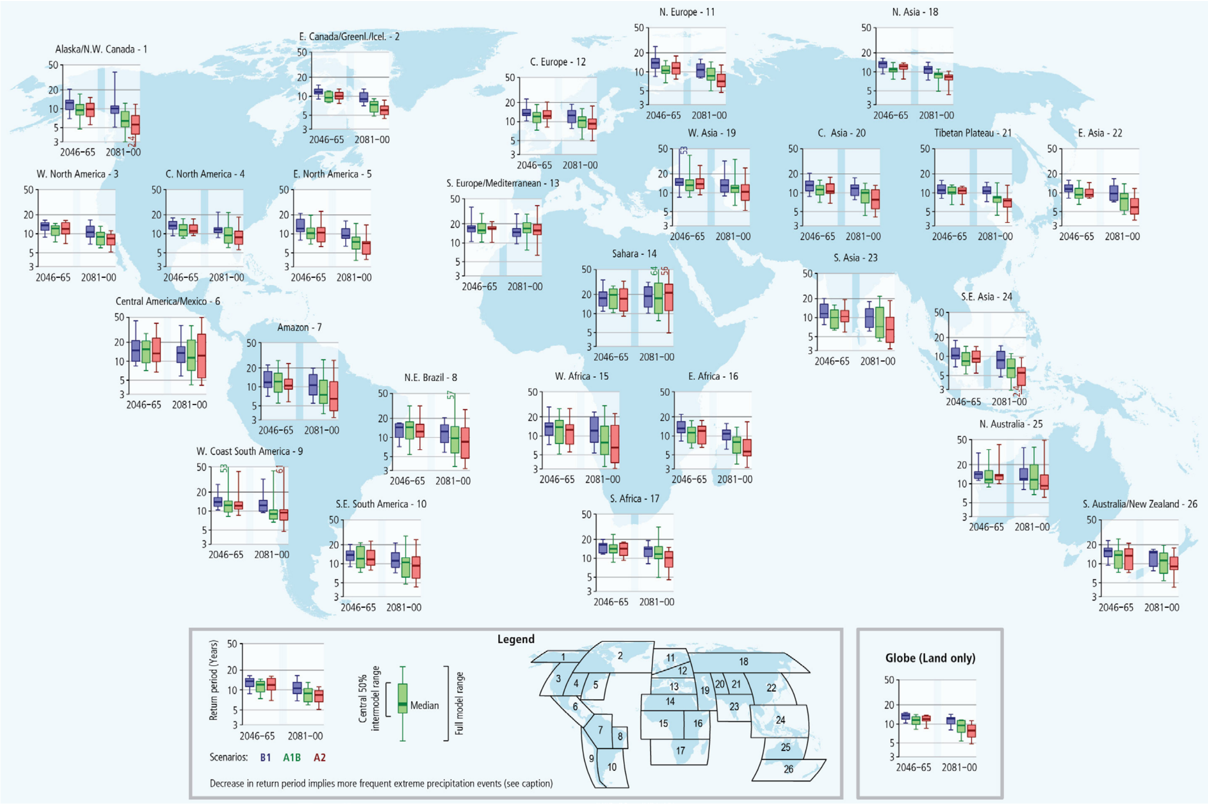
Figure 2.4 Number of Disasters, 1980–2019



Source: EM-DAT, CRED / UCLouvain, Brussels, Belgium – www.emdat.be (D. Guha-Sapir).

The continued emission of greenhouse gases is causing climate change; this, in turn, has led to changes (and often increases) in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and resulted in unprecedented disasters and losses (IPCC 2012; IPCC 2014). The IPCC has projected that, in the 21st century, there will be more frequent extreme precipitation events (approximately every 10 years by 2046–2065) and extreme temperature events (approximately every 2.5 years by 2046–2065), with geographical variations (figure 2.5). Such changes may affect the Southeast and South Asia regions, where many GVCs are concentrated, and manufacturing sectors play key roles in regional economies. In these regions, extreme precipitation is expected as frequently as every 5–7 years.

Figure 2.5 Projected Precipitation Frequencies, 2046–2065



Source: IPCC 2012.

Intensifying and more frequent natural hazards can negatively impact the growth of national economies, industries, firms, and GVCs, as well as employment continuity and the well-being of people. In Haiti, GDP shrank by 5.1 percent following the 7.3 magnitude earthquake in 2010 (World Bank 2010a). In Thailand, floods in 2011 led to estimated economic losses of approximately US$ 46.5 billion due to lost production and turnover, increased production costs, job and salary losses (World Bank 2011; 2012). In the Balkan region, flash floods in 2014 caused a loss of US$ 86.3 million (Republic of Serbia et al. 2014). Economic growth was estimated to have declined by 0.5 percent in 2014, instead of growing by a forecasted 0.5 percent (Republic of Serbia et al. 2014). In 2015, floods in south India led to estimated losses of US$ 2.2 billion, stemming mostly from lost production capacity in the automobile manufacturing sector, a key driver of India's economy (Swiss Re 2016).

The impact of disasters varies according to the kind of disaster and the sector it affects, as well as institutional capacity to identify risks, withstand shocks, and mitigate and avoid further impacts. For example, industrial parks and their tenant firms may experience longer operational disruptions during floods than during earthquakes because the duration and effects of flooding often last longer than those of earthquakes. Flood warnings are issued in advance, and therefore, government decision-makers, firms and industrial park operators may have time to prepare. The impacts of earthquakes may be more intense and of shorter duration, and firms and industrial park operators may have limited time to monitor, respond and reduce impacts. Even with advanced earthquake early warning systems, such as those in Japan, decision-makers have limited time to detect geological hazards, issue warnings and evacuate people, as earthquakes can occur in seconds. Therefore, without disaster mitigation and preparedness actions in advance of earthquakes, including early warning systems and disaster-resilient infrastructures, firms, industrial parks and key industry sectors may suffer significant damage and losses.

Manufacturing industries and firms bear a large proportion of economic losses caused by disasters (table 2.2). Losses to Haiti's industrial sector reached approximately US$ 342.3 million (or 4 percent of all damages). The earthquake created significant business risk for Haiti's apparel sector which, at the time, accounted for 10 percent of the country's GDP and nearly 90 percent of its exports. These losses were caused, in part, by significant production loss within the apparel sector immediately following the quake. Similarly, Thailand's manufacturing sector, which accounted for 38.5 percent of the country's annual GDP at the time, bore roughly 70 percent of flood damages and losses (approximately US$ 32.5 billion), with estimated export losses of US$ 7.9 billion in 2011 alone (World Bank 2012). Much of this loss was borne by the automotive, electronics and machinery manufacturing sectors through damage to industrial park infrastructure, the assembly plants of tenant companies and their suppliers, and through supply chain disruptions. The Serbian manufacturing sector lost US$ 160 million through physical damage and productivity losses (Republic of Serbia et al. 2014).

Disasters, especially large-scale natural disasters, can affect industry competitiveness. The physical and non-physical impacts of disasters disrupt flows of people, goods, infrastructure services, capital and information. In the industry resilience context, direct impacts of disasters include physical damages to firm's assets and to on-site and off-site infrastructure, which incurs repair and reconstruction costs.[16] Indirect impacts include supply chain disruption due to the impacts on suppliers and availability of input materials. They also include disruptions of infrastructure and services such as power, water, transportation networks, and telecommunication systems that service firms, industrial parks, and people living in surrounding areas and employed by affected firms and industrial parks. Indirect impacts often relate to the loss of production capacity and market demand, reputational risk, and loss of investors, which consequently reduces sales and export performance, and increases the bankruptcy risk of firms. In addition, indirect impacts include job losses, and potentially gender-differentiated impacts on employment continuity. Collectively, such impacts may affect competitiveness for long periods through reduced contracts, revenues and investments. With increasingly globalized manufacturing, the effects of disasters can rapidly cascade through GVCs. An overview of how disasters affect industries is given in figure 2.6.

16 Direct impacts are defined as production decreases due to destroyed or damaged facilities, equipment and inventories, while indirect impacts are defined as effects on industries supplying goods and services to companies directly impacted by the disruption (MacKenzie, Santos, and Barker 2012).

Table 2.2 Disaster-Related Industrial Asset Damage and Production Losses in Manufacturing

Case	Disaster event	Estimated asset damage and production losses (US$ million)	Affected manufacturing sectors [a]
Haiti	Earthquake (2010) (M 7.3)	**342.3** [b]	Apparel/garment manufacturing, food processing
India	The South Indian Floods (2015)	**2,200** [c]	Motor vehicles, chemicals, food products, metals, machinery, refined petroleum products
Japan	Earthquake (GEJE) and tsunami (2011) (M 9.0)	**153,600** [d]	Various (automotive and electronic, machinery, food processing)
Kenya	Droughts (2008–2011)	**89.4** [e]	Food processing, agribusiness
Mozambique	Cyclone Idai (2019)	**31.2** [f]	Specific sectors affected are unknown
Serbia	Floods (2014)	**160** [g]	Specific sectors affected are unknown
Thailand	Floods (2011)	**32,500** [h]	Automotive, electronics, machinery
US	New York Metropolitan Area-Hurricane and storm surges (2012)	**6,000** [i] (Direct losses due to business impact in New York State)	Food and beverage, metal, apparel and printing sectors
	Puerto Rico-Hurricanes Maria and Irma (2017)	**94,500** [j] (the figure is not sector-specific)	Pharmaceutical, biotech industry, medical instruments

Note:

a) Refers to major industrial sectors in the country/region.

b) The figure concerns damage and losses in industry and trade sectors in Haiti (World Bank 2010).

c) Data from Swiss Re 2016.

d) The economic damages of the GEJE are estimated as approximately $153.6 billion (¥16.9 trillion) (Cabinet Office 2016) Converted to US dollars ($) at the 2018 annual average exchange rate of $1 = ¥110, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

e) In Kenya, floods also affected industry sectors and the national economy in 1998, 2006, 2016 and 2018. This figure only reflects the impact of droughts on the food processing sector (Republic of Kenya 2012).

f) The greatest losses were registered in the Province of Sofala, one of the provincial governments with a high concentration of manufacturing firms. Losses were estimated based on a survey of 28 firms most affected by the cyclone in the Province of Sofala. The estimate excludes losses in the agribusiness sector, which were approximately US$ 28.5 million (World Bank 2019).

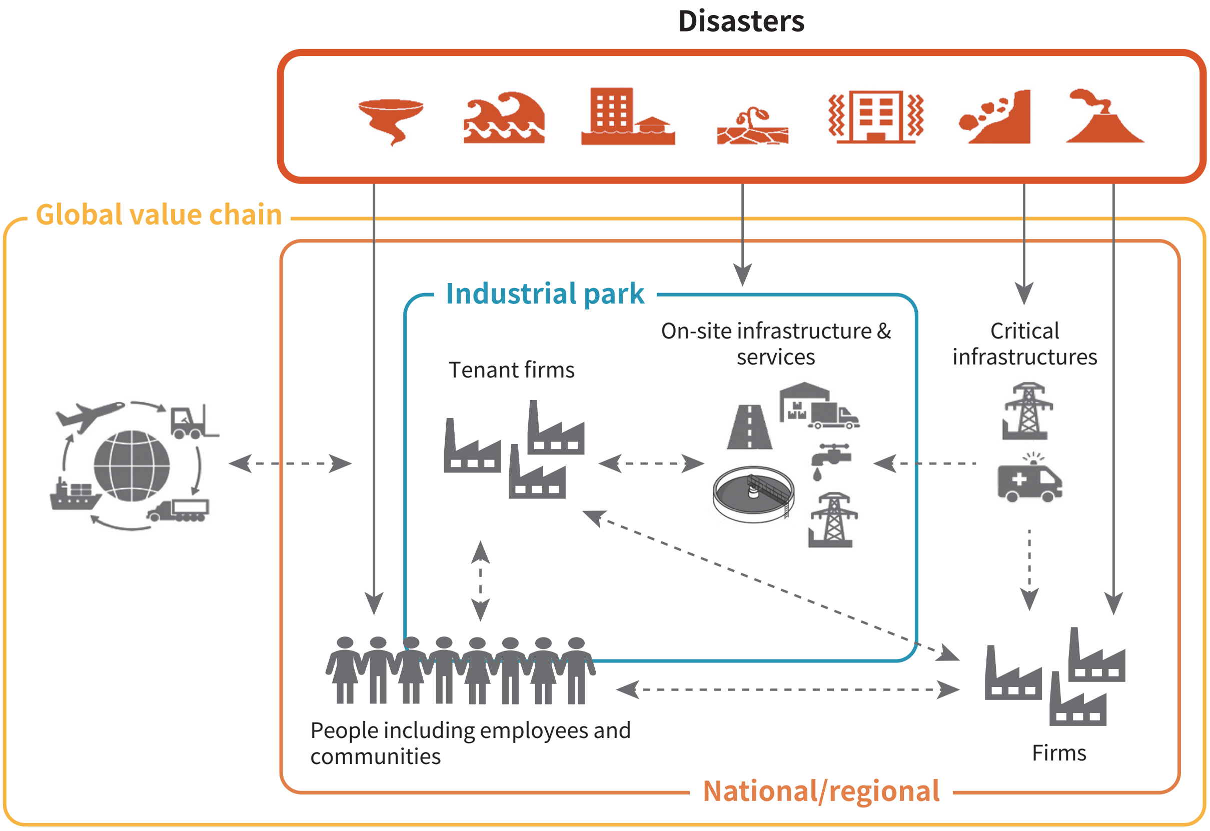
g) The manufacturing sector is a key tradable sector in Serbia; however, this estimation does not include damages and losses in the trade sector. Asset damage was estimated as the cost of repairing and/or rebuilding assets to pre-flood standards. Losses were characterized as declines in value of goods and services produced, reduced production capacity and higher-than-normal production costs (Republic of Serbia et al. 2014).

h) *Source:* World Bank 2012.

i) *Source:* Cambridge Center for Risk Studies and XL Catlin 2018.

j) Data from Smith 2020.

Figure 2.6 Overview of How Disasters Affect Firms, Infrastructure Systems, Industrial Parks, Global Value Chains, and People



Source: Based on Hallegatte, Rentschler, and Rozenberg 2019.
Note: The solid arrows represent direct impacts, including physical damage to firms' assets, as well as infrastructures critical to the operation of industries and industrial parks, such as power and water supply networks, wastewater treatment plants, road and telecommunications networks, levees and dikes. The dotted arrows represent indirect impacts, including those from disrupted infrastructure services (e.g., power outages); supply chain/GVC disruptions due to delays and shortages of input materials; challenges in securing financing for reconstruction and recovery; changes in market prices, market demands, and quantity and quality of unsubstitutable input materials; reputational risks arising from limited production capacity to deliver qualified products on time; and increasing manufacturing firm bankruptcies and job losses.

During disasters, businesses may suffer losses through structural damage to their physical assets including factories, equipment and machinery, and the costs of repair and reconstruction, reduced productivity and discontinued operation. For instance, in Bangladesh, Cyclone Sidr (2007) damaged approximately 1,800 manufacturing establishments (7 percent of total operation at that time). The cyclone damaged premises, inventory and/or equipment, halting production for several weeks (World Bank 2008). Damages amounted to approximately US$ 3.8 million. In India, the South Indian floods (2015) inundated the Toshiba JSW factory, which led to losses of over US$ 64.5 million (¥ 7 billion) (Toshiba 2016). The flood waters at Toshiba JSW's Chennai factory were 1.6 meters deep outside the facility and 1.3 meters deep on the factory floor, which affected most of the factory's production equipment and machinery, including turbines and generators (Toshiba 2016). In New York City, Hurricane Sandy (2012) flooded approximately 720 industrial facilities and sites, damaging parking spaces and inventories (NYC Planning 2015).

Infrastructure and utility service disruption is a major source of productivity loss for firms. Infrastructure provides power, water, logistics and communication services to industries, and frequent and/or prolonged disruptions to infrastructure can prevent firms from operating at full capacity. This "production capacity loss" (Kajitani and Tatano 2014) may be amplified by the poor-quality infrastructure often found in low-and middle-income economies, and this may in turn have significant knock-on effects on the overall supply chains of interrelated sectors. Based on the analysis of the World Bank's Enterprise Survey data available for 137 countries, it was found that disrupted, unreliable infrastructure services can cost firms over US$ 300 billion annually when measured in terms of reduced utilization rates,[17] sales losses, costs of alternative electricity supply, and delayed supplies and deliverables (Hallegatte, Rentschler, and Rozenberg 2019).

Industrial parks, where infrastructures and services are provided to firms operating inside the parks, may also experience physical damage and disruption. The location and agglomeration of firms in industrial parks may make them vulnerable to natural hazards, and damage to infrastructure and utilities can cause productivity losses, as highlighted in box 2.1. Thus, the competitiveness of industrial parks depends on attracting investors who are concerned about safety and business continuity, and the ability of parks to attract such investors may depend on whether they are developed, operated and maintained according to disaster risk management principles.

Box 2.1 Examples of Damage and Disruption to Critical Infrastructure and Industrial Parks

Recent events offer evidence of severe disaster impacts on transport, power, water and telecommunication infrastructures. Physical damage to these infrastructures affects firm-level productivity, trade, logistics, and working conditions.

- **Puerto Rico, Hurricanes Maria and Irma (2017)**
  Power cuts caused by hurricanes had severe consequences due to the reliance of Puerto Rico's pharmaceutical industries on electricity. These industries accounted for 30 percent of GDP and 75 percent of exports (US Bureau of Labor Statistics 2020), and relied on electricity to maintain microbial cultures needed for drug development.[18] The sector's requirement for stringent laboratory conditions to prevent contamination, for refrigeration, and uninterrupted electricity to produce drugs and avoid inventory shortages[19] made it additionally vulnerable. In the aftermath of Hurricane Maria, many pharmaceutical manufacturers relied on industrial-scale off-grid generators. However, their efforts were hampered by an unstable electrical grid, and fuel shortages, which led to disruptions and low productivity (US DHS 2018). Diesel for the generators was difficult to obtain because of damage to roads and the port, and the use of roads and the port's cargo facilities for relief and recovery efforts (Thomas and Kaplan 2017).

- **Tanzania: Heavy rains and floods (2016)**
  Tanzanian firms lost approximately US$ 101 million, or 0.3 percent of GDP, due to power outages caused mainly by heavy rains and floods (figure 2.7) (Hallegatte, Rentschler, and Rozenberg 2019).

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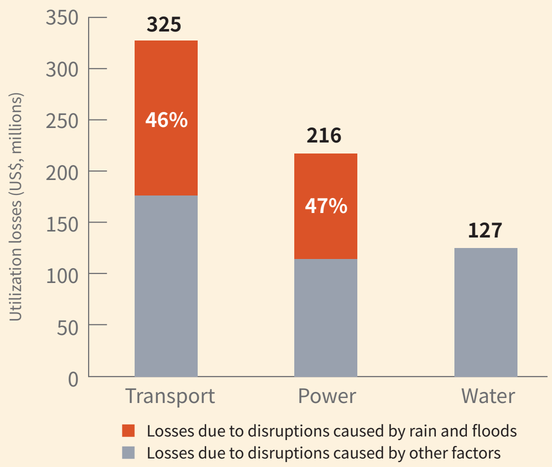
17 For example, utilization can drop in the power or water supply sectors due to physical damage to power plants, distribution lines, and other assets in the network.

18 Ibid.

19 Ibid.

Figure 2.7 Infrastructure Disruptions to Tanzanian Firms



Source: Hallegatte, Rentschler, and Rozenberg 2019.

- **India: South Indian floods (2015)**
  The floods disrupted transportation infrastructure. Renault-Nissan reported production losses of 10,000 cars when flooded roads made it difficult for workers to commute (Rajan and Sridharan 2016). Power generation and transmission infrastructure disruption also significantly reduced firms' productivity.

- **Thailand: Floods (2011)**
  The floods inundated seven industrial parks in the Panthumthani and Ayuttaya provinces, damaging on-site infrastructure, including power plants and electricity distribution lines. More than 800 firms were affected, and approximately 200 factories closed (Savitz 2011; Haraguchi and Lall 2015). Eight months after the floods, 146 firms had not resumed normal operations. In particular, firms were affected by the breaching of flood barriers and prolonged disruption of electricity.

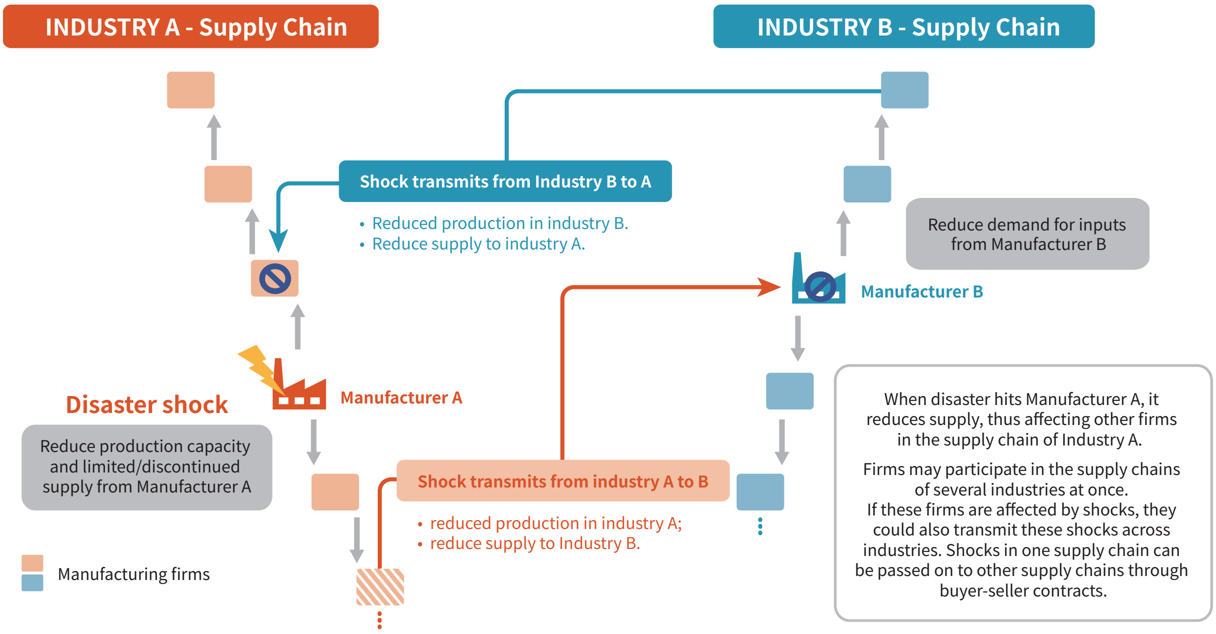
Disasters can also lead to extensive supply chain disruption (Inoue and Todo 2019; Todo, Nakajima, and Matous 2015; Kajitani and Tatano 2014). Manufacturers tend to restrict their supplier bases in favor of building efficiencies and high-quality relationships with a smaller number of suppliers. This may lead to increased dependency on a smaller number of component manufacturers, while reducing the visibility of upstream suppliers, and increasing the vulnerability of supply chains (Sheffi 2005). Supply chain disruptions occur when raw materials, parts and inputs are delayed or discontinued following disasters. In Japan, these shocks affected many industries and regions simultaneously, making it difficult to replace intermediate products (Inoue and Todo 2019).

Disruptions may spread from locally connected supply chains to production networks.[20] The supply chain of manufacturing firms is shaped by their contractual exchange of goods and services between demanding (buyers) and supplying firms (sellers). The aggregation of these exchanges and supply chains forms a production network. In production networks, the transmission of shocks travels between upstream and downstream firms and, also, between enterprises in different supply chains that are connected to each other through market

20 Production networks track and trace buyer-seller contractual relationships. For instance, a producer of shirts needs a variety of inputs and materials such as cotton, polyester-cotton; machines for separating fibers, carding, weaving, cutting, sewing; chemicals for bleaching and dyeing; machines for screen-printing; inks and colors. In turn, inputs and materials have their own requirements for inputs and materials. The supply and demand interlinkages between inputs and materials form a production network. Disasters can generate local shocks to firms which spread across supply chains to production networks. The propagation of shocks can be substantial in an interconnected input-output network, and may have significant macroeconomic impacts (Acemoglu, Akcigit, and Kerr 2012).

contracts; the transmission of shocks across supply chains generates multiplier effects. Figure 2.8 illustrates the propagation of these shocks.

Figure 2.8 Production Network and Transmission of Shocks



Note:

a) Supply chains are structured by buyer-seller contracts.

b) Upward-pointing arrows = the demand for inputs is reduced.

c) Downward-pointing arrows = the supply of outputs is restricted or discontinued.

d) In an example of industry shocks within one supply chain, a disaster that hits car manufacture facilities will also reduce the production of and demand for inputs such as Polyvinyl chloride (PVC) material for car seats and mats.

e) In an example of industry shocks across two supply chains, a disaster event in a coastal area will halt construction in the short and long terms, thus lowering demand for construction materials such as PVC inputs. This will in turn create operational and financial problems for PVC manufacturers, which are also important suppliers of inputs for car interiors.

The structure of production networks determines the speed at which disruptions affect the production of firms in the short term, and the extent of losses in the long term (Carvalho 2014; Inoue and Todo 2019). The grouping of industries in industrial parks, while beneficial for economies of scale and agglomeration effects, may exacerbate the impacts of disasters if appropriate measures are not in place. Inoue and Todo (2019) found that shocks in heavily industrialized regions spread faster than those in less industrialized ones, even if total losses were similar. This is because it is more difficult for firms to replace intermediate products at a regional scale in densely industrialized regions in which demand for these products may be high. Shocks to specific industries may also ramify to depress regional production, including in regions not directly affected. Furthermore, empirical work in the aftermath of the GEJE suggests that the impacts of disruptions may be dampened by the degree to which firms can substitute their suppliers (Boehm, Flaaen and Nayar 2019; Inoue and Todo 2019). Moreover, disruptions have lingering production and market effects on the prices of goods and services, and on the quantity and quality of goods; all of these market changes may result in losses to firms, their employees and consumers. The significance of these impacts, however, remains to be quantified, and more research is needed to understand how production networks translate shocks and how they adjust to shocks to minimize losses (Boehm, Flaaen and Nayar 2019; Barrot and Sauvagnat 2016; Hallegatte 2020).

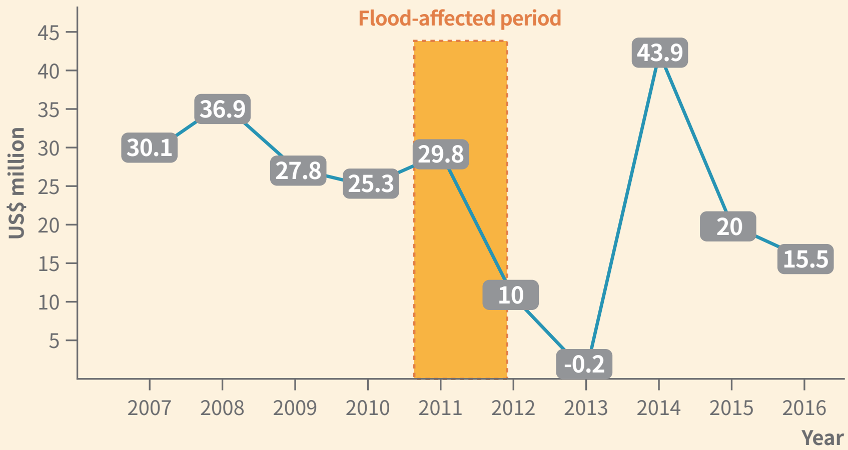
Disasters can also cause shifts in markets through their effects on the quantity and quality of products, market demands, firm's investments, jobs, and market prices. Such changes may be significant, especially in sectors which were underperforming prior to disasters. The drop in cotton prices in Pakistan after floods in 2010 and 2011 illustrates this point (box 2.2).

Box 2.2 Pakistan: Changes in the Availability, Quality and Price of Domestic Input Materials can Affect Volumes of Trade and FDI[21]

The Pakistan textile sector had been struggling to catch up with its competitors before the floods but its potential upgrading in the GVC has been constrained by multiple factors (Frederick and Daly 2019). While Pakistan's potential is apparent, the weak security situation, fragmented industry institutions, inadequate physical infrastructure, and international market activities have limited the sector's competitiveness. Upstream, there are supply chain gaps in critical inputs; cotton production has stagnated in recent years and fibers are of low quality. Downstream, underdeveloped energy infrastructure and challenging security considerations have hampered apparel producers. Lead times also limit the potential for industry expansion because of the potential for delays associated with imported inputs. Cognizant of these issues, global buyers have largely shunned investing in Pakistan, with incoming FDI into the apparel industry below levels seen in regional competitors.

The flood exacerbated these pre-existing challenges to competitiveness. In 2010 and 2011, floods affected over 20 million people and destroyed approximately 21 percent of the country's cotton crop, accounting for nearly 74 percent of overall economic losses (Pakistan Ministry of Finance n.d.). The inflation of the cotton price the following year, a 40 percent increase, depressed Pakistan's textile manufacturing sector, which accounted for nine percent of GDP and 46 percent of manufacturing jobs at that time (World Bank 2010b). In the two years following the floods (2012–2013), FDI inflows to Pakistan's Textile and Apparel Industry plummeted from US$ 25.3 million to US$ 0.2 million (Frederick and Daly 2019) (figure 2.9).

Figure 2.9 FDI Flows in Pakistan's Textile and Apparel Industry, 2007–2016



Source: World Integrated Trade Solution (WITS).

Production and infrastructure networks are complex and interdependent; for this reason, it is difficult to predict the location of risk nodes or occurrence of bottlenecks. The complexity of the manufacturing ecosystem reflects multiple entities and activities, products, process technologies, physical and human resources, financial contracts and transactions across the GVC. Significant impacts may occur in industries in which multiple

21 This negative value for FDI flows means that outflows of investment exceeded inflows. FDI inflows comprise capital provided by a foreign direct investor to a foreign affiliate, or capital received by a foreign direct investor from a foreign affiliate. FDI outflows represent the same flows from the perspective of the other economy. FDI flows are presented on a net basis. Therefore, in cases of reverse investment or disinvestment, FDI may be negative (UNCTAD 2019).

tiers of suppliers and buyers interact in complex networks, such as in the automotive and electronics manufacturing industries (Gereffi and Fernandez-Stark 2011). Infrastructure systems are also interdependent across different levels and sectors, with similar difficulties in predicting disruptions and their effects. Furthermore, governments and industry stakeholders have limited abilities to mitigate these impacts in advance. Thus, the vulnerability inherent in these complexities is often revealed through disasters.

Disasters also affect trade flows, and capacities of firms and countries to increase trade and integrate into GVCs may be reduced by infrastructure disruptions, such as damaged trade routes, and domestic value chain disruptions (WTO 2019; World Bank 2020b). During the 2010 earthquake in Haiti, trade flows were reduced as a result of the US$ 4,302 billion worth of damage (World Bank 2010). The damaged seaport, in particular, caused significant logistical challenges for garment manufacturers and exporters who needed to ship their products to US retailers. Exports were delayed and orders were cancelled despite the fact that most factories remained operational (Zengerle and Frank 2010). As a result, the value of exports plummeted from US$ 80 million in 2009 to US$ 10 million in 2010. Furthermore, the impacts of disasters on domestic manufacturing firms, supply chains and industrial parks can lead to wider GVC disruptions across regions and markets (box 2.3).

Box 2.3 Disruption of GVCs of Automotive and Electronics Manufacturing Sectors During the Thailand Floods (2011)

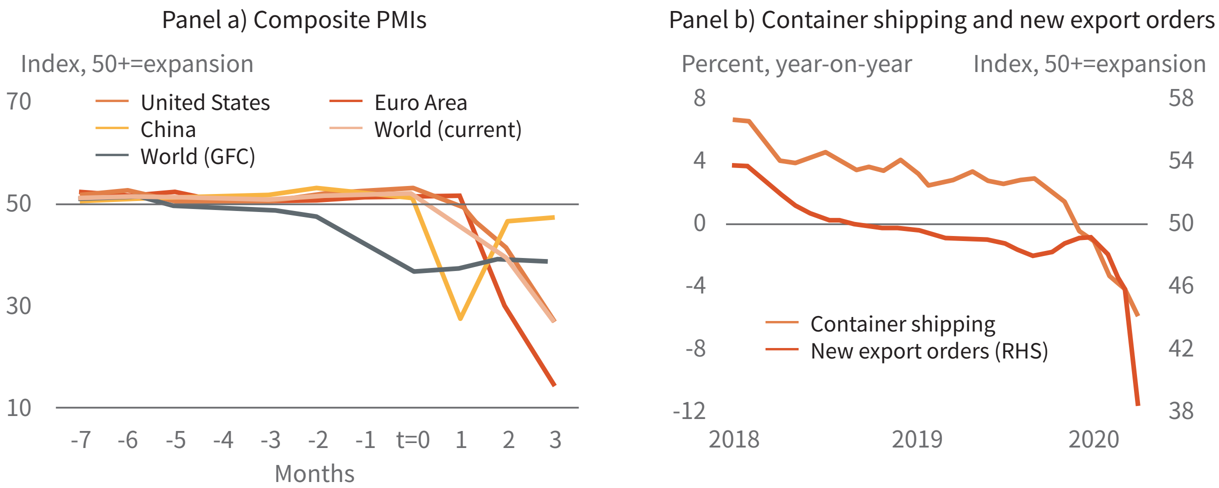
The inundation of industrial parks and Thailand's automotive and electronics manufacturing industries—sectors with high interdependencies among countries—negatively affected regional and global value chains connecting Thailand to regional trading partners. For example, during the 2011 Thailand floods, Japan's exports of semi-finished vehicles ("knock-down units") declined by 24.1 percent following the inundation of factories in Japan and declines in demand from Japanese car assembly lines in Thailand (Chongvilaivan 2012). The import of transport equipment from Thailand to the Philippines decreased by 21.5 percent compared with the same period in 2010 (Haraguchi and Lall 2015). In the hard disk drives (HDD) sector, shipments from five major Thai manufacturers dropped from 175.2 million units to 123.3 million units (approximately 30 percent), accounting for nearly 30 percent of the overall production capacity loss in the sector (IHS Markit 2012). This decline led to a shortage of HDDs, and consequently, 24–33 percent price increases that did not return to pre-flood levels due to the costs to the industry of replacing lost production capacity (IHS Markit 2012).

Source: Chongvilaivan 2012; Haraguchi and Lall 2015; IHS Markit 2012.

GVC disruptions caused by disasters show similarities and differences to disruptions observed during the recent pandemic. The current global pandemic (COVID-19) is causing contraction in global trade, impacting GVCs. PMIs have fallen sharply in major economies. Global trade indicators, such as container shipping and the new export order component of PMI, experienced historically large falls in February (World Bank 2020b). Industries that participate in GVCs often depend on "just-in-time" delivery of intermediate inputs. The just-in-time system contributes to lean inventories and higher productivity, but also makes companies vulnerable to interruptions in supplies from abroad, such as those that have occurred as a result of the regional quarantines, production shutdowns, and border controls implemented to slow the spread of COVID-19. However, shorter value chains based on domestic inputs are no guarantee against disruptions during a pandemic. In terms of their effects on industries, the similarities and differences between pandemics and disasters merit further investigation.

While it is too early to fully assess the effects of COVID-19, the pandemic has generated not only sector-specific but cross-sectoral and regional impacts on GVCs during the past 6 months. While the pandemic has not physically damaged infrastructure, it has led to shifts in buyer-seller relationships and disruptions in production networks for many different production inputs, and these have affected value chains, and have generated cross-sector, economy-wide shocks. For example, regions with more backward linkages, such as the East Asia Pacific (EAP) and Europe and Central Asia (ECA) regions, are vulnerable to wider disruptions, and experienced shortages of critical inputs (figure 2.10). PMIs in these regions have declined sharply. In Vietnam for example, PMI dropped 28 points between January and April. In countries in Central Europe and the Western Balkans, supply chain disruptions and falling demand have caused a significant drop in exports in automotive manufacturing sectors. Such impacts on the value-added manufacturing industries are not confined to production: they end up affecting and/or are caused by decreasing travel, fuel, restaurant and apparel requirements, among others.

Figure 2.10 **Composite PMIs, Container Shipping and New Export Orders**



Source: World Bank 2020b.
Note: Panel a): PMI = purchasing managers' index. GFC = global financial crisis. PMI readings above (below) 50 indicate expansion (contraction) in economic activity. For World (GFC), t=0 at November 2008, the lowest value over the period 2007–2009. For all other data, t=0 at January 2020. Last observations are April 2020 for the Euro Area and March 2020 for China, the United States, and the world.
Panel b): RHS=Right Hand Side.

Consequently, countries may experience significant job losses; low-income workers who are already economically and socially disadvantaged are particularly affected. In Serbia, during the floods in 2014, some 8,700 jobs were lost in the industry, trade, and service sectors, especially among SMEs, because flood-affected businesses were unable to renew contracts with their customers (Republic of Serbia et al. 2014). Many SME employees lost their jobs or worked for reduced salaries. In Haiti, the 2010 earthquake led to significant job losses and working days. Eleven million working days were lost, including 830,650 working days in the production sector, including agriculture and apparel (World Bank 2010). In Thailand, it was estimated that nearly 660,000 manufacturing jobs were either lost or affected (Poaponsakorn and Meethom 2013). During the pandemic, the economic shutdowns in advanced economies and elsewhere are hitting the poor and vulnerable the hardest—through illnesses, job and income losses, food supply disruptions, school closures and lower remittance flows.

Among the most vulnerable groups are women in manufacturing—both business owners and female employees. The manufacturing sector—typically higher paying and with better benefits—is an important employer of women in developing and emerging industrial economies. As of 2017, women made up approximately 43 percent of the manufacturing sector workforce in least developed countries, while in developing countries (excluding China), the female employee share is approximately 35 percent (UNIDO 2019). During disasters in particular, female business owners may lose access to markets, finance, and credit, while female employees may lose jobs.

Firms and economies already face significant costs of inaction. Infrastructure disruption globally costs firms in countries studied in the World Bank Enterprise Survey over US$ 300 billion year (Hallegatte, Rentschler, and Rozenberg 2019). The estimated cost of further delaying investment in resilient infrastructure until 2030 is US$ 1 trillion, a figure which will double with intensifying climate change. By acting now, however, these costs can be reduced. By 2030, in low- and middle-income countries, resilience investments in the power, water and sanitation, and transport sectors will incur incremental costs of around 3 percent (between US$ 11 billion and US$ 65 billion) compared with overall investment needs (approximately US$ 4.2 trillion), over the lifetime of the new infrastructure. This equates to a US$ 4 benefit for each dollar invested in resilience improvements.

In light of this context, there is a growing awareness of the need to enhance industry resilience, and the pandemic has provided an opportunity to build industry resilience. Globally, disasters and failure to address climate change are already perceived as top risks by business communities (WEF 2019, 2020). Policy makers are increasingly aware of the need to integrate disaster risk considerations into industry development strategies and investments. However, the knowledge and frameworks required to scale up industry resilience efforts remain underdeveloped. Little evidence-based understanding is available to inform industry resilience planning and investments. This report aims to help fill this knowledge gap, and to support governments and industry practitioners to enhance industry resilience.

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3

Elements of Resilient Industries

Industrial resilience refers to the ability of firms, sectors, and industrial parks to increase competitiveness by minimizing losses and damages, and by achieving continuity and growth in the face of ever more frequent and intensifying disasters.

In the face of disasters, resilient industries can:

- ***Minimize losses and disruptions*** of physical and human assets, and key business operations; minimize shutdown times and associated losses to both organizations and individuals. Actions taken before, during, and immediately after disasters are critical.
- ***Continue or quickly resume operations*** during and immediately after disasters. This can be enabled through preparatory business continuity and disaster response plans which guide post-disaster actions.
- ***Sustain and increase competitiveness*** following disasters through response and recovery actions. After large-scale disasters, industries need to remain in business and recover quickly within contracted markets or altered economic landscapes. Post-disaster competitiveness may require innovations to regain market share and consumer confidence, and build back better, more resilient businesses, rather than returning to business as usual (World Bank 2020a).

A manufacturing ecosystem that is supported with competitive market structures, resilient production networks, the right market incentives and regulatory mechanisms, and financial resilience prior to a disaster is likely to sustain and increase competitiveness after the disaster. By contrast, in a manufacturing market environment where these features are weak, industry resilience planning and actions introduced in this report may not able to generate competitiveness benefits.

3.1 The Competitiveness Benefits of Industry Resilience Actions

Proactive industry resilience planning and actions incur costs, but generate competitiveness benefits by mitigating physical damage and avoiding business interruption and financial losses. As an example of such mitigation, during the GEJE, roads and expressways built to withstand earthquakes and tsunamis reduced infrastructure disruption and transportation costs, protected the inland areas from tsunami-induced inundation, and served as evacuation routes for emergency response operations (Ranghieri and Ishiwatari 2014).

Equally importantly, they may also yield benefits *even before disasters strike* by increasing operational cost savings, industry asset values and reputation of firms and industrial parks, and creating jobs in related sectors and through other synergies of social, environmental and economic benefits (Tanner et al. 2018; Lavell and Maskrey 2014; Haraguchi and Lall 2019). For example, upfront investments in resilience measures such as higher open foundations to strengthen flood resistance may increase construction costs nationwide; however, the increase in demand for construction materials may create jobs (Multi-Hazard Mitigation Council 2019), and it is essential to tie the upfront costs of resilience investments to rising employment in industries that provide structural materials.

Figure 3.1 provides a schematic diagram of the costs and competitiveness benefits of industry resilience planning and investments in three primary areas: avoided losses, increased development potential, and generating co-benefits.

Figure 3.1 **Competitiveness Benefits of Risk-Informed Industry Resilience Planning and Investments**

Industry Resilience Actions and Investments

Policy actions and investments related to infrastructure, policy and finance measures to help industries avoid or reduce damage and losses and prepare for, and respond to, the impacts of disasters.

Investment Cost

- Life-cycle costs of resilient infrastructure investments
- Firms' implementation of BCPs
- Firms' purchase of insurance
- Potential environmental and social cost

Maintain competitiveness when disaster strikes

Avoided Damage and Losses

- Avoid direct damage to industry assets (buildings, facilities, equipment, machinery, and inventories) and contain repair costs
- Avoid losses in production and sales
- Avoid losses due to infrastructure and service disruption
- Avoid disaster-induced coping cost (e.g. increased transportation costs, or investments in alternative means to continue business operations such as operation costs of back-up generators)
- Avoid job losses

Enhance competitiveness benefits regardless of disaster

Unlocking Development Potential

- Encourage firms save operational costs and build assets
- Increase usability and value of serviced industrial land
- Stimulate firms to invest and innovate
- Increase reputation and competitiveness of firms, manufacturing sectors and industrial parks

Generating Co-Benefits

A wide range of additional benefits across society, income groups, and industry sectors, including:

- mitigation of environmental pollution and greenhouse gas emissions
- increase workforce productivity and safety
- increase resilience of local communities

Source: Adapted from Tanner et al. 2018.
Note: "Co-benefits" of disaster risk management in this diagram refer to "any benefits that accrue in addition to the primary disaster risk management (DRM) objectives of avoiding losses and boosting development. Co-benefits can include economic, social and environmental aspects, and be non-DRM specific" (Tanner et al. 2018). "Industry resilience planning and investments" refer to risk-informed public and private planning and investments in infrastructure, policy and finance measures to help mitigate and prepare for, and respond to, the impacts of disasters.

Research has highlighted three main levers for maintaining and enhancing industry competitiveness in the face of disasters: policies, industry infrastructure, and financial instruments. Governments use industrial policies to increase access to infrastructure and services, and provide streamlined licensing permits, tax breaks, and duty-free imports etc., all of which make sectors and firms more competitive. In addition, governments should encourage firms and industrial parks to make risk-informed plans and investments, and offer policies to raise awareness about disaster risks that can affect industries, and incentivize contingency actions. A Japanese study showed that manufacturing companies which had implemented BCPs prior to the GEJE lost fewer sales than those which had not (Matsushita and Hideshima 2014). Cole et al. (2017) found that contingency planning in advance of disasters had helped firms recover more quickly than plants without such plans. Plans included alternative transport routes to access raw materials and markets when main roads were damaged, and securing back-up suppliers with pre-arranged procurement contracts.

Similarly, disaster-risk-informed industrial development policies, regulations and programs can help industries reduce direct and indirect impacts (damage and losses). These include non-structural measures such as early warning systems, hazard maps, building codes, and disaster-resilient engineering and design standards. While not directly related to industries, the National Institute of Building Science has calculated that adoption of its disaster-resilient building codes would provide a national benefit of US$ 11 for every US$ 1 invested (Multi-Hazard Mitigation Council 2019).

Resilient infrastructure investments can also generate competitiveness benefits for firms by avoiding direct damage or repair costs during and after disasters, and increasing operational cost efficiencies and service provision during normal times. In Peru, investments to mitigate and prepare for potential disruption of road networks critical to supply chains were found to significantly reduce transportation costs for businesses and households during disasters (Rozenberg et al. 2017) (table 3.1). In Shanghai, China, it was projected that, for a storm flood with a 1,000-year return period, investment in flood protection infrastructure could help avoid direct asset damages of approximately US$ 21 billion to the manufacturing industry, and production capacity losses of US$ 24 billion (Li et al. 2019). In Thailand, while flood protection infrastructure investments in industrial parks were highly capital-intensive (approximately US$ 90 million), they were justified by the even higher direct asset damage costs experienced by tenant firms (Bangkok Post 2012). These research findings suggest that governments and infrastructure developers or operators should consider both short- and long-term climate change and disaster risk scenarios when making their investment decisions.

Table 3.1 Maximum Regret in Three Economic Clusters in Peru, Discounted Over 30 Years (Billion US$)

	Investments in disaster-resilient transport infrastructure (investments in flood-prevention and reduction through structural measures)				Reliance on post-disaster response only
Economic corridors in Peru	More frequent maintenance	Large-scale increase in redundancy	Targeted increase in redundancy	Flood-proofing first-best road	Do nothing
Pan Americana	2.1	5.4	2.5	**1.9**	7.4
Piura	0.5	0.82	0.64	**0.04**	4.8
Carretera Central	**0.37**	**0.55**	**0.037**	0.32	4.5

Source: Rozenberg et al. 2017.
Note: Maximum regret refers to the maximum value of the difference between the performance of the option and the performance of the best option for a hazard scenario. Numbers in bold are the options that minimize the maximum regret in each economic cluster.

A review of recent literature and action programs has shown that the optimal arena of influence for policy makers is at national and industrial park levels. This is primarily due to the collective and potentially amplified benefits of actions at these levels (Neise et al. 2018; Neise et al. 2019). In Indonesia, tenant firms in industrial parks in Semarang jointly invested in measures to elevate access roads to their plants to mitigate their exposure to floods. This example suggests the efficacy of actions taken collectively at the industrial park level, especially if incentivized by industrial park operators and governments. For these reasons, the number of projects to increase climate change adaptation and disaster risk management capacity at industrial park level is growing (table 3.2). This report highlights programs that improve resilience of industrial park infrastructure and services, and park management practices.

Table 3.2 Global Initiatives to Increase Disaster Resilience at the Industrial Park Level

Country	Bangladesh	India – Andhra Pradesh/ Telangana	Japan	Morocco	The Netherlands (Port of Rotterdam)	Thailand	Turkey
Name of the project (if relevant)	Enhancing Competitive, Green and Resilient Industries in Bangladesh	Climate Change Adaptation for Industrial Areas - Rapid Climate Risk Analysis of Industrial Parks: Experiences in Telangana	Promoting Area-wide Business Continuity Planning in Industrial Park: Akemi Industrial Park	Strengthening Resilience for SMEs in Industrial Zones in Morocco	Six pilot risk assessment studies for industrial complexes on unembanked sites in Rotterdam	Natural Disaster Risk Assessment and Area Business Continuity Plan Formulation	Lifeline Utilities and Business Continuity Planning in Tuzla, Istanbul
Name of industrial park	Bangabandhu Sheikh Mujib Shilpa Nagar (BSMSN) economic zones	Pashamylaram Industrial park and four others	Akemi Industrial Park	Industrial Zone of Ait-Melloul	Botlek Industrial Complex	Bangkadi Industrial Park Area, Pathumthani Province	Istanbul Tuzla Organized Industrial Zone
Lead government agency	Bangladesh Economic Zone Authority	Telangana Industrial Infrastructure Corporation Limited	Toyohashi City Government (supporting agency)	Ministry of Industry	Rotterdam Port Authority	Office of the National Economic and Social Development Council	Istanbul Tuzla Organized Industrial Zone
Development partner(s), if applicable	World Bank	GIZ	None	GIZ	None	JICA	World Bank

Note: JICA = Japan International Cooperation Agency, GIZ = Deutsche Gesellschaft für Internationale Zusammenarbeit)
Source: ADPC 2017; Bles and Özbek 2018; GIZ 2016; MCII and GIZ 2019; World Bank 2020a; World Bank 2020b.

Measures to improve financial resilience of firms, such as pre-arranged disaster risk financing, can also facilitate recovery. Such actions, in turn, help governments reduce the economic cost of disasters and the need for public investment during and after disasters (Mahul et al. 2019). Governments without disaster risk financing in place often rely on post-disaster approaches such as budget re-allocation and international aid. However, the execution of these funds is often delayed through poor coordination frameworks and operating procedures, hindering recovery. Actions to enhance preparedness of firms and industry through disaster risk financing, in contrast, can rapidly provide governments with funds. Preferential loan programs, contingency budgets, and risk transfer instruments such as insurance, which are all arranged in advance, are such examples. In Japan, the GEJE caused significant impacts to firms directly and indirectly, resulting in more than 1,300 earthquake-related bankruptcies between 2011 and 2013. Following the GEJE, the Japan Finance Corporation (JFC) created and implemented the GEJE special loan program, which supported SMEs damaged both directly and indirectly by the disaster.[22] Financial agencies in Japan also provide incentives for firms to develop BCPs, decreasing the likelihood that a disaster will cause unrecoverable harm to businesses. Through such programs, financial sector stakeholders can help maintain an overall resilient and competitive economy.

Research has also shown that preparations leveraging advanced technologies offer the benefits of prediction, and reduce response times to the unfolding impacts of disasters. These benefits are driven by new technologies including big data analytics, Internet of Things (IoT), artificial intelligence (AI), Blockchain, satellite mapping, and unmanned aerial vehicles

22 In Japan, after the GEJE, many companies which did not have risk finance experienced debt increases of approximately 15 percent, and decreases in their profits of 30 percent (Matsushima and Hideshima 2014).

(UAV) such as drones. These tools improve the predictive power of disaster warning systems and enable rapid responses to dynamic situations. For example, in Japan, the Cabinet Office and METI developed the Regional Economy Society Analyzing System (RESAS) database with data and system design partners (World Bank 2020a). The system synthesizes and visualizes public and private big data such as industrial structures, population movement, and flows. It supports local governments, aid organizations, and educational institutions and is used for evidence-based policy making. The tool has been widely used, particularly for enabling local governments and communities to have better informed planning tools for post-disaster reconstruction planning. The system continues to be updated and expanded, and visualizes near-real-time consumer behavior data. This information is being used to inform planning and decision-making for COVID-19 business recovery at the firm and government levels. In another example, IoT and wireless sensor networks installed on roads, ports, and power grids generated accurate predictions of extreme weather effects at these sites, allowing for rapid responses. Satellites or drones may provide quick damage and loss estimate data to asset registries, allowing firms quicker access to finance (such as insurance) (Mahul et al. 2019).

Policy makers and industry practitioners should recognize the importance of risk-informed, planned investments for disaster mitigation and preparedness; timely responses, which may be activated differently depending on the type and intensity of disasters, and specific socio-economic circumstances, are equally important. Irrespective of preparations, there will always be unexpected impacts requiring additional emergency responses. Therefore, policy makers and industry practitioners should also be in a position to quickly assess and reduce damage and losses during disasters. These actions make use of rapid damage assessments, temporary tax exemptions, streamlined customs procedures, and emergency contract agreements for infrastructure services, as described in Section 7.

3.2 Barriers to Strengthening Industry Resilience

Policy makers and manufacturing industries face a number of difficulties in their efforts to integrate disaster risk management and resilience measures into the competitiveness agenda. These difficulties are described in this report as follows: policy, market failure, infrastructure, finance, sociological and technological challenges.

3.2.1 Policy Challenges and Market Failure

The present and future impacts of climate change pose an unprecedented suite of risks and uncertainties to industries, and call for new paradigms in risk assessment. Increasingly, firms require sophisticated methods that help them understand location-specific climate and disaster risks. The manufacturing sector, however, is insufficiently risk aware, partly owing to a lack of basic information and industry-specific data, localized climate models, and knowledge of area-specific weather patterns and climate histories. Additionally, industrial assets and infrastructure are not often well documented or inventorized, especially in low- and middle-income countries. This makes it difficult to conduct timely assessments and regular monitoring and inspection, or to document sector- and site-specific risks.

Economic incentives for disaster mitigation and preparedness are weak. Various studies indicate the reluctance of firms to plan for supply chain disruptions because the economic and financial benefits of doing so are not sufficiently apparent in the short-term (Sodhi 2014; WEF 2018) (box 3.1). Some of the efficiencies on which supply chain managers rely also render these supply chains vulnerable; and yet, interventions known to increase supply chain resilience, such as broader supplier bases, supply chain databases,[23] and inventories are viewed as costly. The short-term costs of preparedness investments may mean diverting funds from essential overheads such as payroll, taxes, and utilities, and are therefore hard to justify.

Due to insufficient information, lack of competition, and power imbalances that often exist in emerging markets, manufacturing firms are not incentivized or best positioned to collectively prepare for supply chain disruptions or shocks to production networks before disasters strike. Interdependencies, such as those described in Section 2, place a high demand on collaborative endeavor and fair competition. When firms are collectively threatened by extreme events, cooperation trumps stand-alone actions, especially if such cooperation also does justice to other market players and consumers. Recent research has found that collaborative actions to minimize supply chain disruption, such as resource-sharing, can be cost-effective (Dormady et al. 2017). However, competitors in the same value chain or business environment may be unwilling to forego their perceived competitive advantages for the greater good, thus blocking the collaboration required.

Box 3.1 BCP Implementation is Low, Especially Among SMEs

In Japan, a survey conducted in 2019 found that while 81.4 percent of surveyed large firms had established or were developing BCPs, this was the case for only 46.5 percent of medium-sized firms (Cabinet Office 2020).

In Thailand, in a survey conducted after the 2011 flood, it was found that SMEs did not have BCPs; as of 2017, BCP implementation among SMEs remains relatively low, although it increased to 15 percent among small and 21.5 percent among medium enterprises (ADPC 2017). SMEs in Thailand struggle to implement BCPs because of their limited knowledge and understanding of them (Kato et al. 2018).

In the UK, it was found that firms often prepare and activate BCPs only after they have been affected by an extreme weather event. Extreme weather was the most commonly cited reason (69 percent) for activating business continuity management (BCM) strategies. The most commonly cited reasons for not implementing BCMs were the views that “there were no significant levels of disruption in our business,” “We deal with disruption as and when it happens” and “Not a priority,” respectively cited by 45, 43 and 37 percent of surveyed managers.

Source: Cabinet Office 2020; ADPC 2017; Surminski et al. 2016; Kato and Charoenrat 2018.

There is little incentive for industrial park operators, infrastructure operators and service providers to assume responsibility for minimizing risk. As a result, disaster risks are often not sufficiently considered either by, or on behalf of firms, the main users of infrastructure and services. The siting of industrial parks and on-site infrastructures may be decided primarily from cost optimization perspectives. Governments may also prioritize other development goals or political mandates (i.e. regional/rural development, FDI attraction) over risk reduction. And, infrastructure investment decision-makers often prioritize lowering up-front capital or maintenance costs. Consequently, the economic and social costs of industrial infrastructure disruptions are borne by firms, industries and workers.

Finally, there are also coordination challenges at national, sectoral and industrial park levels. Industry resilience planning requires harmonizing of multiple policy goals and implementation plans across a wide range of stakeholders (Haraguchi et al. 2016). Different industry sectors need to integrate their efforts in national and local disaster management

23 For example, after the 2011 earthquake in Japan, Toyota created a database called “Rescue”, for the inventories held by 650,000 suppliers worldwide. This information is being used to locate sources of disruption and to prevent bottlenecks in manufacturing processes. See: “How Toyota Applied the Lessons of the 2011 Quake” (*Automotive News,* April 25, 2016), https://www.autonews.com/article/20160425/OEM/304259956/how-toyota-applied-the-lessons-of-2011-quake.

planning, and integrating disaster and climate risks into their policies and plans; but these cross-sectoral requirements are often overlooked due to sector-siloed planning by governments. Different sectors, including the private sector, may also lack experience of working together, either because the required forums are absent, or through a lack of communication channels.

3.2.2 Infrastructure Challenges

The absence of full life-cycle cost-benefit analyses during project appraisals can increase gaps in resilient infrastructure investments (Tanner et al. 2018). In infrastructure investment planning, economic appraisal is used to accept or reject projects, choose between alternatives, and prioritize options. Conventional cost-benefit analysis has been used to support disaster risk management by weighing the costs of investments against the benefits of avoided losses which only materialize in the case of a disaster.

Challenges remain, including the consideration of co-benefits, some of which are difficult to measure and monetize. In the context of industry resilience, these co-benefits of resilient infrastructure investments should be understood from the perspective of firms and industrial parks, the main users and providers of infrastructure services. These benefits include reputation, buyers' trust, attractiveness of industrial parks, productivity of employees, and other environmental and social co-benefits such as greenhouse gas (GHG) emissions reductions and increased usability and value of industrial land. These co-benefits are often not fully integrated into resilient infrastructure investment decision-making, and as a result, increase the investment gap (Surminski and Tanner 2016).

3.2.3 Financial Challenges

The increasing frequency and intensity of disasters also create challenges for governments, industries and financial sectors, limiting firms' access to finance during and after disasters. These constraints are most serious for smaller firms with limited cash reserves and low creditworthiness, and which need working capital to replace damaged equipment or pay salaries. These firms tend to invest in day-to-day business improvements that generate quick returns, rather than in preparatory measures. During disasters, such firms lose liquidity because of increases in cash outflows and decreases in inflows.[24] Limited liquidity increases financial risks for companies, which are unable to make payments, and are burdened by repayments. In countries with changing and intensifying risk profiles, higher insurance premiums may be set, placing insurance further out of reach for firms.

If unprepared, financial institutions and insurance companies are similarly unable to address shocks and market failures. Insurers are subject to high numbers of claims, while banks are less likely to have finance available for high-risk loans to struggling businesses. In Thailand, for example, the scale of payouts after the 2011 floods crippled the insurance industry, and required government intervention. Financially struggling firms are least likely to qualify for loans in high-risk, post-disaster environments. Administrative inefficiency in the financial sector can also slow the delivery of financial services (i.e. loans) to local SMEs after a disaster. Such delays make it difficult for firms to maintain the cash flows required to keep their businesses open, and slow recovery. Financial illiteracy among firms, or inexperience in damage assessment among insurance claims assessors can further slow post-disaster loan financing. In India, for example, SMEs were unaware of the loans available to them, while loan applicants were ill-equipped to file applications (Idicheria et al. 2016). Others that did

24 An increase in outflow of cash is caused by payments for fixing damaged facilities while a decrease in inflow often happens when suppliers and vendors run out of money.

qualify for loans were sometimes unable to meet repayment obligations, forcing them to use informal channels, or to borrow from friends, family and moneylenders.

3.2.4 Technical Challenges

Governments and industries in emerging economies have limited access to real-time data and tools for damage assessment and recovery. With growing digitalization, data from sensors, satellites, mobile phones and internet activities have shown potential for disaster management of infrastructure (World Bank 2019). They can offer real-time disaster risk information, delivering rapid, detailed analyses, as well as guiding and speeding up coordinated, targeted responses to minimize further losses at the time of the event.

There is also a gap in policy and financial support for firms not only to deploy new technologies but also to realize the full potential of ICT for industry resilience. Governments and industries in developing contexts often lack the technical know-how required to take advantage of these technologies, and there is a need to enhance technical and institutional capacity in this regard. Policy and financing mechanisms are needed to integrate these technologies into industry resilience plans and actions.

3.2.5 Sociological Challenges

Impacts of disasters may be exacerbated for vulnerable groups, especially women entrepreneurs and female workers, who experience pre-existing social and economic challenges. Women-led SMEs in emerging markets typically lack access to finance, credit, banking services, and legal rights needed to establish and operate their businesses. Adoption of disaster mitigation and preparedness measures appears to be low, as a result. For example, in Thailand in 2011, the number of women SME owners who had implemented flood risk mitigation measures such as sandbag dikes, BCP and flood insurance (16.9 percent of 141 firms surveyed) was lower than the number of men (55 percent) (Pathak and Emah 2017). Thus, the status of women, and its effects on women entrepreneurs' ability to implement resilience measures may worsen the impacts of disasters and slow business recovery. In Pakistan, research shows that female owners of SMEs face greater challenges than men in establishing and maintaining businesses, both during normal conditions and disasters (Asgary, Anjum, and Azimi 2012). They struggle to maintain access to suppliers and markets, spend more on security than firms with a male top manager and face the dual responsibilities of balancing family and business commitments (Amin and Zarka 2018).

Female workers may also experience impacts of disasters more severely than men. They suffer workplace discrimination, have limited access to skills training and rewarding jobs, and struggle to obtain promotions. During disasters, female workers may be unable to commute to the workplace, and unable to return to work because of commitments to family and children, and are hence more likely to lose their jobs. Domestic violence may also worsen during financially stressful post-disaster situations (Neumayer et al. 2007). For women seeking employment, these difficulties are amplified during downturns following disasters, making female workforce participation even more challenging (Enarson 2000).

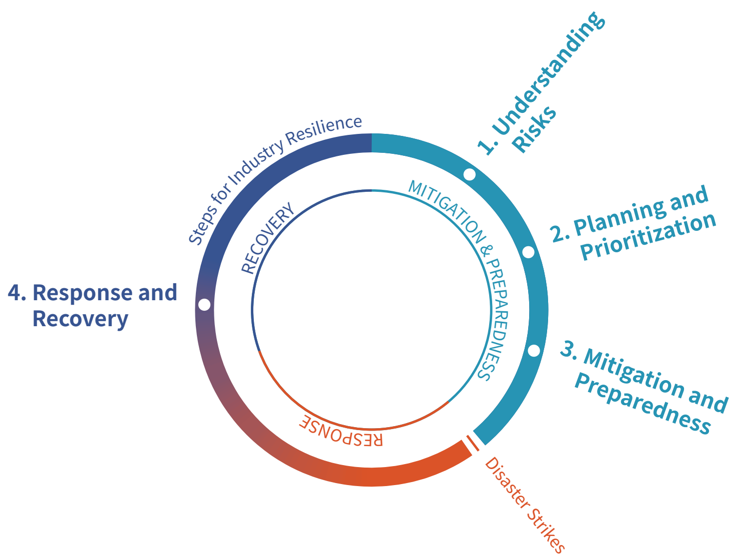
It is therefore important that industry resilience planning and investments are sensitive to these challenges and needs. Approaches may include policy, infrastructure and financial instruments, including: needs assessments, fiscal measures to expand social safety nets for women, tax cuts for women entrepreneurs; cash transfer, credit or trade finance for women-owned SMEs; using digital technologies and social networks to reach vulnerable women entrepreneurs and female workers; procuring goods and services from women entrepreneurs; vouchers to support vocational training for female workers; and infrastructure retrofits in industrial parks to include both gender-sensitive and disaster-resilient designs. In Section 8, this report discusses a number of these solutions, focusing on those that have been or are being piloted, such as: catering for gender-specific needs; market access for women-led SMEs; using existing social infrastructures to support disaster-affected female stakeholders; and post disaster skills training for women entrepreneurs and female employees.

3.3 Resilient Industries Framework

Industry resilience requires concerted planning and actions that address these challenges at multiple levels and different phases of disasters, as illustrated in figure 3.2. Actions to strengthen resilience of industries against climate and disaster risks can be guided by the following four phased-process: 1) ***understanding the range of disaster and climate change risks*** that can affect competitiveness; 2) ***risk-informed planning of national strategies and prioritization*** of *investments and* actions to mitigate and avoid impacts; 3) ***disaster mitigation and preparedness actions*** through policy, infrastructure and finance-based approaches; and 4) ***response and recovery*** to facilitate rapid and sustainable return to build back competitive industries. Gender-sensitive solutions, and measures that leverage new technologies, should be employed throughout these processes.

A Resilient Industry Framework is proposed to guide governments, industry practitioners (including firms, industrial park operators, and industry associations), financial institutions, and development partners in mainstreaming resilience into industry development. The Framework, recommended actions, examples of specific measures and key stakeholders are highlighted in table 3.3.

Figure 3.2 Process of Building Resilient Industries



1. Understanding Risks

Understanding the range of disaster and climate risks that can impact and threaten business continuity and competitiveness

2. Planning and Prioritization

Evidence-based planning and prioritization of investments and actions that could address key bottlenecks and strategically avoid or minimize negative impacts

3. Mitigation and Preparedness

Implementing resilience actions and investments in advance for disaster mitigation and preparedness

4. Response and Recovery

Taking good response decisions and actions during and after disaster events to minimize disruptions and losses, and as a result, maintain and enhance competitiveness

Source: Original compilation based on UNDRR 2015.
Note: This diagram is based on the disaster timeline. Note that the distribution of the steps around the cycle does not reflect their weight or importance, and each action will contribute to industry resilience.

The proposed approaches need to be made available by both public and private sector stakeholders, and to consider multiple types of hazards and the specific characteristics of industries. The measures are interrelated and can be implemented at various levels, including national, regional and local; and firm, sector, industrial park, and beyond (GVC levels). Practitioners should consider this multi-level, multi-sectoral and multi-hazard approach and its mutually determining nature when effecting resilience interventions. For example, preferential loans to address the technical and financial challenges that SMEs face in formulating BCPs and preparing for disasters may be viewed as incentives requiring policy and financial support components. To give another example, risk-informed building and infrastructure codes are policies that generate investments to strengthen industrial infrastructure against hazards by guiding their design and operation. Therefore, risk-informed codes are discussed focusing on their policy design, and how improved codes can lead to public and private investment in infrastructure retrofits. This approach is discussed in detail in the following sections.

Table 3.3 Resilient Industries Framework

Industry resilience timeline		Type of solution	Recommended actions	Examples of measures	Key stakeholders
Actions before disasters	Understanding risks to industries	**Policy:** Data and information	Enhance national understanding of disaster risks to industries.	Collect, analyze and share climate change and disaster risk information specific to the needs of industries.	National and local governments, industry associations, firms, and industrial park operators, infrastructure operators and civil society.
			Develop frameworks and tools to assess risks to firms, value chains and industrial parks.	Climate change/disaster risk assessment tools and hazard maps to assess location- and industry-specific risks to firms, value chains, industrial associations, industrial parks, and regions.	National and local governments, industry associations, industrial park operators, and firms.
			Promote public-private partnerships to enhance sector-and location-specific risk assessments.	An interactive dialogue platform for stakeholders to deepen shared understanding of risks to industries, sectors and/or industrial parks, and facilitate planning and actions.	National and local governments, industry associations, firms, and industrial park operators, infrastructure operators and civil society.
	Planning and prioritization	**Policy:** Institutional arrangements	Identify national priorities for industry resilience.	National Disaster/Climate Risk Assessment documents with ranking of key risk areas and opportunities. Critical analysis for targeted resilience investments.	National and local governments, industry associations, firms, industrial park operators, infrastructure operators and civil society.
		Policy: National strategies for resilient industries	Develop a national resilient industries framework and coordination structures.	Risk-informed national infrastructure development plans, or land use plans. An institution such as the National Resilient Industries Council.	National and local governments, industry associations, firms, industrial park operators, infrastructure operators and civil society.
	Mitigation and preparedness	**Policy:** Economic incentives, supporting programs, and regulations	Promote business continuity planning and management.	National, regional and park level guidelines, manuals or training materials for BCPs and BCMs. Pre-arranged agreements with suppliers. Park-wide BCPs.	National and local governments, industry associations, industrial park developers and operators, and firms (including tenant firms).
			Help industries maintain global value chains.	Risk-informed agreements with trade partners (e.g., cross-border BCPs). These agreements can be either formal or informal.	National and local governments, industry and trade associations, firms, and trading partners.
			Promote resilient industrial park development.	Regulations and guidelines that guide risk-informed industrial park development. National regulations that define acceptable levels of risk for infrastructure development and operation, which also applies to those located in industrial parks. Minimum design standards to account for future risk.	National and local governments, industrial park developers and operators, and firms (including tenant firms).
		Infrastructure: Consideration of natural hazards in the design and (re)construction, operation, and maintenance of industrial park infrastructure and services	Minimize infrastructure disruption in industrial parks.	Structural designs to factor in hazards and climate change (e.g., flood-proofing and seismic-proofing of captive power plants). Increase reliability of infrastructure services through built-in redundancy and resource recovery systems (e.g., backup power and water supply systems, and nature-based solutions, etc.). Rigorous construction inspections, maintenance, operation and monitoring mechanisms. Emergency preparedness and response plans for industrial infrastructures, including response protocols, pre-arranged agreements for restoring infrastructure disruptions, contingency finance for repairs and plans for post-disaster damage assessments.	National/local governments, infrastructure operators, industrial park developers and operators, service providers, tenant firms, and civil society.
			Conduct alternative cost-benefit analyses.	Life-cycle cost analysis of infrastructure system design specifications; multi-criteria analysis.	National/local governments, industrial park operators, service providers, financial institutions, and firms.
		Finance: Financial support and incentives for capital investment in resilient infrastructure, BCP, and pre-arranged disaster risk finance	Analyze financial impacts and needs.	Understanding potential financial impacts of disasters on firms, markets and industry sectors. Financial needs assessment for small firms.	National/local governments, industrial associations, firms, and financial institutions.
			Support up-front resilient infrastructure investment.	Life-cycle cost analysis, reflecting the costs of disaster impacts for industrial parks and infrastructure. Fiscal incentives, resilient infrastructure PPP models, loans, and other financing mechanisms to cover capital and operating costs.	National/local governments, industrial park operators, service providers, and financial institutions including international financial institutions/ development partners.
			Provide financial support for contingency planning and advance disaster risk financing.	Financial measures to incentivize contingency and continuity planning by firms and industrial parks. Pre-arranged financial measures to allow rapid release of funds for responses needed to resume operations and minimize losses.	National/local governments, financial institutions, and firms.

Industry resilience timeline		Type of solution	Recommended actions	Examples of measures	Key stakeholders
Actions during and after disasters	Response and recovery	**Policy:** Institutional arrangements	Activate and refine coordination frameworks for response and recovery.	Activating emergency response plans based on predetermined criteria, establishing an emergency operations center if needed, and adjusting the coordination framework to support and streamline effective response processes.	National/local governments, industrial park operators, service providers, financial institutions, international donors, humanitarian aid, and firms.
		Policy: data and information	Conduct rapid assessment of industrial damage and losses.	Streamline data collection and analysis to inform investment and reconstruction needs. Advanced technologies (e.g., satellite mapping technology) may be used to fast-track assessments.	National/local governments, industrial park operators, service providers, financial institutions, international donors, and firms.
		Policy: Economic incentives, supporting programs, and regulations/de-regulation	Provide support to retain investors and boost market demand.	Increased tax incentives for investors including foreign investors, temporary removal of regulatory barriers to fast-track product certification and facility reconstruction, and investment aftercare programs.	National/local governments, industrial park operators, investment promotion agencies, and financial institutions.
			Support safety and employment continuity.	Security, health, and humanitarian assistance programs. Employee exchange programs with trading partners. These programs may also include working capital loans.	National/local governments, industrial park operators, international donors, trading partners, and firms.
		Infrastructure: Restoration of critical infrastructures and services	Promptly restore critical infrastructures and services.	Pre-arranged agreements and post-disaster emergency contracts to engage private sector stakeholders and mobilize resources to restore infrastructure services critical to business continuity.	National/local governments, industrial park operators, infrastructure providers (including logistics companies), development partners, industry associations and firms.
		Finance: Financial support for post-disaster recovery and reconstruction	Provide financial safety nets targeting SMEs.	Post-disaster emergency loans and credit guarantees for SMEs, group subsidies for firms linked through supply chain networks, and disaster risk financing instruments to cover damage and repair costs.	National/local governments, financial institutions, development partners, and firms.
			Finance investments in building back competitive industries.	Post-disaster financial support programs or existing sustainability initiatives to attract private investments toward resilient infrastructure development. Financing greenfield industrial park development in disaster-affected regions.	National/local governments, financial institutions, industrial park developers and operators, development partners, and firms.
Integrating gender and technology solutions		**Gender-sensitive resilience planning and actions**	Conduct gender-sensitive needs assessment.	Gap analysis to identify gender-differentiated impacts of disasters in manufacturing sector. Post-Disaster Needs Assessment (PDNA) that integrates data analysis to support gender-informed responses in the manufacturing sector.	National and local governments, industry associations (e.g., women entrepreneurs' associations), firms, development partners, and civil society (e.g., employees' associations).
			Finance women-owned SMEs through disaster risk financing.	Disaster risk financing instruments (e.g., insurance) directed to assist women entrepreneurs or businesses with high percentages of female employees. Trade finance that targets women-owned SMEs.	National and local governments, financial institutions, industry associations (e.g., women entrepreneurs' associations), firms, development partners, and civil society (e.g., employees' associations).
			Enhance market access for women-led SMEs during disaster response.	Provide access to contracting opportunities for women-owned SMEs pre- and post- disasters. Training programs to involve women entrepreneurs in post-disaster/emergency restoration work.	National and local governments, and industrial associations, infrastructure operators, and firms.
			Maintain training programs for women entrepreneurs and female employees during and post-disaster.	Skills and awareness-raising programs on digital payments, e-commerce, disaster risk management, BCP, evacuation plans, etc.	National and local governments, and industrial associations, industrial park operators, and firms.
		Improving resilience through technology	Encourage ICT uptake by firms.	Low-interest loans for the purchase of equipment, machinery, computer hardware and software. A program to encourage the use of e-commerce and digital payment/contractual arrangement systems to lower transaction costs during disasters.	National and local governments, industrial associations, industrial park operators, firms, and technology providers (ICT providers).
			Enhance supply chain resilience and visibility utilizing new technologies.	Big data or blockchain technologies tracing and visualizing end-to-end supply chains; big data analysis monitoring complex production networks and mitigating potential supply chain disruption risks.	National and local governments, industrial associations, firms, and technology providers.
			Minimize industrial infrastructure disruption with new technologies.	New technologies that diversify industrial infrastructure services. Digital technologies to embed redundancy into infrastructure system design and operation.	National and local governments, industrial park operators, infrastructure developers and operators, and technology providers.
			Use innovative technologies to fast-track asset damage assessments and insurance claims payouts.	New technologies to collect real-time data and provide early warning and asset monitoring systems, such as sensor data that allow technicians and engineering teams to track the structural integrity of infrastructure.	National and local governments, financial institutions including insurance companies, firms, and technology providers.

Source: Original compilation.

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4

Understanding Risks to Industries

Countries need to adopt risk-informed and evidence-based approaches to enhance industry resilience. As manufacturing sectors in many countries continue to grow and connect to one another, and the frequency and intensity of disasters increase, so does the exposure of industries and infrastructures to these risks. Understanding industry-specific exposures to these disaster and climate change risks is a first step toward industry resilience, and to planning and prioritizing national strategies. Key actions include integrating industry sector considerations into disaster and climate risk assessments, and analyzing various types of hazards that industries are exposed to, the likelihood of their occurrence, their potential impacts, and the intensity of these impacts. The assessments can be conducted at various levels, including at the national, regional, value chain, industrial park, and firm levels, depending on the intended use of the analysis. Sector characteristics, as well as the location of industries and key infrastructure assets, need to be considered. The assessments should also recognize interdependencies among firms and sectors along domestic and global value chains, and firms' dependence on infrastructure and services, including those provided within industrial parks. Such comprehensive risk assessments will help policy makers plan and prioritize multi-sectoral and multi-level actions to enhance industry resilience. In developing countries, however, data and information on various types of natural hazards, including climate change projections, are lacking. Capacities and tools to assess the potential impacts of natural hazards and make risk-informed decisions are improving, but need to be tailored to industry needs and sector-specific characteristics.

Recommended Actions

- **Enhance national understanding of risks to industries by integrating industry sectors into national climate change and disaster risk assessments.**
- **Develop frameworks and tools to assess risks to firms, value chains and industrial parks.**
- **Promote public-private partnerships to enhance sector- and location-specific risk assessments.**

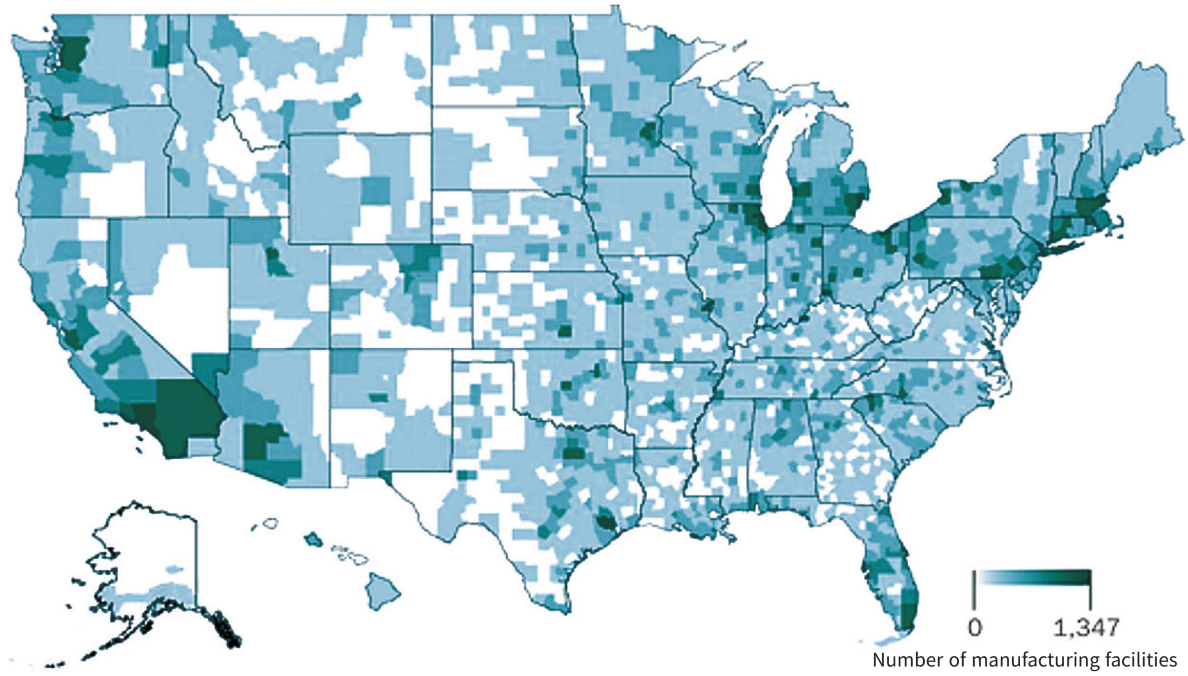
4.1 Enhance National Understanding of Disaster Risks to Industries

It is important to ensure that disaster and climate risk assessments are comprehensive yet specific, tailored to different objectives and needs including those of industry practitioners. Policy makers and industry practitioners require climate modelling and risk information for resilience planning (Stenek et al. 2013); however, in many developing countries, little such information is available, especially on long-term climate change projections, due to the costs of maintaining hydrological and meteorological monitoring stations (HydroMet).[25] During the 2011 floods in Thailand, flood risk data were unavailable; this made it difficult for stakeholders from government and industrial parks, and insurers and re-insurers themselves to prioritize investment plans or to plan for future insurance needs based on flood frequency projections. After the floods, the Government of Thailand implemented a plan to develop database and disaster warning systems to monitor and analyze water situations. Water monitoring stations were constructed in major rivers, CCTVs were installed at the water gates and pumping stations, and satellite and remote sensing systems were upgraded to enhance disaster warning systems (Thailand Strategic Committee for Water Resource Management 2012).

25 The average cost of comprehensive hydromet improvements for developing countries amounts to over US$ 30 million (Stenek et al. 2013).

National disaster warning systems and climate risk assessments can integrate manufacturing sector considerations. A National Climate Change Adaptation Plan can be an effective platform to engage private sector stakeholders, raise risk awareness, and promote coordination and partnership. Multi-hazard risk maps are also effective tools to aggregate and share national-level risk data/information for governments and industries, and identify areas prone to earthquakes, tsunamis, floods, cyclones and strong winds. To inform national planning strategies, priorities or resilient industry frameworks, these assessments should include industry-specific information such as infrastructure development plans, and types of critical industry assets, and their location. For instance, figure 4.1 shows the location of facilities for manufacturing sectors in the United States, including processing and distribution facilities. The map shows their coastal location near transport hubs to facilitate import/export needs (US Department of Homeland Security 2015), alerting policy makers and stakeholders to possible disaster and climate change impacts that may damage industry and infrastructure assets, disrupt their operations, limit access to capital and markets, and lower profits.

Figure 4.1 Concentration of Manufacturing Facilities in the United States



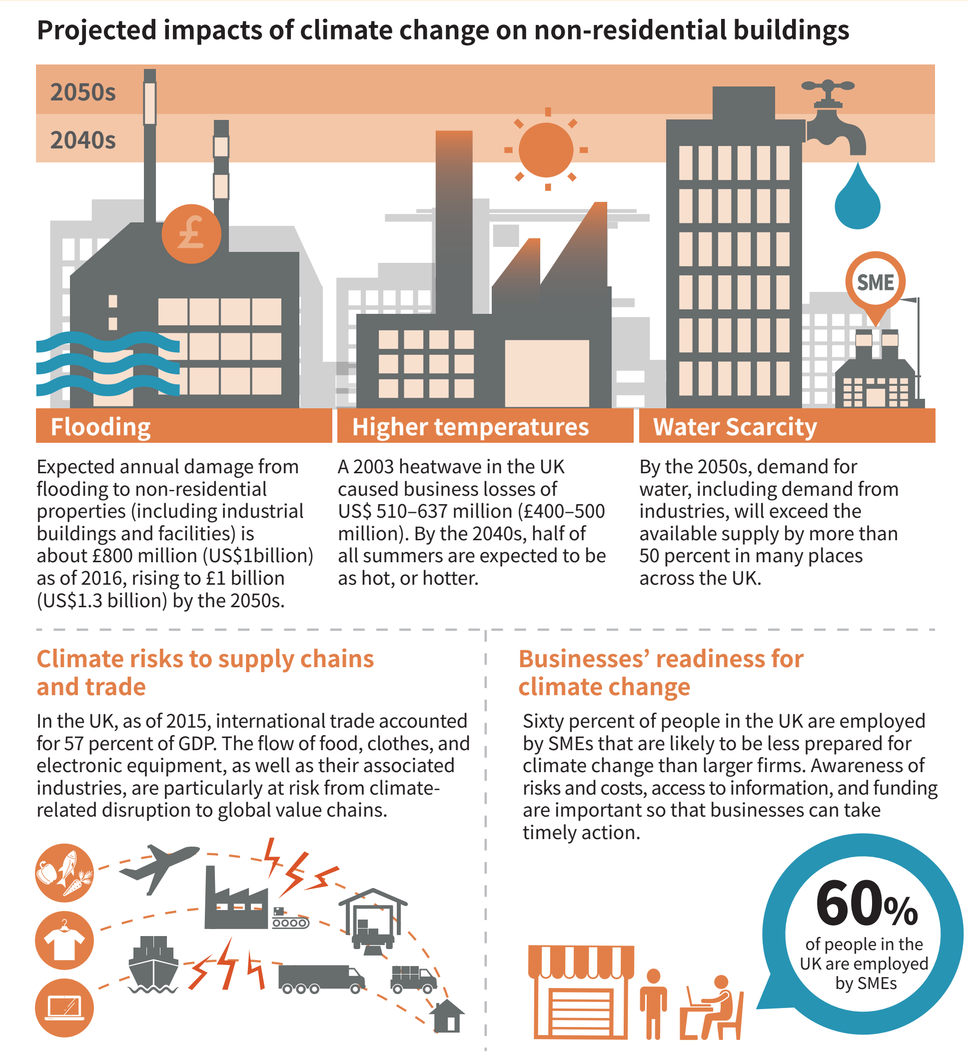
Source: US Department of Homeland Security 2015. Critical Manufacturing Sector-Specific Plan: An Annex to NIPP 2013.

If possible, governments need to collect data, assess current and future disaster impacts specific to different industry sectors and the location of industries, and make relevant information accessible. This can, in turn, inform mitigation and preparedness for industry practitioners and infrastructure operators. For example, the government of the United Kingdom identifies climate change risks and opportunities for industries at the national level (box 4.1). Required under the Climate Change Act 2008, the Department of Environment, Food & Rural Affairs (DEFRA) publishes climate risk assessment reports every five years. These reports describe how current and future climate change may damage industrial properties and disrupt businesses, and the expected costs. Major risks, and actions required to minimize them, are identified, and inform UK National Adaptation Programmes.

Box 4.1 UK National Level Assessment of Climate Change Risks to Industries

The UK Climate Change Risk Assessment (CCRA) is commissioned by the UK Government to help national and subnational governments identify actions to minimize impacts on economic sectors, the environment and society, including businesses and industry sectors, energy sectors, and building and infrastructure sectors. The CCRA reviews over 700 potential impacts of climate change specific to the country. Detailed analyses examine the likelihood and intensity of potential consequences, and the urgency with which action may be needed to address them. The studies showed that non-residential properties, including industrial and commercial properties, already suffer significant damage and disruption costs (approximately US$ 1,124 million). These impacts are expected to increase from 2050–2080, respectively, due to coastal and river flooding, and this threat requires urgent action as climate change intensifies (figure 4.2). The integration of industry and business sectors in the national climate change risk assessment helped the government to prioritize and decide on actions to increase industry resilience, such as flood protection infrastructure investments in chemical manufacturing hubs.

Figure 4.2 **The Effects of Climate Change on Business and Industry**



Source: Adapted from UK CCC. n.d.
Note: Non-residential properties include industrial and commercial buildings, as well as public buildings such as schools and hospitals. The damage and loss figures were converted to US dollars ($) at the 2019 annual average exchange rate of $1 = £ 0.784, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates.

Source: Sayers et al. 2015; Surminski et al. 2016; HM Government 2012.

Private sector stakeholders, such as a reinsurance company, also develops a database of industrial parks that may be exposed to earthquakes and floods, which helps clients identify and evaluate potential risks (Guy Carpenter 2012). The database contains location data and sizes of industrial parks in various countries these private stakeholders operate. The insurance company also developed a database of firms operating in the various parks, with their supplier information and type of industry sector.

4.2 Develop Frameworks and Tools to Assess Risks to Firms, Value Chains and Industrial Parks

More granular analyses may be conducted once the national risk landscape has been mapped. To date, various industry tools are used at the firm, value chain, and industrial park levels, as described below. These assessments are used to define industries' exposure, identify bottlenecks and hotspots, and help stakeholders identify risks and take action. Governments and stakeholders need to monitor changes in risk profiles and update assessments accordingly.

Assessing Disaster Risks to Firms and Value Chains

Firm-level risk assessments can help businesses understand risks they face and plan actions to mitigate such risks. Some governments offer assessments and tools enabling firms to rank risks and analyze potential damage and disruption costs. In the United Kingdom, the UK Climate Impacts Programme (UKCIP) developed a climate risk assessment tool called BACLIAT for businesses and the private sector. The tool helps firms to understand climate change risks including heatwaves, landslides, and floods, and related impacts, including damage to buildings/subsidence, damage to infrastructure (roads, railways, communication networks), and disruption to supply chains.

Value chain perspectives have also been integrated into risk assessments to increase understanding of sectoral vulnerabilities and identify potential sources of supply chain disruption. In low- and middle-income countries, agriculture (e.g., rice, coffee, cotton, and maize value chains) and food-processing sectors are vulnerable to various hydro-meteorological hazards (Dazé and Dekens 2016; Lim-Camacho et al. 2016; Lim-Camacho et al. 2017; UNIDO 2017). However, the vulnerabilities of food-processing sectors remain poorly understood. The Value Chain Vulnerability Matrix, developed by the UNIDO, offers a schematic understanding of climate change risks to targeted manufacturing sectors (table 4.1). It identifies production processes or supply chains with natural hazard exposure, and is used to raise awareness among stakeholders (box 4.2).

Box 4.2 Egypt: Vulnerability Assessment of the Food Processing Sector

In Egypt, temperatures are expected to rise significantly. By 2030, the mean annual temperature is projected to increase by 1.07°C under a moderate emissions scenario, which can affect water and energy-intensive firms by increasing their utility costs.

A vulnerability matrix was used in the vegetable and fruit juice processing sectors, and the meat industry, to understand industrial processes vulnerable to climate change impacts (UNIDO 2017b; 2018). The Egyptian Environmental Affairs Agency, Food Technology Center, Egyptian Meteorological Authority, Egyptian National Cleaner Production Center, and UNIDO conducted the assessment. It was found that washing, storage, and transportation were most vulnerable to heavy rain, droughts and temperature rise. The findings helped firms identify investments to address climate change impacts on their businesses. As an example, a food and beverage manufacturer decided to invest in solar panels. Blue Skies installed solar photovoltaic (PV) plants whose roof-shading panels lowered heat absorption of factory buildings and reduced cooling and refrigeration costs. The plants save an estimated 240,000 kWh per year, and 120,000 kWh per year are generated by the solar panels (UNIDO 2018).

Table 4.1 Egypt: Vulnerability Matrix for the Beverage Manufacturing Industry

		Extreme weather events					Climate change events		
	Hazards	**Heavy rain**	**Flood**	**Frostbite**	**Strong wind**	**Drought**	**Temperature rise**	**Rise in sea level**	**Number of 3s**
	Frequency	-	-	-	-	+	+	+	
Key industrial activities	Collection	1	0	0	0	0	0	0	0
	Transportation [a)]	1	2	0	2	0	2	0	0
	Storage	3	0	1	2	0	3	0	2
	Washing	0	0	0	0	3	0	0	1
	Cutting	0	0	0	0	0	1	0	0
	Blanching	0	0	1	0	3	2	0	1
	Water Cooling	0	0	0	0	3	2	0	1
	Freezing	0	0	0	0	0	3	0	1
	Sorting	0	0	0	0	0	1	0	0
	Packaging	0	0	0	0	0	1	0	0
	Cold Storage	0	0	0	0	0	3	0	1
	Transportation [b)]	1	3	0	2	0	3	0	2
	Number of 3s	1	1	0	0	3	4	0	

Note: Scoring method used. 3=significant impact on the exposure unit; 2=medium impact on the exposure unit; 1= low impact on the exposure unit; 0=no impact on the exposure unit. [a)] transportation of raw materials; [b)] transportation of final products.
Source: UNIDO 2017, 2018.

Governments can further support industries with online assessment tools. In the Republic of Korea, private sector stakeholders were invited to use a web-based Climate Change Risk Assessment System (CRAS) to predict impacts and estimate damages. For the food processing sector, manuals were developed to help companies registered in the system plan for multi-hazards, including extreme heat, cold, floods and snowfalls. The risks included changes in quality and availability of produce, water scarcity and its effects on produce quality, damage to production facilities, logistics disruptions, heatwave-related costs, changes in market demand and worker impacts.[26]

26 CRAS website: https://cras.kei.re.kr/main.do.

Assessing Disaster Risks at Industrial Parks

Assessments are particularly appropriate at the industrial park level, and the number of park-level assessments is growing.[27] In India and Morocco, they have been used to guide adaptation strategies for industrial park operators. In Thailand and Turkey, multi-hazard assessments were conducted to inform industrial park- or area-wide BCP development (ADPC 2017; Bles and Özbek 2018) (box 4.3). These assessments helped to define acceptable levels of risks, update design standards needed to mitigate impacts and develop other preparedness measures to secure the attractiveness of the industrial parks in the face of disasters.

Box 4.3 Turkey and Morocco: Multi-Hazard Assessments in Industrial Parks

Figure 4.3 Istanbul Tuzla Organized Industrial Zone, Turkey

Photo Credit: © Istanbul Tuzla Organized Industrial Zone Authority.

In Turkey, the park-level assessment guided a park-wide BCP in Istanbul Tuzla Organized Industrial Zone (ITOIZ) located in Istanbul, where more than 110 metal manufacturing companies operate as of 2017. The key features of the assessment were:

- *Identifying hazard scenarios* for infrastructure and firms. Both climate risks and other hazards such as earthquakes were considered in these scenarios, as well as their return periods and potential consequences.
- *Analyzing susceptibility of on-site infrastructure* to the interdependencies between infrastructure components, and potential cascading effects of disruptions of infrastructure services (table 4.2). Infrastructure examined in the analysis included gas, electricity, road networks, process water supply networks, wastewater treatment plants, storm sewer networks, and communication/ICT.
- *Understanding the duration of service outage*, which refers to how long on- and off-site infrastructure disruption lasts during emergencies. Sub-optimal operation of on-site infrastructure is a high-risk factor for tenant firms, which must be minimized.
- *Establishing Recovery Time Objectives (RTO),* or pre-defined target times for the resumption of critical infrastructures in industrial parks when disasters occur, and identifying on-site industry and infrastructure assets requiring emergency preparedness and response plans.
- *The significance of disruptions was scored in terms of competitiveness factors,* including safety, business continuity cost, repair cost, environmental impact and reputational risk.

27 These plans also include structural measures related to the design or retrofit of coastal and river flood protection infrastructure.

Table 4.2 Significance of On-Site Infrastructure Outage on Tenant Firms

Industry sector	Infrastructure system						
	Gas	Telecommunication	Electricity grid	Internal road network	Storm sewer	Process water	Wastewater treatment plants
Automotive	Severe	Significant	Severe	Moderate	Minor	Moderate	Moderate
Steel	Severe	Moderate	Severe	Moderate	Minor	Moderate	Moderate
Electronics	Minor	Moderate	Significant	Minor	Minor	Minor	Minor
Pharmaceutical	Minor	Significant	Significant	Minor	Minor	Minor	Minor

Note: The table describes the significance of infrastructure failures in terms of potential business interruption.

In Morocco, climate risk assessments were conducted for food processing SMEs in an industrial park. Ait-Melloul Industrial Zone is vulnerable to climate change risks such as floods, drought, and water scarcity. Approximately 300 SMEs operate in the park, the majority of which are exporters engaged in food processing. Despite their importance to national and regional economies, the firms were unaware of these risks, and lacked knowledge about various disaster mitigation and preparedness measures including insurance. The park operator, industrial associations, infrastructure operators, regional councils and resident firms assessed regional climate risks with the "Climate Expert" tool.[28] The exercise helped participants to understand the damages that can be inflicted by hydrometeorological hazards, and how these damages might affect them.

Source: GIZ n.d.; Bles and Özbek 2018.

4.3 Promote Public-Private Partnership to Enhance Sector- and Location-Specific Risk Assessments

Industrial park level disaster risk assessments reveal that collaborative decision-making is needed to integrate stakeholders' diverse needs and perspectives, and to enhance their understanding of risks and uncertainties. These methods help integrate disaster risk assessments conducted by various stakeholders, and include public-private dialogue (PPD), role-play, simulation games, focus groups, consultation workshops, and conferences (World Bank Group 2016; Rumore, Schenk, and Susskind 2016). These approaches help to integrate multiple risk scenarios, needs and perceptions (see table 5.2 for a more comprehensive list of industry resilience stakeholders). They raise awareness, foster common understandings of risk and resilience, build consensus around critical functions and priorities, share responsibilities, and highlight the differently perceived costs and benefits of resilience investments.

In the industry resilience context, public-private partnerships are useful during the risk assessment stage because roles and responsibilities of public and private industry stakeholders are often not clearly defined, despite their interdependencies (Haraguchi et al. 2016). Collaborative efforts improve planning for risk mitigation, preparedness, cost optimization and voluntary actions by industries. The Netherlands case illustrates how this can be done (box 4.4). In this case, government agencies and firms operating on unembanked

28 The tool has been used by a number of industrial zones and stakeholders to examine climate risks, for example, in the Ait Melloul Industrial Zone in Morocco, and India's Telangana State industrial parks. For a general description of this tool, see: https://www.sia-toolbox.net/solution/climate-expert.
For climate risk assessments conducted in Ait Melloul Industrial Zone, Morocco, see: https://www.climate-expert.org/fileadmin/user_upload/Case_Study_Summary_IZ_Ait_Melloul_EN.pdf. For the Indian case, see: https://tsiic.telangana.gov.in/wp-content/uploads/2016/05/6.-RAPID-CLLIMATE-RISK-ANALYSIS-REPORT.pdf.

areas—or areas that are not protected by flood protection infrastructure such as dikes—near the Port of Rotterdam came together to study flood risks and develop resilience measures. Through this process, the participants were able to: 1) build a common understanding of the low-risk/high-impact floods to which the port and industrial areas are prone; 2) develop collective action plans despite high uncertainties associated with flood risks; and 3) enhance capacity of firms to deal with risks and their attendant resilience requirements.

Box 4.4 Collaborative Disaster Risk Assessments Help Plan for Resilience at Multiple Levels

Figure 4.4 Rotterdam Harbor Industrial Complex

Photo Credit: © Opla

Rotterdam is one of the largest harbors and industrial complexes in Europe. As of 2019, the area contributes 6.2 percent of the Netherlands' GDP. The value added by the port cluster in Rotterdam in 2019 was estimated at approximately US$ 51.0 billion (€ 45.6 billion).[29] The disruption of port operations would have significant economic impacts both throughout the Netherlands and across global value chains. The port area contains over 120 industrial sites, 60 chemical companies, biochemical factories and oil refineries. The area is owned and managed by the Port of Rotterdam Harbor, 70 percent of which is owned by the Rotterdam Municipality and 30 percent by the Dutch government.

Challenge: Climate risks to industries in the Netherlands' critical industrial complex in Rotterdam Harbor

Fifty-nine percent of the country's land surface is susceptible to coastal or river flooding. Rotterdam Harbor falls within these flood prone areas, most of which are unprotected by dikes, and vulnerable to storm surges and coastal flooding. The economic impacts of flood damage would be significant. Under Dutch flood risk management policies, governments have no obligation to protect companies located in unembanked areas, and do not compensate them for flood damages. Twelve companies operating outside the flood defenses (e.g. dikes and storm surge barriers) are therefore responsible for their own flood preparations and damage costs. These companies thus need to understand the risks they face, and the need to prepare for them.

29 Converted to US dollars ($) at the 2019 annual average exchange rate of $1 = € 0.893, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates. € = Euro.

Solution: Establishing a public-private partnership during flood risk assessments
To address this challenge, the Port of Rotterdam initiated pilot collaborative risk assessments, and worked together with resident companies to incentivize voluntary risk mitigation actions. Six pilot studies have been conducted with tenants from unembanked areas, including chemical complexes in Botlek, and areas hosting light manufacturing, logistics, and food storage and processing companies. The participants investigated projections for floods and flood intensities, identified high risk areas, and ranked adaptations for each study area. These strategies included 1) structural measures to mitigate flooding of industrial sites by raising barriers, elevating sites and bank structures like quay walls, or "floodproofing" industrial buildings; and 2) non-structural measures such as emergency management schemes to maintain the operation of infrastructure and business functions during extreme weather events.

Participants acquainted themselves with Rotterdam's flood risk scenarios, and the challenges of planning for low-risk-high-impact events and their economic impacts. They discerned their responsibilities under current legislation and worked out the most suitable responses. In one pilot assessment conducted in Merwe-Vierhavens, an old port and industrial area, raising the ground level was not an optimal option from a cost perspective, and wet/dry proofing of the built structures was chosen. A "living with water" scheme was selected and wet-proofing is considered to lower costs of retrofitting infrastructure. All in all, flood risk at the Port of Rotterdam was best addressed as a shared concern involving companies, the port authority, municipality and national government entities.

Source: Port of Rotterdam 2017; Knulst 2017; Merk 2013; Port of Rotterdam 2019a, 2019b, 2019c and 2019d.
Note: See also Section 5 on the role of new technologies in industry resilience planning in Rotterdam.

Box 4.5 Long-Term Climate Change Impacts on Manufacturing Industries

The adverse effects of slow onset climate change events on the industry sector are expected to be felt gradually through changes in the supply of infrastructure services, climate-sensitive resources, utility costs, market demands and labor productivity. According to the IPCC (2014), climate change may impact manufacturing industries through: changes in price and quality of inputs; disruptions or changes in supply chain networks; and changes in market demand. For instance, increasing temperatures, sea level rise and salination, ocean acidification, land and forest degradation and desertification may alter the locations suitable for industrial production, and hence change the landscape of GVCs. Energy and water-intensive manufacturing sectors may suffer, especially in countries that already face water scarcity problem (GIZ 2017). Temperature rise can also significantly reduce labor productivity while increasing overall energy consumption in the manufacturing sector (UNDP 2016).

Industrial parks, utilities and facilities in coastal areas may be especially vulnerable, as shifting climate conditions are expected to alter the suitability of these locations for a wide range of industrial activities. Operation of industrial parks may also be at risk due to reduced water availability and significant changes in the operating permits of firms (WRI, Oxfam, and UNEP 2011; GIZ 2011). For example, Vietnam is exposed to substantial flood risks. In Ho Chi Minh City, by 2050, flood-prone areas within the city may increase from 23 percent to 35 percent (McKinsey 2020). As of 2018, Vietnam has 17 coastal economic zones with a combined inland and water-covered area of over 8,450 square kilometers (Ministry of Planning and Investment). Services will need to be provided to tenant firms over long periods during which these areas may be exposed to sea-level rise and more frequent floods. As just one example of impacts, many electricity substations and transmission lines are within or close to projected zones for extreme flooding events predicted for between now and 2050 (ADB 2010; 2013).

Governments in developing countries are working with international organizations to integrate long-term climate change projections into industry development and industrial park planning process. For instance, GIZ's Climate Change Adaption for Private Sector Project developed a comprehensive program to enhance adaptation of industrial parks and their tenant firms. Through the Andhra Pradesh and Telangana Industrial Infrastructure Cooperation body (APIIC/TSIIC), industrial park authorities from these regions worked with GIZ to clarify their exposure to natural hazards and the long-term effects of climate change. A Climate Change Adaptation Steering Committee was established to engage stakeholders, and the Climate Expert tool was used to help participants learn about climate change risks and opportunities. A guideline document, and various manuals on structural/nonstructural measures, financing options, etc. were developed to embed climate change perspectives in the planning of new industrial areas and development and retrofitting of existing ones.

However, there are gaps in the information needed to develop risk-informed industry policies and investments. Information on climate change impacts at smaller spatial scales is inadequate, and limited by the inherent uncertainties associated with climate models and their projections. To inform industry resilience measures for long-term climate change, further research is needed to clarify the location-specific impacts of slow onset events on industries.

Table 4.3 Understanding Risks to Industries: Example Projects

Intervention area	Name of intervention	Location	Brief description	Outcomes
Enhance national understanding of flood risks to industries.	UK National Level Assessment of Climate Change Risks to Industries	United Kingdom	The UK government periodically assesses and updates flood risk projections for the country, as well as industry damage and disruption costs associated with these projections.	The assessments inform the location of exposed industrial and commercial assets, and guide the UK government's policy actions to mitigate flood risks and inform businesses about their exposure, and options for mitigation.
Develop frameworks and tools to assess climate change risks to value chains.	Low-carbon and climate resilient industrial development in Africa.	Egypt	The Government of Egypt and UNIDO used a matrix analysis to identify industrial processes and value chains in the vegetable and fruit juice processing sectors that are vulnerable to climate change. Multiple government agencies were involved in the assessment.	The vulnerability assessment enabled firms in the value chains of food processing sectors to identify investment options to address climate change impacts on their businesses.
Develop frameworks and tools to assess climate change and disaster risks to industrial parks.	Multi-hazard risk assessment to inform BCP at Istanbul Tuzla Organized Industrial Zone.	Istanbul Organized Industrial Zone, Turkey	Multi-hazard risk assessments were performed at the industrial park, involving the park operator and tenant firms to analyze lifeline utilities and inform park-wide BCPs.	A park-wide BCP was developed based on the results of the assessments and through a PPD mechanism.
	Adaptation to Climate Change in Industrial Zones: A guide to climate risk management and opportunities in industrial zones.	Ait-Melloul Industrial Zone, Morocco	A climate expert tool was used to assess multiple hazards relevant to food processing SMEs in an industrial park, and to raise awareness of these risks, and the role of insurance as a disaster preparedness measure.	This exercise helped participants to understand a range of climate change risks specific to their SMEs, and to consider mitigation strategies, including disaster insurance.
Promote PPPs to enhance sector-and location-specific risk assessments	Collaborative climate/disaster risk assessments to inform planning and prioritization of industry resilience measures.	The Netherlands Port of Rotterdam	The Port of Rotterdam Authority piloted collaborative risk assessments to raise awareness of flood risks among firms operating in industrial complexes located in unembanked areas near the port. Flood risks were best addressed as a shared concern involving companies, the port authority and national government entities.	Participants authored a common understanding of flood risks, prioritized collective actions, and built the capacity of firms to deal with these risks.

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5

Planning and Prioritization

Once potential risks to industries have been assessed and gaps identified, the next step is to develop a national framework for resilient industries, benchmarking the framework proposed in table 3.3. Detailed strategies and action plans to integrate resilience into industry development may be further developed based on this framework. These may be implemented as part of existing national and subnational planning processes. For example, disaster and climate can be considered in the development of national industry development strategies, infrastructure development plans, industrial park's master plans and development guidelines, or area-wide business continuity, emergency preparedness and response plans. At the same time, industry perspectives can be integrated into existing national and subnational disaster risk reduction and management frameworks.

Recommended Actions

- **Identify national priorities for industry resilience.**
- **Develop a national resilient industries framework and coordination structures.**

5.1 Identify National Priorities for Industry Resilience

National governments can prioritize resilience actions and investments based on findings from the assessments described in Section 4, and in line with the national policy agenda. Governments can develop national strategies with reference to areas with high exposure to prioritized hazards, as illustrated in the UK example in box 5.1. In the UK, the Department of Business, Energy & Industrial Strategy improved flood alleviation schemes and infrastructure to protect businesses and residential areas in one of the country's main chemical-producing regions.

The policies of government agencies may be structured by risk-informed national priorities for industry resilience. In Japan, the Cabinet Office, responsible for mainstreaming DRM in sectoral policies and institutions; and the Ministry of Economy, Trade, and Industry (METI), responsible for policies and institutions for promoting industry competitiveness including SMEs, collectively create an enabling environment for industry resilience. While there is no single law, industry resilience is integrated into policies for industrial development, industry competitiveness, industrial land use planning, and DRM. For example, the Cabinet Office of Japan has been providing guidance to firms and institutions on how to go about assessing and evaluating risks for their BCPs and BCM within its Business Continuity Guidelines, last updated in 2013 (Cabinet Office 2013).

Prioritizing industry resilience actions and investments may not always occur at the national level; in some countries like India, state governments have this responsibility. In India, the provincial government of Andhra Pradesh has a State Action Plan for climate change that integrates adaptations across key industries and vulnerable areas, and identifies those requiring additional preparedness.[30] For the food processing sector, the Plan prioritizes various resilience options, such as risk mapping, shifting supply chains to less vulnerable zones, assessing climate change risks in key industrial hubs, minimizing risks by protecting transport networks, improving drainage of industrial areas such as Hyderabad, and harvesting rainwater (EPTRI 2012). In Telangana State, areas that required additional research were also identified, and approximately US$ 33.8 million was awarded to the Telangana State Industrial

30 For more details, see: State Action Plan on Climate Change for Andhra Pradesh. 2012. http://moef.gov.in/wp-content/uploads/2017/08/Andhra-pradesh.pdf.

Infrastructure Corporation (TSIIC), which is responsible for providing industrial infrastructure and has developed more than 150 industrial parks (EPTRI 2017). More than 90 percent of this fund was used to assess the vulnerability of major industrial hubs to climate-related risks and to promote adaptation measures such as sea walls, alternative rail and road access, improved drainage and alternative water supplies.

Box 5.1 UK: Prioritizing Risks and Opportunities for Industry and Business Sectors

In the UK, based on the CCRA and using the "urgency scoring method," the government identified risks and opportunities that need to be prioritized for business and industry development over a five-year period (table 5.1). It became clear that, in England, and especially the southeastern parts of the UK, more effort would be required to address flood risks and inform businesses about their risk exposure and options for mitigation. In the rest of the UK, on the other hand, the priority strategy for improving industry resilience was to better understand how firms implement flood protection, and the effectiveness of their methods.

Table 5.1 UK: Urgency Scores of Risks and Opportunities for Business and Industry

Risk/ opportunity	More action needed	Research priority	Sustain current action	Watching brief
Risks to business sites from flooding	England	Northern Ireland, Scotland, Wales		
Risks to business from loss of coastal locations and infrastructure		UK		
Risks to business operations from water scarcity			UK	
Risks to business from reduced access to capital				UK
Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments		UK		
Risks to business from disruption to supply chains and distribution networks			UK	
Risks and opportunities for business from changes in demand for goods and services				UK

Source: Sayers et al. 2015.
Note: More urgent actions include "more action needed" and "research priority"; less urgent actions are those categorized under "sustain current action" and "watching brief."

In line with these national priorities, the UK Department for Business, Energy & Industrial Strategy invested US$ 53.6 million in the Humber region to protect businesses in coastal locations from flood risks, targeting areas with high importance to industries and the national economy (UK Department for Business, Energy & Industrial Strategy 2017). Major investments included flood alleviation schemes and infrastructure to protect 113,000 businesses and residential properties in the Humber Region along the River Hull—one of the UK's four main chemical-producing regions. Key industrial assets in the flood-prone Humber Region include two major oil refineries, steelmaking sites, and major chemical producing clusters such as Saltend Chemicals Park (Humber Local Enterprise Partnership 2019). This area is one of the largest industrial clusters in the UK, and is highly vulnerable to floods and tidal surges (Humber Local Enterprise Partnership 2019; UK Department for Business, Energy & Industrial Strategy 2017).

Governments can direct land use and infrastructure development plans according to national-level risk assessments while accounting for factors such as land availability and proximity to ports, etc. Governments can invest in infrastructure that strengthens industrial parks' resilience during the development process. Road networks within or connected to industrial parks may be planned with resilience, with national-level assessments and criticality analysis informing the placement of last mile infrastructure or roads. In Mozambique, Peru, and Tanzania the World Bank used criticality analysis to support for planning infrastructure investments that can help enhance supply chain resilience (Rozenberg et al. 2017; Espinet Alegre et al. 2018; Colon, Hallegatte, and Rozenberg 2019) (box 5.2).

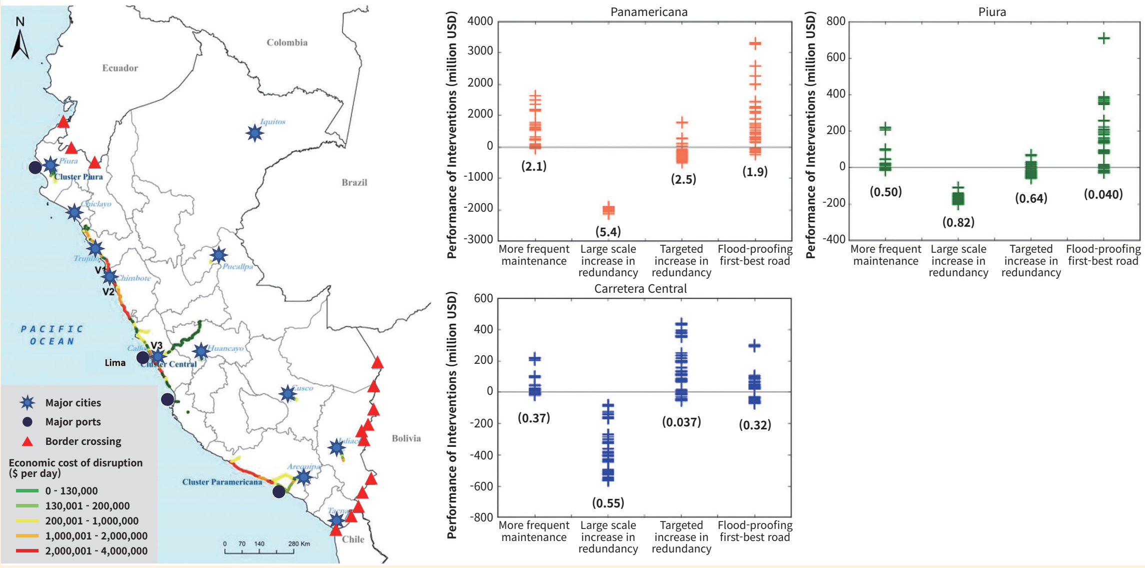
Box 5.2 Peru: Criticality Analysis for Prioritizing Resilience Investments

In Peru, technical support was provided to address difficult topography, extreme temperatures, floods, and flood-related landslides that make it difficult for firms receiving input materials and products by road to remain competitive. Overlays of flood maps with road networks allowed planners to proactively strengthen and prioritize vulnerable parts of the network (figure 5.1, panel a). Investment in flood-proofed roads was deemed advantageous, and hence prioritized, in the Piura region, where the manufacturing sector was growing following new industrial park development (figure 5.1, panel b).

Figure 5.1 Peru: Criticality Analysis for Targeted Resilience Investments in Road Networks

Panel a) Economic cost of road disruption in Peru in three critical economic clusters.

Panel b) Net benefits of four different interventions over 30 years



Source: Rozenberg et al. 2017.

Note to Panel b: The net benefits focus on avoided losses and do not include benefits of reduced road user costs during normal times. The analysis shows those proactive interventions which best protect roads against uncertain disruption losses. Numbers in parentheses refer to maximum regret expressed in billions of US dollars in the three clusters, discounted over 30 years. The shaded box shows the resilience option that minimizes the maximum regret in each cluster.

5.2 Develop a National Resilient Industries Framework and Coordination Structures

Industry resilience requires multi-sectoral and multi-level actions, which need to be coordinated across the private and public sectors. To be meaningful, these actions also need to be integrated into broader national economic strategies, industrial development policies, and institutional mandates, and should include national government agencies, municipalities, infrastructure operators, private sector entities, local communities and organizations, as in the examples of risk assessment approaches introduced in the previous section. Governments would also need to strengthen institutional capacity to coordinate and implement the framework and actions. Table 5.2 provides a detailed list of key stakeholders with suggested roles and responsibilities for enhancing industry resilience.

A leading government agency, such as cabinet offices and/or prime ministers' offices, can coordinate the efforts of government agencies which develop resilience policy and legislation at firm, supply chain, industrial park, and infrastructure servicing levels. Based on national-level disaster risk assessments, priorities for intervention, and stakeholder needs, governments can support coordinating structures and operating procedures to implement preventive measures and emergency responses. These frameworks should clarify the roles and responsibilities of leading agencies and line ministries so as to optimize synergies and avoid duplication. Stakeholders should consider the interdependencies of different sectors and functions, and identify potential bottlenecks in the value chains of a manufacturing sector, prevent common conflicts, and harmonize sectoral plans to incorporate multiple industry resilience goals (box 5.3). National governments are often best placed to:

- Identify functional relationships, interdependencies and gaps;
- Increase information flow and knowledge exchange across sectors about the disaster risks industries face;
- Prioritize policies that can be implemented and integrated across different public sector agencies; and
- Advance the integration of national efforts for promoting resilient industries.

Table 5.2 Key Stakeholders: Roles and Opportunities for Implementing the National Resilient Industries Framework

Stakeholder	Key roles and responsibilities	Opportunities for resilient industries interventions
Cabinet Office, Prime Minister's Office, etc.	Support central government policies so as to advance implementation of legislation. Promote the release of government data and improve transparency. Coordinate government's responses to crises.	Develop a national framework for resilient industries, considering the roles of different line ministries. Oversee and coordinate different policies, standards and processes set by the line ministries. Oversee disaster management and develop evidence-based post-disaster reconstruction plans.
Ministries of Finance	Develop fiscal and economic policy framework. Collect and allocate public revenues and strengthen the level of financial accountability and efficiency of the public sector. Regulate financial institutions. Create an efficient and equitable tax system.	Budget for resilient industry investments. Define the scope of risk sharing and provide finance for recovery and reconstruction. Strengthen resilience of financial institutions to address post-disaster challenges such as large insurance payouts.
Ministry of Industries/ Ministry of Trade and Industry/SME Agency	Develop, govern, and implement national industry development policies and investment promotion strategies to strengthen competitiveness of key sectors and SMEs. Develop standards to regulate competition, and quality systems to meet production requirements for domestic and international markets. Facilitate job creation, innovation and entrepreneurship in formal and informal sectors. Manage and enforce statutory obligations of the registries of companies and other legal entities. In some countries, these ministries also oversee the development of industrial parks and economic zones.	Integrate disaster resilience into industry development policies and strategies. Develop policies and guidelines to incentivize businesses to implement BCPs/BCMs, and emergency preparedness and response plans. Help key sectors and firms maintain access to domestic and international markets during disasters. Ease regulatory requirements for production and streamline licensing processes. Develop post-disaster response policies and programs to support affected industries.
Ministry or Agency Responsible for Disaster Risk Management and Emergency Response	Develop policies and mechanisms for disaster risk management across various sectors, ministries and levels of governance. Provide hazard maps and risk information.	Address DRM concerns across different national policies including industrial development agendas.
Ministry of Infrastructure and Transportation	Develop regional strategic planning and policies, technical standards, and mechanisms for managing infrastructure, including transportation infrastructure and public transport policy. Promote public infrastructure safety (e.g. roads) and provide policy support for air and seaports. Responsible for river and sea defense maintenance, and the construction of flood protection schemes. The Ministry of Infrastructure may also be involved in the development of last-mile infrastructures for industrial parks and economic zones.	Drive investment toward resilient infrastructure development. Require industrial park/infrastructure developers and operators to meet national standards or building codes, and international best practices. Recover from infrastructure and service disruptions during disasters.
Port Authority	Institute policies to manage ports and port areas.	Develop resilience-driven technical standards for port infrastructure design and construction, and logistics services. Engage businesses in port areas to collect data and raise awareness of natural hazard risks.
Ministry of Water Resource Management/ Environment	Plan, develop and coordinate long-term national policies for sustainable water resource management and environmental management. Promote conservation of natural resources. Provide technical guidance, evaluation and monitoring of oversight, and provide support to local government regarding water development and use. Coordinate and mediate different interests with respect to water use. Prepare flood control master plans for rivers and river basins. Establish data collection and monitoring centers.	Develop policies and standards to reduce disruption of water supply, and to promote wastewater treatment by industries. Integrate sustainability and circular economy principles to enhance the resilience of water supply. Minimize the release of hazardous substances into the environment during disasters.
Ministry of Energy	Develop national energy policy to enhance energy efficiency and conservation, and increase domestic energy supply. Promote the use of renewable and alternative energy through clean energy initiatives and innovative technologies, and initiate relevant research.	Develop and implement policies and standards that minimize power outages, including promotion of renewable energy, and timelines for the recovery of the national grid when disruptions occur.
Local governments (States, cities, and municipalities)	Develop policies related to land use, water management, waste management etc. Execute national building codes and other infrastructure design and maintenance standards.	Coordinate with national governments to implement disaster resilient policies and standards at the local level. Coordinate with local financial institutions to finance resilience investments by businesses.
Industrial Park Developers & Operators	Develop and operate industrial parks, and provide infrastructure and services to investors. Work with national governments, investors and resident firms meet investment needs. Showcase industrial parks to attract investors.	Craft the business case for resilience investments in support of competitive industrial parks. Develop park-wide BCPs and emergency response plans with tenant firms and service providers.
Industry or business associations/trade associations	Represent the interests of member firms, promote their collaboration, offer services and support networking among them.	Develop sector-specific contingency actions (e.g. BCPs). Communicate with governments and member firms to identify sector-specific disruption risks. Develop and provide member firms with training and educational materials.
Financial institutions	Provide loans to firms. Invest in the development and operation of industrial parks.	Conduct project appraisals for resilient infrastructure investments. Integrate disaster resilience benefits into investment analytics. Incentivize pre-and post-disaster financing as key competitiveness criteria. Help strengthen financial resilience of businesses.
Manufacturing firms	Responsible for industrial production and job creation.	Develop contingency plans, such as BCPs. Invest in disaster mitigation and preparedness through risk-informed facility designs, insurance and pre-arranged agreements with suppliers and service providers.
Civil society organizations	Support research (academia), agenda setting, represent members' interests, provide information and advice on technical issues, support capacity building of members.	Collaborate with governments and industries to assess the needs of women-entrepreneurs and female workers during disasters. Develop education and training materials on industry resilience measures.

Source: Original compilation.
Note: The names and list of line ministries are suggestive, not definitive.

Box 5.3 The United States: A National Coordination Structure for Resilient Industries

The Department of Homeland Security (DHS) established the National Disaster Recovery Framework (NDRF) and the National Infrastructure Protection Plan (NIPP) to coordinate wide-ranging stakeholder and policy inputs. The DHS defines the Critical Manufacturing Sector (CMS), which includes primary metals, machinery, electrical equipment, and transportation equipment manufacturing sectors, recognizing its key resources, national importance, and significance in upholding the continuity of other sectors of national economic importance. The CMS-Specific Plan identifies sector-specific vulnerabilities, and details options for enhancing resilience under the NIPP risk management framework. The framework accounts for the sector's unique characteristics, interdependencies with other infrastructure sectors, and risk landscape. It also identifies and protects nationally significant manufacturing industries within the sector that may be susceptible to disasters. Since its inception, the CMS has also built cross-sector partnerships, improved information sharing, created best-practice sharing forums, and improved incident response and recovery tools.

Figure 5.2 Critical Manufacturing Sector Partnership Structure

Source: Adapted from US Department of Homeland Security 2015.

The CMS-Specific Plan identifies the following goals, priorities and cross-sectoral partnership structures to manage these vulnerabilities, including:

(1) Identify relevant government agencies or departments, and develop policies and action plans for promoting resilience and security; (2) improve information sharing through focus on supply chain resilience, engagement with CMS partners, and broad cross-sector collaboration with manufacturing businesses, local and regional entities; (3) raise sector-specific risk awareness by working with sector partners to describe CMS-specific cyber, human, and physical risk profiles; (4) reduce these risks by developing knowledge, tools and capabilities to secure critical assets; and, (5) support CMS resilience through cross-sector training to improve response and recovery from disruptions.

Source: US Department of Homeland Security 2015.

Table 5.3 Planning and Prioritization: Example Projects

Intervention area	Name of intervention	Location	Brief description	Outcomes
Identify national and regional priorities for industry resilience.	UK Climate Change Risk Assessment.	United Kingdom	The UK government used an urgency scoring method to rank the natural hazards faced by industrial parks and their infrastructure, including risks and opportunities.	The assessment informed key industry resilience investments such as flood alleviation schemes and infrastructure investments for the UK's main chemical producing regions.
	State Action Plans on Climate Change for Andhra Pradesh and Telangana.	India	The provincial governments of Andhra Pradesh and Telangana developed Action Plans that integrated adaptations across key industries and industrial areas, and prioritized various resilience options.	The State Action Plans enabled the State Industrial Infrastructure Corporation to access finance required for additional risk assessments and industry resilience investments.
	Criticality analysis for targeted resilience investments in road networks.	Peru	Highly vulnerable road networks in the country's major economic clusters were analyzed using map overlays to rank vulnerabilities and prioritize interventions.	Flood-proofing was identified as a priority proactive intervention for specific areas of the road network.
Develop a national resilient industries framework and coordination structures.	Critical Manufacturing Sector Partnership Structure	United States	The US DHS established a national coordination structure for resilient industries, integrating various stakeholder inputs and accounting for interdependencies and responsibilities among firms and the infrastructure system.	The national coordination framework enabled stakeholders to identify sector-specific vulnerabilities, and to enhance resilience under the NIPP risk management framework.

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6

Mitigation and Preparedness

Mitigation and preparedness actions may be the most important and cost-effective promoter of industry resilience. While the precise occurrence, location, and impacts of natural hazards may not be predictable, the high-risk profiles of certain areas may justify advance, pre-disaster investments. Governments can encourage disaster mitigation and preparedness through policy, infrastructure and financing interventions.

Recommended Actions

- **Promote business continuity planning and management.**
- **Help industries maintain global value chains.**
- **Promote resilient industrial park development.**
- **Minimize infrastructure disruption in industrial parks.**
- **Conduct alternative cost-benefit analyses.**
- **Analyze financial impacts and needs.**
- **Support up-front resilient infrastructure investment.**
- **Provide financial support for contingency planning and advance disaster risk financing.**

6.1 Policy

Disaster risk management principles need to be integrated across various policies to support economic and industrial development, and infrastructure development plans and investment frameworks.

6.1.1 Promote Business Continuity Planning and Management

Business continuity is an essential element of industry resilience, and governments need to encourage firms to develop plans to ensure business continuity. Business continuity planning and management (BCP and BCM) help organizations identify the potential effects of disruptions to their critical operations before a disaster strike, and specify effective responses and recovery measures for postdisaster business continuity (Ono & Ishiwatari 2011). National governments can promulgate regulations and provide incentives for the development of BCPs among firms, and they can support firms, industrial park operators, infrastructure operators and service providers to develop contingency plans. "In Japan, the GEJE (2011) revealed that BCPs developed by firms and organizations in isolation were insufficient to manage the impacts of disasters on industries. Therefore, regulations and policies were introduced at national, subnational, sectoral, industrial park, and firm levels to encourage the adoption of BCPs and to establish a broad culture of preparedness transcending individual firms (World Bank 2020b). They include, but are not limited to:

- ***Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry (2013)*** promotes the disaster preparedness in the private sector through awareness raising, capacity building, and the development of guidelines and tools for private sector business continuity planning.
- ***Act on Strengthening of SMEs (2019)*** incentivizes SMEs to take preparedness measures through tax benefits, financial support, and/or subsidies to SMEs with an approved Cooperative Business Continuity Enhancement Plan. The law also emphasizes the roles of large firms and financial institutions in supporting SMEs to enhance resilience.

Government-issued BCP guidelines, manuals and resources can also help firms raise awareness of the importance of contingency planning to mitigate losses and the assessments needed to inform BCPs. In Japan, the Cabinet Office and METI provides manuals to guide companies of various sizes to develop BCPs. The guidelines describe a general flow and timeline for BCP activation and implementation. They advise on when and which response and recovery actions should be implemented. For example, the guideline recommends that initial responses, including checking the safety of employees, damage assessment, contacting partner companies and securing business continuity should be completed within a few days. By 2017, 64 percent of large companies and 32 percent of SMEs surveyed in Japan had developed BCPs, showing a substantial growth in BCP development since 2007, when only 19 percent of large companies and 12 percent of SMEs had developed BCPs (World Bank 2020b). In the United States, Continuity Guidance Circulars *(*FEMA 2018) and other BCP-related manuals and resources made available online to guide:

- *Risk assessments to identify threats and hazards.* The assessments detail likelihood and impacts of disasters, peg levels of readiness, and identify opportunities to improve continuity processes.
- *Business process analysis (BPA)* to identify essential functions and map resources needed to execute them. Within the analysis, businesses must identify workflows, processes, personnel, stakeholders, systems, data, and facilities required to deliver specific functions.
- *Business impact analysis (BIA)* to evaluate the impacts of disasters on business continuity. This involves determining the vulnerability of different functions to specific impacts, anticipating times and durations of these impacts, and their predicted effects on operations. The scope of analysis includes direct and indirect impacts on business activities, e.g., day-to-day sales and income, expenses, and contractual delays.

To better assist industry associations and firms to develop BCPs, governments need to examine specific data from production networks, market structure traits, and the competitive environments of firms. Businesses need government support on providing comprehensive industry-level studies that detail options, costs (e.g. business disruption costs), and possibilities on alternative suppliers. Governments could also provide resources or ideas to fund and create public-private or just private platforms to manage cross-sector disruptions due to disasters (see also box 8.1). Access to more accurate information and updated forecasts should also be developed based on deeper understanding of the competitiveness benefits of BCP for enterprises of all sizes and include their best practice examples, such as those highlighted in box 6.1.

Box 6.1 BCP Best Practices for Large and Small Firms in a Competitive Environment

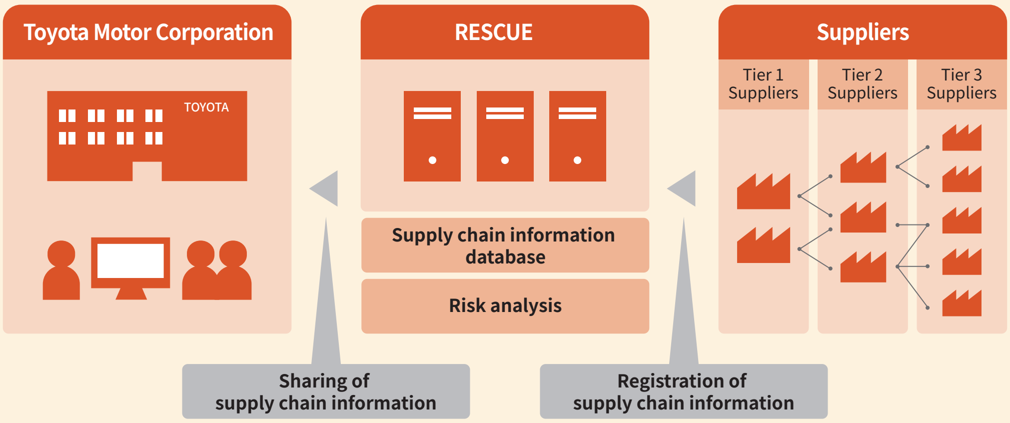
How can large firms improve BCPs and mitigate supply chain disruption risks?

Large firms have numerous multi-tiered suppliers; therefore, they can play a leading role in catalyzing collaboration with firms in their supply chain. For example, since 1983, Toyota's supply chain management strategy is based upon the principle of "Just-in-Time", in which each process produces only what is needed for the next process in a continuous flow. Following the GEJE, to adapt and strengthen their supply chain strategies, Toyota conducted a survey of suppliers to identify vulnerable supply linkages, and developed a supplier database called REinforce Supply Chain Under Emergency or "RESCUE" (Toyota 2019). RESCUE stores information about thousands of parts stored at 650,000 supplier sites, including information on small suppliers, such as what components they make, where they are made, and which companies contribute to the production process (Kubota 2016). This database helped Toyota identify and bypass bottlenecks by diversifying production where possible (Greimel 2016; Kubota 2016) (see also Section 8.2.2 for new technologies that increase visibility of complex supply chain networks).

Balancing trade-offs between geographically diversified production networks and efficiency is essential for mitigating disruption following disasters. Toyota also changed its supply management structure from a "pyramid" to a "diamond-shaped" structure which allowed the company to substitute disaster-affected suppliers with operational ones at times of disasters. In addition, it implemented an improved "just-in-time" production and delivery system, effectively limiting the storage of components that can cause economic losses when stored items are damaged (Tajitsu 2016). In this sense, the RESCUE system helped visualize diversified production networks, accelerate the recovery of damaged facilities, and enhance the portability of production capability (Fujimoto et al. 2016). These contingency plans or BCPs cannot be implemented effectively without the cooperation of suppliers across the country, many of which are SMEs that received support from the government to develop BCPs.

This strategy has proven effective. In particular, these changes were effective during the earthquakes that hit Kumamoto's automobile and electronics factories. In the immediate aftermath of the quakes, Toyota and Aisin Seiki, whose plants were located in Kumamoto, began working on Plan B according to their joint BCPs. Aisin Seiki's plants, which produced parts for Toyota, had no electricity for at least 4 days. This forced Toyota to suspend operations at one of its plants. Aisin shifted production of the components needed by Toyota to other factories, including plants in China and Mexico, minimizing disruptions to Toyota's output (Mainichi Daily News April 25, 2016). These strategies, including the RESCUE database system, are now shared with other suppliers and manufacturers, and have generated collective transformation of the automotive sector (figure 6.1).

Figure 6.1 RESCUE System to Store Supply Chain Information



Source: Adapted from Toyota 2019.

How can small firms improve BCPs and mitigate their supply chain disruption risks?

Small firms, on the other hand, have limited capacity and resources to manage supply chain disruption. Therefore, SMEs should consider developing BCPs and pre-arranged agreements with partner companies, clients, and banks to secure financial and human resources support post-disaster. Oil Plant Natori, a small firm that recycles industrial waste to manufacture fuel-related products in Natori city, Miyagi Prefecture, Japan, provides an example. During the GEJE, their factories and offices were inundated by the tsunami, and employees had to evacuate to the rooftops. However, despite the loss of large tanks, and damage to machinery and facilities, they resumed operations 11 days after the earthquake, primarily because of the following features of the company's BCP (Sasaki and Okano 2013):

- The company had identified its core business activities and was able to identify business areas critical for resuming operations.
- The company had a backup IT system, and could obtain needed information right after the disaster destroyed their facilities.
- The company had pre-arranged agreements with partner companies, clients, and banks. Based on these agreements, it obtained supplies and equipment from its partners, and was rapidly granted a bank loan.

Source: Toyota 2019; Kubota 2016; Greimel 2016; Tajitsu 2016; Fujimoto et al. 2016; Mainichi Daily News April 25, 2016; Sasaki and Okano 2013.

Collaborative approaches are essential to scaling-up of contingency planning across sectors and regions. One effective strategy is to encourage joint development of BCPs between state, local, and city governments, and industry stakeholders in line with national disaster risk management and industry development policies. Before the GEJE, BCPs were formulated primarily at company level, with little partnership between companies, or between companies and local government. To address this problem, the Kyoto Prefecture government provided support for private sector stakeholders to collectively develop and implement BCPs based on their common interests. This new ethos was instilled by the Kyoto BCP Promotion Council, founded in 2012 to effect prefecture-wide application of BCPs across industry sectors. Various measures have emerged, including MoUs between the prefectural government and industrial associations to share damage scenarios, joint workshops to enhance disaster preparedness, and mutual support agreements among local financial institutions. These measures are enhancing BCP implementation rates, and collaboration between stakeholders, including industrial entities, infrastructure companies, financing institutions, logistics companies, municipal governments and the Kyoto Prefectural Government (for further details, see World Bank 2020b).

Pre-arranged agreements, or strategic contractual arrangements, established *prior to* disasters, can also help governments, industry associations, industrial parks, and a large number of firms collectively minimize losses and recover quickly. Pre-arranged agreements can be made as part of collective BCPs. They allow for coordinated disaster responses which address the complex interdependencies underlying collective vulnerability, and the efficiencies made possible through coordination. Firms need to identify interdependencies coupling them with each other, and other stakeholders, and to align their BCPs with as wide a spectrum of these constituencies as practically possible. These alignments may span sectors and regions, crossing multiple formats, objectives and operational boundaries, and can take the form of legally binding contracts, non-binding memoranda, and undertakings to share information, equipment, personnel and other resources. Once activated, pre-arranged agreements provide innovative ways to implement contingency plans, speed up recovery and maintain competitiveness.

Policy support from national and local governments to encourage the collaborative approach to BCP can help improve firms' supply chain risk management strategies, which, in turn, help mitigate impacts across multiple value chains and sectors. These strategies include joint BCPs with partnering companies, pre-arranged agreements across sectors and regions, and diversifying supply chain networks across the country (and even cross borders) as part of their BCPs. In Japan, after the GEJE, automobile manufacturers implemented these strategies and significantly reduced supply chain disruption (box 6.1). Geographically-diversified supply chains connecting multiple firms are more likely to offer substitute sources of supply when disasters strike, and supply chains extending beyond affected areas are more likely recover quickly from impacts (Todo et al. 2015). During the 2011 Thailand floods, a Japanese automotive manufacturer recovered more quickly than its competitors because it had diversified its supplier base, and owned alternative sources of supplies (Haraguchi and Lall 2015).

BCPs may also help firms prepare for disruptions caused by disease outbreaks or pandemics (box 6.2). For example, firms may be able to identify:

- Need for employees to self-isolate, care for families and avoid public/workplaces during outbreaks, leading to lack of manpower;
- Delayed procedures, cancelled orders, or difficulties exporting products;
- Supply chain disruptions;

- Changes in demand for specific goods and services such as disinfectants, masks, and delivery services;
- Restrictions on business trips and meetings; set-up costs of remote working systems; and
- Securing financial resources to prepare for prolonged impacts of pandemics.

Box 6.2 BCPs During Pandemics

BCPs for pandemics may need to consider different impacts to those for disasters. Pandemics do not damage physical assets such as infrastructure, buildings, and equipment, but may disrupt infrastructure services and business operations through their effects on people, inputs, and demand. Pandemics cause people to become sick, and sometimes to die, with attendant consequences. Disasters are location-specific, and of short duration, and their direct physical impacts may be easier to contain. Disease outbreaks or pandemics may occur over large areas, for long periods, affecting entire economies and societies, and producing multiple, complex, and cascading consequences.

BCPs for pandemics must account for these differences. For example, they may need to consider whether and how remote-work should be arranged, which core functions can be maintained, how to furlough employees, whether to product switch, when to resume operations, and under what conditions. During pandemics, major consequences flow from the responses of governments, and whether or not lockdowns or states of emergency are imposed. Responses may also be affected by the actions of the World Health Organization (WHO). At the level of firms, the effects of illness, social distancing requirements, and loss of employees through lockdowns will have multiple consequences for businesses.

BCP activation may also be determined by the sizes of firms and types of sectors. For instance, during pandemics, the food processing sector faces increased consumer demand since consumers are expected to stay and eat at home. However, suppliers, employees, and customers may be infected during pandemics, leading to labor shortages which impact on business continuity. Thus, BCPs for the sector must include plans to maintain business continuity while meeting increased demands; or weather decreases in supply, demand, and availability of labor. BCPs may also need to identify core business items, alternative suppliers or logistics partners, and product substitutes.

Source: UNIDO 2020; The Food Industry Association 2020.

Industrial park-wide BCPs are effective policy tools for collective contingency actions. Firms, infrastructure operators, and utility service providers are jointly vulnerable to disasters. Therefore, it is in their interests to plan together because they often rely on shared resources, infrastructure and services. In Japan, an industrial park-wide BCP has been developed for Akemi Industrial Park, led by the Akemi District Disaster Management Committee. With more than 120 companies located on the 659 hectares of reclaimed land, strategic areas of park-wide collaboration and collective solutions were identified to complement the BCPs of tenant firms. The park-wide BCP emphasizes collective approaches, including shared evacuation sites and resources for medical staff, search and rescue efforts, fuel for heavy/construction equipment, support systems for emergency restoration of business facilities, and disaster response activities. The Akemi Industrial Park BCP was informed by the experiences of significant supply chain disruptions and associated losses from the Niigata Chuetsu-Oki Earthquake in 2007, a large typhoon in 2009, and the significant future risk of the Nankai Trough Earthquake. The GEJE of 2011 led the Akemi Industrial Park to review and revise its BCP to focus on the safety of its workers. The updated BCP integrates tsunami evacuation, search and rescue, communication, protection from liquefaction, and transportation disruptions. In Turkey, ITOIZ management entities and firms have collaborated with on-site technicians and engineers, using BCPs to address lifeline utility disruptions (box 6.3). Park-level or area-wide BCPs also help identify opportunities for structural measures, including resilient infrastructure investments.

Box 6.3 **Turkey: Industrial Park BCP in Istanbul Tuzla Organized Industrial Zone (ITOIZ)**

Challenge
ITOIZ, one of the 8 organized industrial zones in Istanbul, hosts automotive, steel, electronic and pharmaceutical firms. Despite its geographical and economic advantages, Istanbul and Tuzla are prone to disasters. Istanbul city is located on a highly active seismic zone, prone to earthquakes.

Solution
The Istanbul Chamber of Industry and the World Bank partnered with ITOIZ to increase competitiveness of the OIZ and its tenant firms by identifying risks and developing a BCP. The BCP was developed in stepwise fashion to assist ITOIZ management staff and firms in emergency decision support.

Result
The BCP development process highlighted the role played by the Organized Industrial Zone (OIZ) management entity in minimizing the impact of industrial infrastructure damage on business operations. The OIZ understood that reputational damage and disaster-recovery costs reduced ITOIZ's competitiveness, and used its coordinating functions to minimize lifeline utility disruptions. As part of the BCP, stakeholders established Recovery Time Objectives for lifeline utilities—i.e. time frames for lifeline utilities to resume operations before generating unacceptable consequences for tenant firms. During BCP development, it was recognized that on-site technicians and engineers, and other service providers, required capacity building to help them participate in developing the BCP. Furthermore, it was found that monitoring, evaluation, and reporting systems required tailoring to meet BCP standards.

Source: Bles and Özbek 2018.

In addition to serving as policy tools for collective contingency actions, park-wide BCP development processes themselves can serve as capacity-building tools. This is because these processes require the participation of many stakeholders. In Thailand, for example, the Bankadi Industrial park BCP engaged numerous stakeholders across different sectors, including but not limited to: the National Economic and Social Development Board of Thailand (NESDB), Industrial Estate Authority of Thailand (IEAT), Communication Authority of Thailand Plc., the Federation of Thai Industries (FTI), Department of Disaster Prevention and Mitigation (DDPM), Department of Water Resources, Department of Highways, the provincial government of Panthumthani Province, Metropolitan and Provincial Electricity Authorities, Provincial and Metropolitan Waterworks Authority, and Bank of Thailand (ADPC 2017). These stakeholders learned how to develop and implement BCPs in industrial parks by jointly identifying bottlenecks, business impact areas, and critical resources needed for post-disaster situations. A wide range of Area BCM strategies were identified, and evaluated for their cost-effectiveness, environmental sustainability, social impacts, efficacy, political sensitivity, and risks.

There is a growing demand in the industry sector for training on DRM and the development of BCPs. However, most developing countries lack these training opportunities, particularly for SMEs. Surveys by the ADPC (2017) discovered that only 10 percent of firms in Indonesia and Vietnam, 20 percent in Thailand and 25 percent in the Philippines have attended training. The same survey revealed that the most desired training was on how to improve disaster preparedness, including disaster drills (ADPC 2017). In Vietnam, the top three government incentives for BCPs were: 1) tax credits, deductions, and exemptions; 2) subsidies, grants, and soft loans for disaster preparedness; and 3) provision of technical assistance, consultancy services, or training in BCP preparation and disaster preparedness (ADPC 2017). To address this challenge of capacity development for BCP preparation, there are several manuals and seminars, including those developed by the APEC (2013, 2014).

BCP/BCMs may be effective for SMEs lacking technical resources to adopt resilience measures (Kato & Charoenrat 2018). In Thailand, the Ministry of Industry, Office for Small and Medium Enterprise Promotion (OSMEP), Department of Disaster Mitigation and Preparedness

(DDPM) and representatives of SMEs, including those who had gone out of business during the 2011 floods, were offered BCP training. SMEs account for 90 percent of businesses in Thailand, and at the time of the 2011 floods, 30 − 40 percent of these firms had to close their businesses due to damages and losses. The training included essential steps of developing BCPs, including conducting business impact analyses, risk assessments, various BCP and recovery options, and costs and benefits of these strategies.

Finally, and importantly, policy makers should make sure that BCPs and pre-arranged agreements are established in ways which maintain competitive market structures, so that opportunities associated with industry resilience planning do not lead to price fixing, cartel formation, or discriminatory practices by privileging the interests of certain types of firms. Firms in Japan have found establishing reciprocal cooperation agreements between competitors in different regions to be beneficial and effective in strengthening overall business and resilient industry (World Bank 2020b); however, this may not always be the case in emerging economies. Large or dominant firms with multi-tiered suppliers can exert undue influence on supply chains through their power to dictate contractual agreements with smaller firms. Pre-disaster inter-firm agreements relating to industry resilience initiatives should not be used to perpetuate negative buyer-seller relationships, protect privileged organizations, entrench oligarchs, or create barriers to market entry. Such negative alterations to market structure may occur in emerging markets, where large firms are often politically connected state-owned enterprises (SOEs) which operate across multiple markets and sectors (Pop et al. 2019). Policy reforms to preserve healthy competition in the manufacturing environment should be implemented in parallel or in advance of industry resilience programs to prevent the excessive dominance of specific firms, prevent collusion, moderate the costs of market entry and halt the protection of vested interests.

6.1.2 Help Industries Maintain Global Value Chains

Studies indicate that disaster-resilient trade regimes and the continuity of port and logistics functions are critical to business continuity. Recent WTO research identified a number of customs and border issues, including: delays in triggering emergency legislation, burdensome and complex license requirements, delays in securing visas and recognizing qualifications of relief personnel or engineers; control, inspection and release procedures that are not well prepared for emergency situations, and uncertainties with respect to the scope and duration of exemptions (WTO 2019).

Trading partners of disaster-affected countries, or of countries facing relatively high disaster risks can consider how best to support industry resilience through their trade policy regimes (Adinolfi 2019). Ideally, such consideration should be given before disasters disrupt their trade infrastructures and flows. In some cases, this may mean refraining from measures that would restrict trade in the disaster-affected countries. In others, it may involve taking positive actions to facilitate the trade of a disaster-affected country (i.e. encouraging exports from that country, such as purchasing personal protection equipment and test-kits during pandemics, or importing drainage pumps to remove flood waters). Regulatory measures can provide “continuity management” in customs operations (Adinolfi 2019). The WTO study (2019) asserts that trade facilitation measures can expedite the movement, release and clearance of traded goods, which can in turn help mitigate supply chain disruptions. The study cited the increase of container traffic into the damaged port of Roseau in Dominica following Hurricane Maria, in which imports rose from 80 to 300 containers per week. The study noted that trade facilitation among bilateral and regional partners (e.g., the Caribbean Disaster and Emergency Management Agency and the Caribbean Customs Law Enforcement Council for the case of Dominica) could have played a vital coordinating role in managing this surge of imports to affected nations.

Trading partners of disaster-affected countries can establish cross-border BCP initiatives to minimize global value chain disruptions. Cross-border BCPs can enhance collective actions between firms operating across many countries to minimize GVC disruptions during emergent situations. For example, after the GEJE and the floods in 2011, the Governments of Japan and Thailand signed an MoU to initiate "the Otagai Project"[31]—a project to encourage cooperation among companies in the two countries under the "sister-cluster" concept through a BCP (box 6.4). Following the floods, the two governments agreed to attend to supply chain resilience and strengthen industrial cluster partnerships beyond borders (JICA 2014). METI proposed a comprehensive package of government measures to support the recovery of SMEs, including the Otagai project. Officially launched in 2011, the project was executed by the Thailand Ministry of Industry, with support from NESDB. The industrial parks affected by floods in Ayutthaya, Pathumthani, Bangkok and Samut Prakan, were initially selected as target groups of the project.

Box 6.4 Cross-Border BCPs Minimize GVC Disruptions

The Otagai business network improves the trade and supply chain functions of the partner countries. In Thailand, where much FDI came from Japanese investors, strengthening supply chain resilience and maintaining its attractiveness as a major industrial hub in Asia was critical in the face of disasters. Therefore, Thailand's Ministry of Industry developed the project as a means to increase FDI and attract more Japanese SME manufacturers into Thailand; the Ministry introduced technologies used by Japanese infrastructure and construction companies to Thailand, increasing investment by Japanese firms. These actions created business opportunities for Japanese firms and SMEs seeking to expand their businesses in Thailand. During emergencies, the network preserved customers' confidence in both Thai and Japanese companies. A similar project was launched in 2014, connecting rice processing companies in Nakhon Sawan Province in Thailand with those in Niigata Prefecture in Japan. The project aimed to increase cooperation between the countries to maintain rice supply during disasters, and to help Thai companies learn and leverage Japanese rice processing technologies to develop new value-added products.

Source: JICA 2014.

Governments can use trade agreements to support firms and value chains to maintain business continuity and GVC access during disasters. Following the Haiti earthquake, trade preferences made available through the Haitian Hemispheric Opportunity through Partnership Encouragement Act II (HOPE II Act) helped secure business and reputational continuity of Haiti-based garment manufacturers. In this case, earthquake damage to Haiti's Port-au-Prince port infrastructure cut the garment industry's export-reliant connections to the GVC. Haiti's link to the textile and apparel GVC was particularly vulnerable to port disruption because it specialized mainly in final assembly and export of garment products (World Bank 2009). These exports, accounting for over 80 percent of the country's export revenue, were jeopardized when harbor damage severed access to US markets. This jeopardy was mitigated, however, by HOPE II's specification that Haitian apparel exports, if directly shipped from either Haiti or the Dominican Republic, could enter duty-free into the US market regardless of the source of origin.[32] These direct shipment and flexible rules of origin clauses allowed Haitian garment manufacturers to re-route exports through the neighboring Dominican Republic,

31 Otagai, in Japanese, means "each other" or "together"; Otagai Business Continuity therefore refers to "a plan to help each other while facing trouble."

32 In May 2008, the US Congress passed an extended HOPE bill—HOPE II. A number of important preferences under the HOPE II bill were relevant to increasing industry resilience at the time of the 2010 earthquake. These preferences included 1) duty-free treatment for apparel products that are wholly assembled or knit-to-shape in Haiti with between 50 and 60 percent value from Haiti, the United States, a US free trade agreement partner or preference program beneficiary, or a combination thereof; and 2) permission for Haitian goods to enter the United States duty-free if shipped either directly from Haiti or through the Dominican Republic, which allowed "co-production with the Dominican Republic." (*Source:* International Trade Administration. 2019).

keeping their businesses alive and maintaining export performance until Port-au-Prince harbor's operational capacity was restored. Therefore, the strengthening of trade preferences could be considered, particularly for developing or least-developed country (LDC) members that have adopted domestic legislation on disaster risk management (Adinolfi 2019).

For firms in GVCs, redundancy confers resilience in the face of shifts in market supply and demand. In the supply chain management context, redundancy includes increasing inventory, contracts with multiple suppliers for the same parts, and duplicating components of production and IT systems (Haraguchi et al. 2016). Redundancy allows firms to continue operating despite supply shocks. For example, during the 2011 floods in Thailand, Nissan recovered faster than Honda and Toyota because of stored inventories and multiple suppliers (Haraguchi and Lall 2015). Research shows that redundancy increases competitiveness during disasters and normal operation (Bain & Company 2020). During normal times, companies with resilient supply chains respond rapidly to shifts in market demand, increasing plant output, customer satisfaction, savings and cash flows.

Firms may need to consider trade-offs between redundancy and just-in-time strategies for efficiency and cost-reduction (Christopher and Peck 2004; Sheffi and Rice 2005; Haraguchi et al. 2016). Just-in-time strategies see companies receive goods only as needed, thereby reducing inventory costs, and contrast with the redundancy approach in which sufficient inventories are held to absorb unexpected demand.

Flexible assembly or production systems help firms address the trade-offs between efficiency and redundancy required to survive disasters. Flexible supply networks offer alternatives, and accommodate rapid material sourcing, product design, development and testing, and distribution (Sheffi 2005; Schatteman, Woodhouse and Terino 2020). Flexible supply is conferred, for example, by standardizing parts and production systems so that they are interchangeable and interoperable, and thus more likely to survive disruptions (Haraguchi et al. 2016). Toyota has multiple capabilities at each of its plants to add flexibility to supply chains (Sheffi and Rice 2005), and many of its plants are able to produce cars, when needed, for different regions/markets (Sheffi and Rice 2005). During the global COVID-19 emergency, the notion of establishing flexible production systems has taken the form of repurposing production processes—a rapid response to the global shortage of COVID-19 PPE that can save lives by using idle manufacturing capacity (see more details in box 7.3).

6.1.3 Promote Resilient Industrial Park Development

Policy makers and industrial park operators can use master plans and guidelines to integrate resilience into the siting, design, development and operation of new and existing industrial parks, which can collectively enhance competitiveness across firms and sectors. During greenfield developments, governments and industrial park developers need to make sure the following core elements are met: site selection based on risk analyses; essential and efficient infrastructure, utilities, and road networks; review of environmental and social impacts; internal land zoning; buffer zones for ecologically sensitive areas around or within industrial parks; procedures to safely locate high risk industries and cluster synergistic industries. Master plan development should be informed by the site-specific risk assessments highlighted in Section 4 and reviewed periodically and updated if required. Appropriate risk mitigation or reduction efforts, including risk-informed critical infrastructure planning, siting and structural designs (discussed in more detail in Section 6.2), should also be included in the master plan.

Although the location of industrial parks is based on availability of land, existing infrastructure and access to labor and markets, governments can, from the outset, restrict industrial park development in areas with high exposure to natural hazards. In India, by law, industrial park siting is disallowed in natural hazard zones, including areas with high risks of floods, tsunamis, and earthquakes (GIZ 2018). Examples of the industrial park siting restrictions in India include:

- In coastal areas, the industrial site should be at least 0.5 kilometers from the high tide line.
- In flood plains of riverine systems, the industrial site should be at least 0.5 kilometers from floodplains.
- Areas likely to be affected by floods with a 10-year return period should be kept reserved only for gardens, parks, playgrounds, etc. Residential or public buildings, or any commercial buildings, industries, and public utilities should be prohibited in these areas.

In Gujarat, India, the Special Economic Zone (SEZ) Authority developed guidelines to protect firms from earthquakes, floods and cyclonic storms (Government of Gujarat 2004, 2007). Critical Area guidelines were added to the Gujarat SEZ Act to identify extreme and low risk zones in which industrial activities and design requirements were specified.[33] These guidelines noted that sites with high disaster risks were not to be considered for industrial use. They also required that site evaluations should note the possibility of failure of protection works during extreme disaster events. Specific requirements included:

- Industrial buildings and infrastructures in hazard prone areas should meet standards in the Indian National Building Code;
- Construction of embankments/bunds;
- Raising the planning area above the high flood level;
- Construction/improvement of drainage from the planning area;
- Flood-proofing of infrastructure works;
- In the Extreme Risk Zone, manufacturing or handling, storage, and disposal of hazardous substances are not allowed. Electric substations, sewerage treatment and disposal plants, buildings and hospital complexes are also restricted;
- Electricity infrastructure designed to withstand cyclonic wind pressures;
- Cyclone shelters and schools should be constructed on raised ground with retaining walls and be able to resist winds of at least 150 kilometers per hour.

Governments can also enact and enforce regulations to protect ecologically sensitive areas such as national parks, wetlands, and forests to increase disaster management capacity and regulate industry development in these areas. In Gujarat, India, for instance, SEZs should not occupy sensitive areas such as wetlands, forests, mangroves and coral reefs (Government of Gujarat 2004). Protecting ecologically sensitive areas is critical for environmental impact mitigation and conservation, but also has resilience implications. In coastal areas, for example, mangroves improve resilience in the form of coastal defense services by attenuating tidal waves and storm surges (World Bank Group 2016), and are a reminder that natural capital should be considered as resilience measures from the outset in master planning processes (for details, see table 6.2).

Ideally, industrial infrastructure should be planned, designed, constructed and operated, based on risk-informed national standards and hazard maps, and updated to integrate lessons learned from recent disasters. Such updates can trigger public and private

33 Extreme risk zone is an area within 0.5–3 kilometers from high tide line; low risk zone is an area located within 3–10 kilometers from the high tide line.

investments in both structural and non-structural measures of resilient infrastructure (e.g. coastal embankments and dikes). As an example, following the 2011 floods, the Government of Thailand updated design criteria, unlocking public investment in dikes and embankments. Before the 2011 floods, dikes and embankments were constructed on the basis of 10-year return periods,[34] or a 10-percent chance of floods, with built-in safety margins. The height of dikes around industrial parks in the Chao Phraya Basin were at one to two meters above mean sea level, which did not protect tenant firms from the 2011 floods. Following the 2011 floods, the Cabinet Office of Thailand authorized the Industrial Estate Authority of Thailand (IEAT) to modify design criteria for flood protection and drainage (table 6.1). The Thai government changed the design return period to accommodate more frequent and intensifying floods. Drainage capacity requirements for retention ponds and dewatering systems have also been updated to take account of the 2011 flood data.

Table 6.1 Thailand: Revised Standards for Flood Protection Infrastructure in Industrial Parks

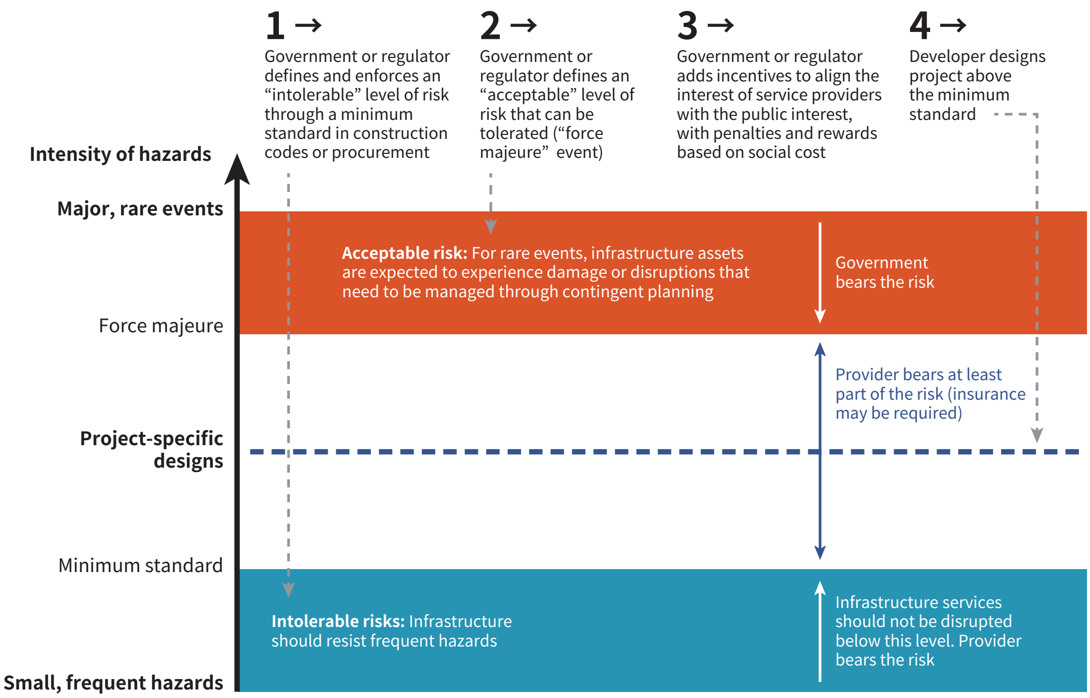
Type of measure	Design criteria (Before floods in 2011)	Revised design principles and criteria (After floods in 2011)
Flood protection dikes	• Must be higher than 10-year period max. flood level (+ 0.5 m free board) • Width of road should not be less than 2.5 m • Compacted clay 0.2 m thickness • Dikes should not disturb waterway	• Must be higher than ***70-year period max. flood level*** (+ 0.5 m free board) • Width of road should not be less than 2.5 m • ***Strong structure that can resist hydro-pressure*** • Dikes should not disturb the ***volume and direction*** of the waterway
Fill earth cover	• Cover the entire area, allow 0.5 m higher than the maximum flood level	• Cover the entire area, allow 0.5 m higher than the ***70-year period maximum flood level***
Retention pond and dewatering station	• Provide retention ponds and dewatering stations for drainage with spare pumps and serviced roads (compacted clay of 0.2 m thickness and 2.5 m width at the minimum) for maintenance	• Provide retention ponds and dewatering stations for drainage with spare pumps available ***within two hours. Capacity and efficiency of spare pumps should equal those of working pumps. Provide service road around the retention ponds.***
Dewatering system	• None	• ***Capacity and direction of outer waterway should be considered in designing the dewatering system*** • ***Provide water monitoring system, early warning system and emergency response plan for flood protection*** • ***Provide periodic maintenance and prepare annual inspection report***

Source: IEAT 2012.
Note: In bold are the revised standards.

Governments need to make sure that the designs of industrial infrastructures, buildings and facilities comply with national engineering design criteria, technical standards and building codes (figure 6.2). Consistent regulations and standards on the acceptable risks create incentives for developers, service providers, and investors to comply (Hallegatte, Rentschler, and Rozenberg 2019), and can unlock resilience investments. Governments also need to set minimum standards for disaster mitigation for different levels and types of hazards based on the best available information, and to update them periodically to reflect changes in understanding of natural hazards.

34 This means that there is a 10 percent chance of a flood occurring in an any given year.

Figure 6.2 **Design Standards and Minimum Requirements for Disaster Mitigation for Different Levels of Hazards**



Source: Hallegatte, Rentschler, and Rozenberg 2019.

Examples from around the world show that governments in disaster-prone countries have identified high-risk areas and established these minimum standards. They are either informed by risk assessments conducted at the national level, or benchmark international standards**.** In Bangladesh, which is increasingly threatened by floods, cyclones and earthquakes, the government has structured the National Building Code to address risk areas, defined as: Cyclone Prone Areas, Surge Prone Areas, Risk Areas (RA) and High Risk Areas (HRA). These areas are designated according to the possibility of cyclone storm surges (Government of Bangladesh 2015).[35] To guide construction, flood elevations, surge heights and wind velocities are specified for each area. These standards also inform the design of industrial buildings, site-specific master planning, and infrastructure and services in industrial parks, as in Thailand (table 6.1) and New York City (see box 6.5).

Updating resilient building codes for industry and infrastructure assets requires coordinated efforts between national and local level governments. Local governments play essential roles in land use planning, compliance with risk-informed national building codes for industrial infrastructure, and incentive programs linked to design standards. They are also well placed to respond to emerging locality-specific data or updated information following disasters. Following Hurricane Sandy, the New York City government updated building codes called Flood Resilience Zoning Texts, which are applied to industrial building construction and reconstruction (box 6.5). The revised building codes reflected both national and local level risk information.

Governments can also establish comprehensive national guidelines to promote resilient industrial park development, as in Bangladesh. In partnership with the World Bank, the Bangladesh Economic Zone Authority (BEZA) developed the National Green and Resilient Economic Zone Guideline (World Bank 2020a). This offers a new national performance

35 Bangladesh National Building Code 2015. http://bsa.com.bd/cms cpanel/upload/pdf file upload 1540152875.pdf.

standard for economic zones and aims to enhance their sustainability, resilience, and competitiveness through actions such as:

- Mitigating and avoiding greenhouse gas (GHG) emissions, pollution, and resource depletion;
- Setting higher labor standards;
- Focusing on community development; and
- Avoiding and minimizing damages and disruptions to businesses from natural hazards and shocks.

Emergency preparedness and response are core principles of the guideline. Economic zones are encouraged to integrate risk-informed site selection, master planning, infrastructure design and operation; and establish zone-wide BCPs so that they can protect critical assets, infrastructure, services, and tenant firms amid various types of hazards. In line with National Building Codes and various other regulations, the guideline will help mitigate disaster events' direct and indirect impacts on industry assets and critical infrastructure, prevent secondary impacts on supply chains, and expedite recovery processes.

Box 6.5 United States: Local Governments Enforce Resilient Design Standards for Industrial Buildings and Offer Tax Rebates for Retrofits

In the United States, advisory flood maps produced by the Federal Emergency Management Agency (FEMA) stipulate flood-resistant construction standards; the Government of New York City integrates these standards into its zoning texts, which are also applied to industrial building construction and reconstruction (figure 6.3). These maps identify areas within floodplains, and set elevation levels to which flood waters are anticipated to rise during flood events with a one-percent-annual-chance. The Texts also incorporate local risk information from the New York City Panel on Climate Change (NPCC), which provides information on extreme temperatures, coastal flooding, sea-level rise, storm surges, etc. based on localized climate models.

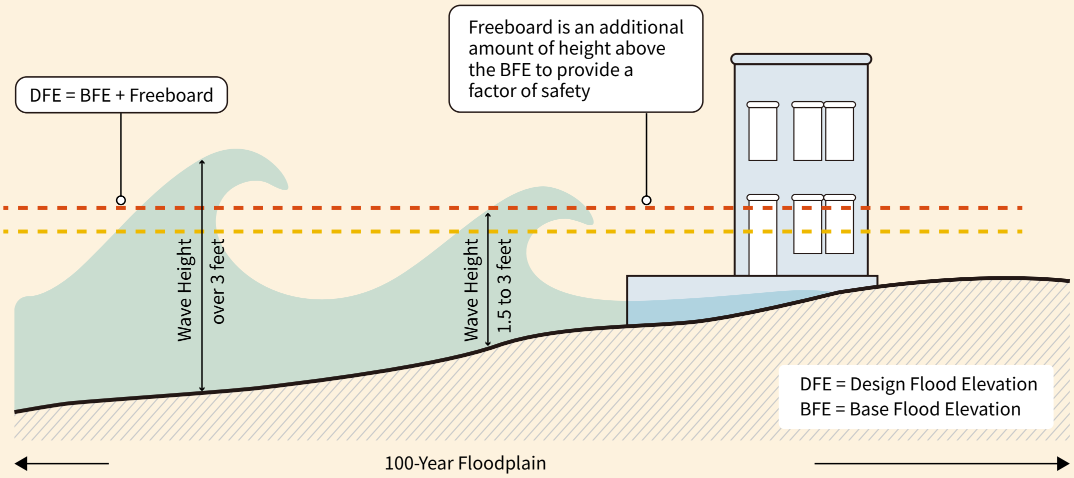
The city government also conducted an industry-specific study on industrial properties and businesses operating in the floodplains, which found that: 1) one-tenth of lots in the floodplain are in districts zoned for manufacturing and heavy commercial uses; 2) around 3,600 private businesses that employ approximately 87,000 people, and 1,680 industrial businesses were at risk of coastal floods and storm surges (NYC Planning 2019). These projections and flood risk maps, and spatial analyses at the local level informed design standards for industrial buildings to withstand coastal flooding and storm surges.

Figure 6.3 New York City-Specific Building Requirements for Manufacturing Districts and Industrial Buildings

Panel a) Manufacturing District Located in a Floodplain

Photo credit © Felix Lipov

Panel b) Design Requirements for Building on Floodplains



Source: Adapted from New York City Government 2013.

Specific flood-resilient construction standards required by the flood maps included:

- mechanical and electrical systems (e.g. electrical substations, electrical panels, boilers, heating and air conditioning systems) need to be elevated to at least the Design Flood Elevation (DFE) to be fully compliant with the NFIP and eligible for lower insurance premiums;
- the lowest floor of industrial buildings should be elevated to the DFE;
- only certain types of industrial activities (e.g. parking, building access, and storage) are allowed in spaces below the DFE;
- "dry floodproofing" (e.g. flood shields) should be applied to retrofitting or construction of industrial building walls and foundations.

Although industrial areas are concentrated near coastlines where they are vulnerable to storm surges, dry-flood proofing of industrial structures can be technically difficult or costly for small, or struggling firms; therefore, the city government introduced a sales tax abatement program for flood resilience in industrial buildings. The program provides a tax exemption of up to US$ 100,000 per company on the purchase of building materials used for flood resilient construction, and US$ 10 million in sales tax abatements to qualifying industrial businesses seeking resilience retrofits (US EPA 2016).

Source: New York City Government 2013; NYC Planning 2018, 2019; US EPA 2016.

6.2 Infrastructure

Placing industrial infrastructure in low-risk sites is not always possible, and it is important that resilience principles are integrated into the design, construction, operation and maintenance of the infrastructures that provide services to industrial parks and firms. Site-specific infrastructure risk assessments should be undertaken for various types of hazards as part of the infrastructure design phase of a project. Furthermore, lifecycle management approaches are essential for resilience investments in industrial infrastructure. They help to achieve higher levels of performance throughout the lifecycle of a given asset, including during disasters. Industrial parks offer opportunities for synergistic resilient infrastructure investments for common infrastructure and services such as power, water supply and wastewater treatment systems. The benefits of these investments are also best assessed via lifecycle cost analysis which takes account of optimized cost and performance of infrastructure assets throughout their lifecycles.

6.2.1 Minimize Infrastructure Disruption in Industrial Parks

Integrating Resilience Principles into Structural Designs

Governments investing in public infrastructures, park developers and operators can use structural measures to improve resilience when developing and retrofitting industrial park infrastructure. These options should comply with national technical standards such as design flood levels, and national guidelines for construction and operating permits. Designs that exceed national standards and meet international standards or best practices may be required to mitigate disaster risks.

Structural measures vary by types of hazards (appendix II). For example, in earthquake-prone countries such as Japan, power, water and other services may require earthquake-resistant structures, while floods require large-scale mitigation infrastructures such as river levees and coastal dikes. These are often developed by the public sector, while smaller scale and site-specific infrastructure may be developed by industrial park developers and operators themselves.

In Thailand, the national government drove construction and retrofitting of dikes and embankments in at-risk industrial estates. Across seven industrial estates, 200 kilometers of dikes were raised (between +3.8 and +5.4 meters above mean sea level) (Bergado et al. 2017), using flood-resistant construction materials (World Bank 2012), to meet upgraded design standards (design standards in table 6.1 were applied) and attract investment after the Bank of Thailand (BOT) tied foreign investment to the credibility of the government's floodwater management strategies. For example, a total of approximately US$ 38 million was invested to construct and retrofit flood dikes in 5 industrial estates, whose length totaled 46 kilometers in length (IEAT 2012). The structural designs of these dikes followed the new flood design standards developed based on new evaluations of flood frequencies; new construction materials were used for building and retrofit, along with new flood design standards.

In Bangladesh, with support from the World Bank, the Bangladesh Economic Zone Authority (BEZA) is integrating resilience into the design and costing of planned infrastructure investments in the Bangabandhu Sheikh Mujib Shilpa Nagar (BSMSN) Economic Zone—one of the first flagship green and disaster-resilient economic zones in the country. Located on the mouth of the Feni River, and occupying 25 kilometers of coastline in the Bay of Bengal, this area is susceptible to floods, earthquakes, and land subsidence. To protect the site and investments from coastal and river floods, the site level of BSMSN was raised to 6.5 meters above sea level, and coastal embankments (super dikes) and river dikes were constructed. Furthermore, BEZA is considering additional measures for internal road networks, bridges, buildings, and water and power supply networks to further enhance resilience and competitiveness of the economic zone.

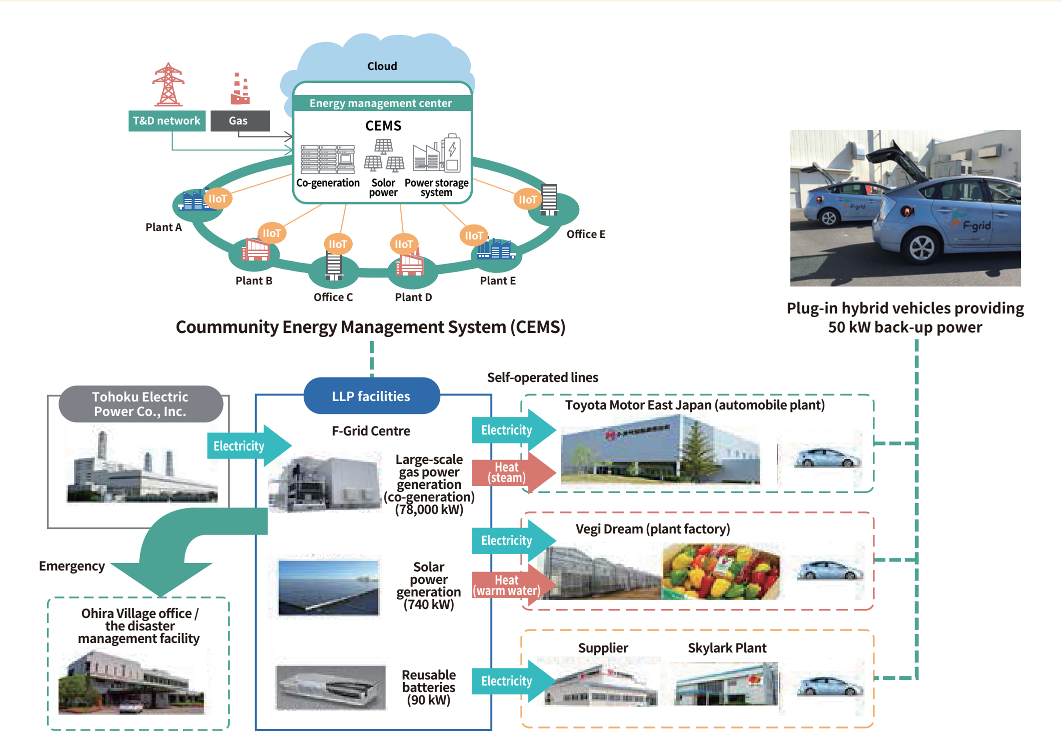
Improve Built-In Redundancy, Circularity and Reliability of Infrastructure Services

Industries require uninterrupted services, even during disasters, and interruptions are best managed by increasing the redundancy of infrastructure networks through cost-effective mechanisms for backups, circularity of water and energy resources, and diversification of input supplies. Japan's Ohira Industrial Park offers a good illustration of this approach (see World Bank 2020b for further details) (box 6.6). A limited liability partnership (LLP) with 10 firms in the Ohira Industrial Park has established a comprehensive energy management system to improve energy efficiency in the park during normal times and supply backup power during disasters. Favorable conditions and enabling environments for such investments should be met to enable cost-effective redundancies of critical infrastructure services, and governments have a critical role to play in close coordination with industry stakeholders. These include: national policies to promote renewable energy, convening diverse utility and industry stakeholders for discussion and consensus-building, energy market drivers to reduce costs, financing, and innovative technologies for efficient power generation and lower investment costs.

Box 6.6 Japan: Enhancing the Resilience of Power Supply Networks in Industrial Parks

Following major power outages during the GEJE, tenant firms in Ohira Industrial Park invested in an energy management and micro-grid system[36] called "F-Grid" (figure 6.4). The system allowed the park to balance consumption from the national grid with renewables-based on-site backup from F-Grid, increasing the reliability of power supply and lowering costs, even during normal operations. The F-Grid backup increased redundancy, enhanced disaster preparedness, improved energy efficiencies (by 24 percent) and reduced carbon emissions (by 31 percent). The system also supplies power to local disaster response centers and evacuation shelters in Ohira village.

Figure 6.4 System Diagram of F-grid Project in Miyagi Prefecture, Japan



Source: World Bank 2020b.
Note: IIoT = Industrial Internet of Things. kW = kilowatt; LLP = limited liability partnership; T&D = transmission and distribution.

Nature-based approaches combined with conventional "gray" infrastructures can enhance industry resilience by diversifying water resources, protecting coastlines from tsunamis and storm surges, increasing the circularity and reliability of water supply,

36 The micro-grid is a "localized group of electricity sources and sinks (loads) that typically operates connected to and synchronous with the traditional centralized grid (macrogrid), but can disconnect and maintain operation autonomously as physical and/or economic conditions dictate" (The Microgrids Group at Berkeley Lab n.d.).

and improving storm water management capacity in industrial parks. "Nature-based solutions" refer to a range of investments and actions that protect, sustainably manage and restore natural capital and ecosystem services in ways that address societal and economic challenges effectively and adaptively (Cohen-Shacham et al. 2016). Nature-based solutions include parks and open spaces, green and blue roofs, rainwater harvesting systems, natural filtration areas, natural embankments, permeable pavements and bioretention areas (Davis et al. 2009; Wamsley et al. 2010; GSA 2011; Narayan et al. 2017; Browder et al. 2019). Because of their multifunctionality, nature-based solutions alone may not be the most effective means to achieve resilience of industrial parks and their infrastructure. However, in combination with gray infrastructure, they offer ways to reduce the risks of service disruptions by creating redundancies, while generating social and environmental co-benefits (Akratos, Tekerlekopoulou, and Vayenas 2018) (table 6.2). For example, open spaces and street greening, together with underground drainage systems may offer cost-effective approaches to stormwater runoff management and flood control. The nature-based components of such a system offer additional protection from low-frequency, high impact floods, and increase amenity values by enhancing the environment in normal times.

Table 6.2 Green and Gray Infrastructure Can Work Together to Minimize Service Disruption in Industrial Parks

Service	Gray infrastructure	Examples of green infrastructure and their function
Water supply and wastewater treatment	Reservoirs, wastewater treatment plants, water supply network (pipelines)	**Rainwater harvesting system**. Directly capture rainfall, and store and reuse stormwater. Provide redundancy to the water supply system. Helps reduce water consumption by reusing stormwater and increasing the circularity of water resources within zones. **Treatment wetlands/Constructed wetlands.** Increase flood management capacity, provide wastewater treatment services, promote water reuse, restore wildlife habitat and increase public use benefits.
Renewable energy supply	Reservoirs and power plants (e.g. floating solar plants installed in reservoir)	**Watersheds.** Reduce sediment inflows through erosion control and extend the service life of reservoirs and power plants.
Coastal flood protection	Coastal dikes, levees, sluice gates	**Mangrove forests.** Decrease the heights and energy of waves and storm surges, limiting coastal erosion and flooding. This can reduce embankment requirements of economic zones.
Drainage	Storm drains, pump stations, gates at drainage outfalls, retention ponds, underground stormwater storage facilities, box culverts	**Green roofs, permeable pavements, green and open space, etc.** Filtration, storage and slow release of stormwater, thereby reducing drain and pump requirements in economic zones.

Source: Adapted from Almuktar, Abed, and Scholz 2018; Browder et al. 2019; Ezeah, Reyes, and Gutiérrez 2015; World Bank 2020c.

Global practices show that policy makers and practitioners are considering nature-based methods in the design, construction and operation of economic zones and infrastructures including ports. In Kenya, the Kenya Port Authority invested in reforestation at the Port of Mombasa to reduce recurring flood impacts (box 6.7). In New York City, green stormwater infrastructure has been installed in major industrial and manufacturing districts that historically relied on a combined sewer system[37] (box 6.8).

37 A combined sewer system collects rainwater runoff, domestic sewage and industrial waste into one pipe.

Box 6.7 Kenya: Reforestation at the Port of Mombasa

Challenge

Kenya's port of Mombasa is the industrial hub of the country, and the biggest port in East Africa. Logistics efficiency at the port is critical to the country's export performance, and in attracting FDI. However, the port, and its nearby industrial parks have been repeatedly affected by disasters. The terrain surrounding the port is hilly and steep, and the area receives high rainfall. This topography leads to frequent floods and landslides, affecting port logistics and export performance. For example, in 1997, following El Niño rains, the port was shut for two weeks, and in 2006, floods severely damaged the port again, precipitating a two-year period of economic stagnation (Awour et al. 2008). Additionally, the lack of a water management system causes health hazards and water shortages.

Solution

To reduce the impacts of frequent floods and landslides on port logistics, the Kenya Port Authority (KPA) implemented a comprehensive Port Resilient Infrastructure Program under its Green Port Policy. KPA conducted topographic surveys, geo-technical investigations, and environmental impact assessments. These studies revealed where hillsides surrounding the port were unstable, and required protection to secure them against landslides (TradeMark East Africa n.d.). Ecosystem-based methods led to the re-forestation of hillsides to arrest surface runoff, increase infiltration, stabilize landslide-prone soils/zones, combat erosion, and break the impact of heavy rains. These effects all reduce the impacts of heavy rains, and thus the severity of floods and landslides. Additionally, mangrove forests were restored to improve the buffering capacity of the port area's coastline. Mangroves reduced the energy of storm surges and tidal waves, and greatly increased carbon drawdown in coastal zones.

Source: Awour et al. 2008; TradeMark East Africa n.d.

Box 6.8 New York City (United States): Green and Gray Infrastructures Increase Drainage Capacity in Industrial Districts

Challenge

In New York City, it is expected that storm frequencies and sea level rise will increase due to climate change. Storm surges will impact businesses in industrial zones and manufacturing districts in the waterfront areas of the city, such as the core industrial areas of the East New York Industrial Business Zone and Greenpoint neighborhood. Furthermore, during heavy rains, the volume of wastewater and stormwater may exceed the capacity of the combined sewer system built throughout the city. When this occurs, untreated stormwater and wastewater discharges directly to nearby streams, rivers and other water bodies, which can affect water quality. The city government identified increased drainage capacity as a cost-effective means to minimize the impacts of local flooding in these areas, and others in the city.

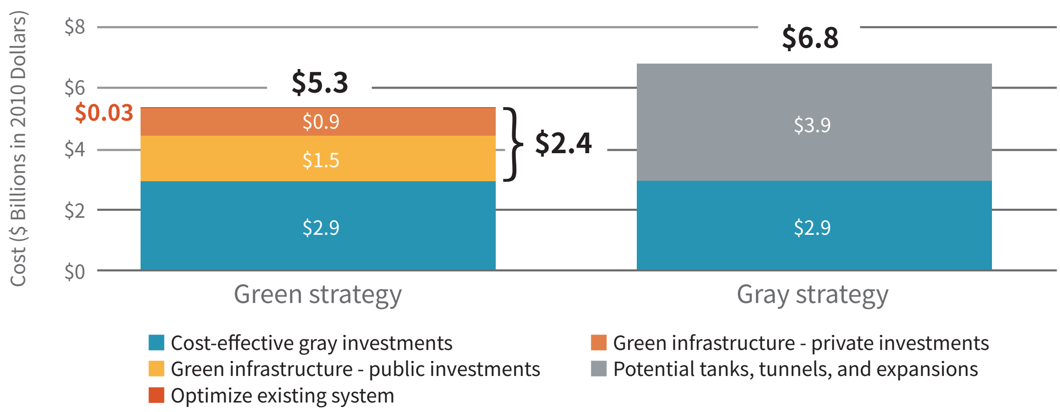
Solution

To meet these needs, the New York City Department of Environmental Protection and New York City Economic Development Corporation (NYCEDC) have invested over US$ 2.7 million in nature-based green infrastructure, including 150 bioswales—vegetated channels designed to capture, retain and purify stormwater runoff. Bioswales are expected to prevent flooding of streets and businesses during heavy rains. At the same time, the city government is planning to upgrade and replace sewer infrastructure—the gray infrastructure—in the same areas to further enhance drainage capacity and reduce flooding. These installations require maintenance, and enabled the city government to create jobs.

Source: NYC Department of City Planning 2018; The City of New York 2017.

Integrating green and gray infrastructure can reduce life-cycle costs, while generating climate co-benefits. A cost-effectiveness analysis of infrastructure options in New York City found that capital costs for nature-based solutions would be approximately 22 percent less than for gray infrastructure alone, as these approaches reduce investment requirements for tanks, tunnels and other types of infrastructure asset expansion (figure 6.5). Nature-based solutions typically have low operation and maintenance costs, and reduce the life-cycle costs of infrastructure systems. For example, treatment wetlands can reduce pumping, compliance, and equipment maintenance costs. Through such interventions, park operators can improve resource efficiency, lowering operation and maintenance costs, while reducing carbon and environmental footprints. Green roofs, through their cooling effects and rainwater collecting features, can also lower the energy and stormwater management costs of industrial and administrative buildings. In the United States, for example, it was found that green roofs provide a payback period of approximately 6.2 years (internal rate of return of 5.2 percent) (GSA 2011). Such economic efficiencies and resilience efficiencies are potentially attractive to private investment in industrial park infrastructures, and may make private-public partnership (PPP) models more feasible.

Figure 6.5 **New York City: Reducing Costs by Mixing Green and Gray Infrastructure**



Source: Browder et al. 2019.
Note: Integration of green and gray infrastructure costs 22 percent less than having gray infrastructure alone.

Guidelines and incentives for integrated green-gray approaches are increasingly available from many countries. In Bangladesh, policy makers, with technical support from the World Bank, are integrating this mixed approach into BSMSN design and construction.[38] For example, although they are not directly related to industrial park designs, the New York State stormwater management design manual provides practical guidance on how to achieve such approaches; the New York City Environment Protection Department has recently launched a Private Property Retrofit Incentive Program to incentivize installation of green infrastructure assets on private property for improving stormwater management.[39] Costing and returns on such investments should be carefully examined during feasibility assessments, and take into account the long implementation time frames for nature-based solutions and uncertainty associated with their performance.

38 For example, Bangladesh Economic Zones Rules (2017) already require the inclusion of nature-based solutions such as rainwater harvesting systems and green and open spaces into the design and operation of economic zones. In line with this regulation, the Green and Resilient Economic Zone guideline recommends that native flora and fauna are conserved in economic zones and by tenant firms for their eco-system services, including coastal flood protection and stormwater management.

39 For more information, see: New York State Department of Environmental Conservation. Stormwater Management Design Manual. 2010. http://www.dec.ny.gov/docs/water_pdf/swdm2010entire.pdf. New York City Department of Environmental Protection. Green Infrastructure. Private Property Retrofit Incentive Program. https://www1.nyc.gov/site/dep/water/private-property-retrofit-incentive-program.page.

In developing countries, institutional and technical capacity needs to be strengthened to achieve resilience-informed construction goals. Supervision, documentation and monitoring of construction, with feedback to governments and implementing agencies is needed. Recently, new technologies have been introduced to monitor and control the quality of infrastructure construction in real time (Yao et al. 2018). In Bangladesh, construction of super dikes and embankments in BSMSN have been monitored to confirm that design capacity and standards have been met (figure 6.6). Governments in these countries may also be provided with additional technical assistance, training and strategic studies for construction quality control.

Figure 6.6 Super Dike Construction in BSMSN

Photo credit: © Nah-yoon Shin.

Strengthen Maintenance, Operation and Monitoring Mechanisms

To be resilient, infrastructure systems should be supported with asset maintenance, regular inspection, and monitoring plans, including those for structural performance monitoring. For example, infrastructure operators can develop real-time monitoring systems for water levels and geo-technical parameters in order to improve site-specific water level measurements and soil stability/liquefaction estimates. To improve stormwater management capacity, drainage networks, ponds, retention areas, and permeable surfaces need to be cleaned, and cleared of debris. The movements of concrete blocks in coastal embankments need to monitored as part of their maintenance, and bridges and roads require real-time monitoring for structural integrity as illustrated in figure 6.7. Sensing systems provide measurements of displacement or malfunctioning that can be collected wirelessly, optimizing asset management (FPrimeC 2020). However, such systems require training and supervision for technicians, service providers and inspectors, and budgets for monitoring, repair and replacement.

Figure 6.7 **Various Devices Can Be Used for Structural Health Monitoring**

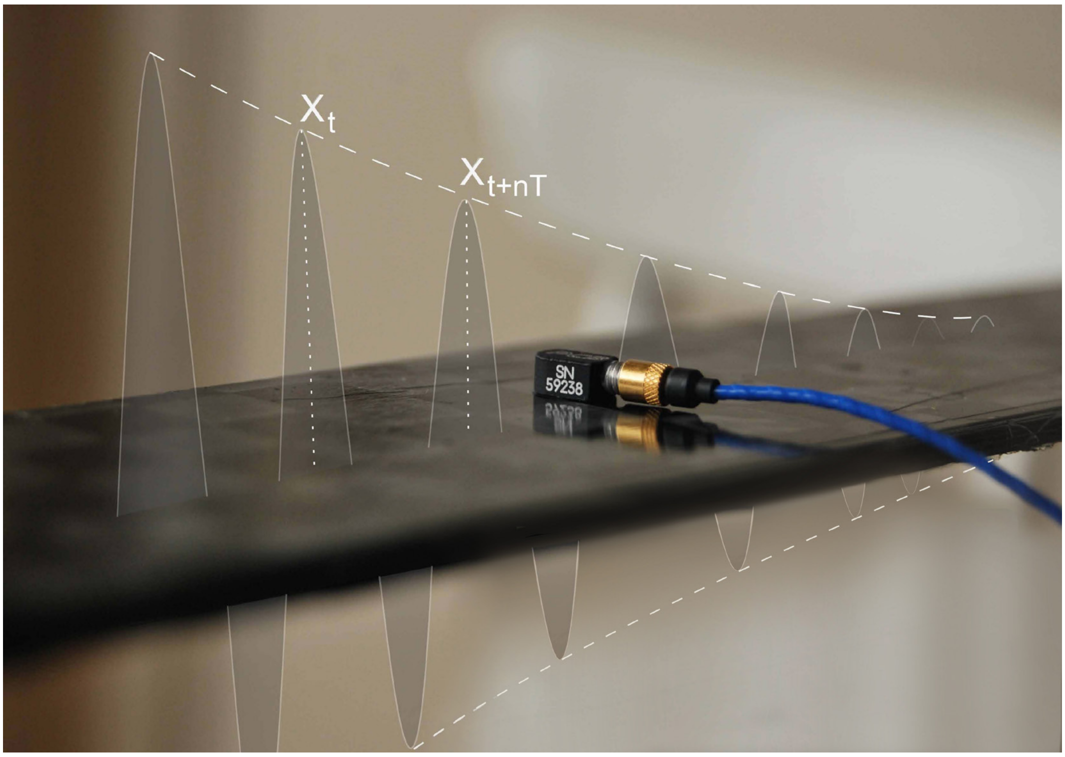


Photo credit © David Garcia
Note: Accelerometers are used for real-time monitoring of changes in structural performance and informs real-time damage diagnosis.

Establish Emergency Preparedness and Response Plans for Industrial Infrastructure Failure

In addition to maintenance and monitoring, resilient infrastructure investments should also consider emergency preparedness and response (EP&R) plans and service agreements, which may be developed together with, or as part of, the park-wide BCP illustrated in Section 6.1.1. During disasters, recovery is often hindered by time-consuming procurement and contractual procedures, and these are further slowed due to the attention governments must give, of necessity, to other needs. Pre-arranged agreements, however, are rapidly activated, have lower administrative burdens, and minimize contractual and procurement time frames, and governments should work with stakeholders to institute such agreements. Ideally, pre-arranged agreements should be integrated into BCPs or EP&R plans developed by governments, infrastructure owners / operators, and industrial park operators and so on with pre-defined triggers in place for the activation of these plans. For instance, combining alerts from earthquake warning and infrastructure monitoring systems at an industrial park may allow staff to implement the automated agreements that will most effectively reduce industrial damage and/or service disruption from earthquakes (Tajima and Hayashida 2018).

Pre-arranged agreements have proven effective in Japan to reduce disruption time of critical infrastructure, and accelerate response. Following floods in Sendai, the Sendai City government established a "Post-Disaster Emergency Response Partnership Agreement" prior to the GEJE. This pre-arranged agreement between the Sendai City government and the

Sendai Construction Company Association provided human and mechanical resources needed for restoring road networks during emergencies (World Bank 2020b), and was activated during the GEJE to repair roads without the need for standard contractual processes, and led to rapid recovery. Through the agreement, the City government also had access to construction vehicles and personnel, and roads within the city were usable eight days after the earthquake. This outcome supported industry recovery in the Sendai Port area, including Kirin brewery and others.

Sometimes, pre-arranged agreements can be made among private service providers as part of their BCPs, considering their geographical proximity and exchangeable technical/human resources. In another example from Japan, a company providing waste disposal services to industries in Sendai City had a pre-arranged agreement with its partner company (World Bank 2020b). The partner company was similarly resourced, but its location in a less-affected prefecture enabled it to rapidly assist, resulting in only minor disruptions to waste disposal (6 days). Benchmarking such cases, national and local governments can help identify, and establish strategic agreements with private service providers *prior to* disasters, thereby minimizing risks of infrastructure/service disruption and quickly restoring affected infrastructure and services.

6.2.2 Conduct Alternative Cost-Benefit Analyses

While resilient infrastructure investments may have high capital costs, these costs are a small proportion of total infrastructure costs, and may justify themselves through indirect and intangible benefits generated over the lifetime of the infrastructure. These benefits must be examined from the perspectives of firms, workers and local communities, whose economic and social well-being depend on the industrial parks.

High capital costs can also be offset over the life cycle of infrastructure through reduced repair and reconstruction costs, as in the Thailand case. The initial construction cost of the levee system in Rojana Industrial park was approximately US$ 64.2 million. However, these costs need to be seen in the context of impacts on the park, its tenant firms, and their up- and downstream suppliers after the floods. These losses included physical asset damages of US$ 35.5 million, and losses associated with disruption to Toyota's supply chain (Rojana Industrial park Public Co. Ltd. 2012). After the floods, approximately 14 percent of the 218 tenant companies had ceased operating, and only 69 of the affected firms were fully operational seven months after the flooding event, with an additional 85 having partially recovered (Haraguchi and Lall 2015). Equally importantly, the park also had to contend with investors' perceptions of flood hazard—an intangible but significant "coping cost" (Hallegatte, Rentschler, and Rozenberg 2019). These tangible and intangible costs may have been substantially mitigated through investment in flood protection measures in advance of disasters, and the US$ 64.2 million cost of the Rojana levee system must be viewed in this context.

Importantly, examples from around the world show that investment in resilient infrastructure and services can pay off, even during periods of normal operation. While indirect, these benefits offset their capital costs through gains in usability, value and availability of industrial land, and by enhancing energy efficiency, attracting private investment, and reducing GHG emissions. In the Republic of Korea, public investment in improved drainage capacity of an industrial park augmented the availability of serviced industrial sites and attracted private investment in renewable energy projects—an important source of revenue for the park. The investment in embankments made the detention pond useable in normal periods, and functional as a multi-purpose flood protection infrastructure. In its improved state, the pond also generated climate benefits (box 6.9).

Box 6.9 The Republic of Korea: Public Investment in Improved Drainage Capacity Secures Private Investment and Climate Co-Benefits

Challenge

The Republic of Korea's 1,207 industrial manufacturing complexes account for 29.2 percent of GDP, but some have become vulnerable to various types of disasters including heavy rainfalls. The Gunsan National Industrial Complex 2 (GNIC2), sited on low-lying, reclaimed land, is one such case. The complex caters to transportation equipment, machinery production, and petrochemical sectors, and as of 2018 hosted 373 tenant companies. It has been subject to frequent floods, and a detention pond was constructed in 2005 in an area adjacent to the GNIC2 (the size of the pond is approximately 51,429 m^2). The pond was designed to prevent seawater from intruding into the complex during high tides by closing sluice gates, and to manage stormwater by opening the gates and releasing it into the sea. In 2012, nine of GNIC2's tenant companies were flooded, and roads inside the complex were damaged, despite the operation of the detention pond. Asset damage totaled approximately US$ 2.15 million (Kim 2012). Following the flood, the detention pond was designated as an "area zoned to manage natural disaster risks"—or a zone with high flood risks under the Countermeasures Against Natural Disasters Act.[40]

Solution

Subsequent improvements to the detention pond infrastructure were made as part of the Gunsan Comprehensive Natural Disaster Reduction Plan. These included building a 375m-long embankment and cut-off wall, and increasing the capacity of pump facilities.

Co-Benefits

Because of its enhanced flood protection, GNIC2 was able to attract private investment in floating solar panels in the retention pond. As they float on the pond, these panels must be able to withstand storm surges, high waves and strong winds, and these design requirements also influence a project's overall capital expenditure and maintenance costs (World Bank Group et al. 2019). In short, the investment in the embankment upgrade generated the following co-benefits:

- Protected by the embankment, the detention pond expanded the availability of serviced land for renewable energy generation, while at the same time, providing flood protection services.
- The park generated additional electricity and climate benefits. 24,600 MW is produced, avoiding approximately 12,000 tons of CO_2 emissions annually.
- The industrial park operator (in this case, Korea Industrial Complex Corporation) and the city government generated revenue by selling electricity, a co-benefit driven by the initial investment in embankments that made the retention pond suitable for electricity generation.
- The industrial park operator was able to brand GNIC2 as a "high-tech renewable energy park".

Source: Korean Ministry of Public Safety and Security 2018, Interview with the City government of Gunsan, The Ministry of Public Safety and Security.

Industrial park developers and operators should be alert to the indirect benefits that accrue to parks as a result of investment in resilience. While not all of these benefits have quantifiable market values at the time of investment, they can nonetheless benchmark international best practice in the resilience arena.

To account for the direct and indirect nature of resilience co-benefits in infrastructure investment decision-making, new cost-benefit analyses are needed. In resource scarce contexts, cost-effectiveness is paramount, and financial tools which capture the costs and savings attached to such co-benefits are needed. Alternative cost-benefit analyses should account for damages and losses that have been or are likely to be avoided, and economic, social, and environmental co-benefits gained (ODI and World Bank Group 2015, Haraguchi and Lall 2019). For example, Samarasekara et al. (2017) demonstrated that coastal infrastructure in Sri Lanka for physical protection (e.g., revetment) against tsunamis could double as roads and railway embankments during normal times, generating economic co-benefits.

40 Korean Legislation Research Institute. Korea Law Translation Center. 2018. Countermeasures Against Natural Disasters Act. 2018 (Act No. 15344). https://elaw.klri.re.kr/kor service/lawView.do?hseq=46613&lang=ENG.

To decide which infrastructures to invest in, and how, where and when to invest, stakeholders need data and tools to quantify the returns they anticipate. While benefits may be quantitatively assessed, they can also be intangible (e.g. increase in trust among customers), as illustrated in Section 3, and difficult to state as monetary values. Additionally, the scope of potential losses, and hence the need for resilience interventions may be viewed differently by stakeholders with differing objectives, further complicating which investments are viewed as most needed. In this context, an important method is multi-criteria analysis (MCA) or multi-criteria decision analysis (MCDA). MCA is a complementary approach to standard cost-benefit analyses which considers non-economic benefits, the uncertain nature of disaster risk, and the conflicting criteria, values, expected costs and benefits, and policy agendas that may pertain to the choice of possible resilience investments (Ward, Dimitriou, and Dean 2016). Because investments deliver both monetary (damage and repair cost mitigation) and intangible benefits (i.e. reputational), semi-quantitative and multi-criteria analyses should be used to rank investment choices and assess their costs (Darwin et al. 2016).

Some governments, such as Japan's, aim to consider both direct and indirect flood damage to businesses within cost-benefit analyses for public infrastructure construction projects such as river embankments, roads, stormwater and water supply networks, wastewater management plants and ports. The "Manual for Economic Evaluation of Flood Control Investment (draft)" developed by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (2005) requires that both direct (physical damage) and indirect (lost production) effects be considered. Direct damage to businesses estimated in the economic evaluation of flood infrastructure include damage to buildings and assets, and depreciation in land values, buildings, and inventory due to inundation. Indirect damage includes reduced production due to flooding; the cost of disaster response activities such as cleaning up disaster waste, and procurement of emergency supplies such as drinking water, etc.; the ripple effects of business disruption in the area due to limited access to supply or lifeline utility services; and the psychological effects on people from loss of business properties and assets (for more details, see World Bank 2020b). In the United States, direct damages and business disruption costs are estimated considering various parameters, including: sector inoperability—that is, unrealized production relative to the ideal production level of the industry sector; region-specific interdependency among industry sectors, and demand disruption to each sector in the region; types of buildings in key manufacturing sectors including food processing, minerals processing, high technology, heavy and light industry sectors; and social costs such as death and injuries. Net benefits are considered across different stakeholder groups, including developers, lenders, tenants and communities, including number of jobs created through reconstruction activities and higher construction material demands (Multi-Hazard Mitigation Council 2019).

Life-cycle cost analysis (LCCA) is also used to evaluate competing resilient infrastructure investments, and has application to investment-related decision making. The expected service life of public infrastructure such as roads and bridges is typically between 30 and 50 years, assuming that it is regularly maintained, and user costs, or savings, should be calculated over this period (table 6.3). This requires assessment of the cost-saving possibilities of multiple engineering alternatives. While such alternatives may be similar from a technical design standpoint, their resilience outcomes over the service life of the infrastructure may vary. In such contexts, LCCA is used to compare the costs of conventional design and construction with those of resilience-informed and/or higher quality designs. In Bangladesh, LCCA is being used to select infrastructure that will enhance the resilience performance of a flagship economic zone that is being developed, as illustrated in table 6.4.

Table 6.3 Breakdown of Life-Cycle Costs

Cost	Description
Direct cost	Avoided repair costs, or savings associated with resilience measures; primarily concerned with structural (physical) damage.
Indirect cost	Secondary costs and savings associated with resilience measures and are primarily linked to operations of the resilient infrastructure.
User cost	Costs or savings absorbed by the direct user, such as delays associated with repair, increased travel time, higher accident rates and vehicle maintenance costs.
Third party cost	Costs impacting other stakeholders that are not direct users of resilient infrastructure, such as impact on revenue due to changes in traffic volume during construction of the resilient infrastructure.

Source: World Bank 2020c.

Table 6.4 **Bangladesh: Example of a Conceptual Life-Cycle Cost Analysis for Prioritizing Resilient Infrastructure Investments Against Floods**

Stage	Proposed structural and non-structural measures to enhance resilience	Performance enhancement	Initial Costs	Life-Cycle Cost Savings
Site Development				
Planning	Apply higher demand	High capacity for storm surge, rainfall and flooding	Moderate	**Substantial**
Design	Meet international standards	Longer service life and higher capacity to resist floods and earthquakes	Moderate	**Substantial**
Construction	Ensure quality control of construction and soil settlement	Prevent adverse effects during heavy flooding	Moderate	**Substantial**
Maintenance	Develop enhanced maintenance plan	Maintain and extend service life	**Low**	Large
Monitoring	Develop real-time monitoring network and warning system	Reduce impacts of heavy flooding on people and facilities	Moderate	Moderate
Response	Develop flood hazard map and emergency response protocol	Mitigate damage, prevent secondary impacts and expedite recovery	**Low**	Moderate
Super Dikes and Levees for Coastal Protection				
Planning	Apply higher demand	High capacity for redundancy, storm surge, rainfall and flooding, sea level rise due to global warming	Moderate	**Substantial**
Design	Meet international standards	Longer service life and higher capacity to resist floods and earthquakes	Moderate	**Substantial**
Construction	Quality control	Prevent adverse effects during heavy flooding and earthquakes	Moderate	Large
Maintenance	Develop enhanced maintenance plan	Maintain and extend service life	**Low**	Large
Monitoring	Develop real-time monitoring network and warning system	Reduce impacts of heavy flooding on people and facilities	Moderate	Moderate
Response	Develop flood hazard map and emergency response protocol	Mitigate damage, prevent secondary impacts and expedite recovery	**Low**	Moderate
Drainage				
Planning	Apply higher demand	Longer service life and higher capacity	Moderate	**Substantial**
Design	Control water discharge flow	Prevent adverse effects during heavy rainfall and flooding	**Low**	Moderate
Construction	Meet international standards	Longer service life and higher capacity to resist floods and earthquakes	Moderate	**Substantial**
Maintenance	Consider nature-based measures for green and resilient stormwater management	Enabling redundancy and additional capacity to store excess water during heavy rainfall and flooding	Moderate	Large
Monitoring	Quality control for construction	Prevent adverse effects during heavy flooding	Moderate	**Substantial**
Response	Develop an enhanced maintenance plan	Maintain expected water discharge, extend service life	**Low**	Large
	Develop real-time monitoring network and an early-warning system	Reduce impacts of heavy rainfall and floods on people and facility	Moderate	Moderate

Source: World Bank 2020c.

6.3 Finance

Proactive financial support and disaster risk financing are key to protecting industries. Financial support for industrial resilience is needed before disasters so that investments to mitigate their impacts are in place when disasters strike. These ex-ante financing measures are as important as the ex-post financial mechanisms which enable industry stakeholders to secure financing for business continuity, emergency response, and recovery. Ex-ante financial measures and tools are available to governments, businesses and financial institutions, industrial parks, infrastructure operators and firms, and help them to shoulder recovery costs.

6.3.1 Analyze Financial Impacts and Needs

Financial protection requires knowing how to cost disaster impacts, and of the range of financial instruments available for different kinds of disasters. Costs include repair and replacement of damaged infrastructure and services, and these need to be understood for disasters of differing magnitude and frequency. In the BCP guidelines issued by the Japanese government, these assessments included cost estimations for repairs and restoration of business operations, and losses incurred from business interruption. Once the potential costs are estimated, different financial instruments will be appropriate for varying combinations of cost assessment and risk profile, and informed firms will be better able to navigate this financial arena, and to choose financial instruments, implementation frameworks and monitoring procedures. Firms will also have different priorities and expectations of risk financing, and these will affect their choice of financial protection, ranging from self-finance from cash deposits, sales of company assets, and insurance; or external financing (such as low/no interest disaster loan programs), and layering of diverse instruments. When integrating financial protection into BCPs, it is important to factor in time frames for accessing various funds; and, to reduce response costs, firms may need to consider pre-arranging rapid-access emergency loans.

6.3.2 Support Up-Front Resilient Infrastructure Investment

Up-front investment in resilient infrastructure is cost-effective and urgent, **but investments need to be supported by technical and financial backup.** While the investment costs of resilience in low- and middle-income countries are small relative to overall investment needs and GDP[41], they still need to be interrogated with the right data, risk models, and decision-making methods, and technical/financial assistance may be required to accomplish this. Costs depend on asset types and anticipated hazards, and while they may range from "negative to a doubling of the construction cost" (Hallegatte, Rentschler, and Rozenberg 2019), these proactive investments can lower repair and maintenance costs over the life cycle of the asset.

Fiscal incentives and financial support programs, often available for promoting sustainable infrastructures such as renewable power plants, may partially cover these costs, and even stimulate private investment. As noted in Section 6.2.1, innovative system designs and new technologies such as renewable energy for back-up power, or wastewater recycling for business/industrial park operation, can increase industry resilience. Investments generating co-benefits can be financed from existing fiscal incentives or support programs for decarbonization, energy and resource efficiency, circular economy, smart city, urban revitalization, and so on.

41 Although not negligible, this range accounts for only 3 percent of infrastructure investment needs and less than 0.1 percent of the GDP of low- and middle-income countries. It would, therefore, not affect the current affordability challenges that countries face (Hallegatte, Rentschler, and Rozenberg 2019).

PPP models are important drivers of infrastructure investments that strengthen industry resilience. They mobilize investment finance, distribute risk in capital-intensive developments, and support long-term investment in resilient infrastructure. These gains can be consolidated through risk allocation mechanisms that minimize disaster impacts, contractual allocation of disaster risk, and management for PPP profitability (World Bank Group 2019b). These goals are best served when governments support PPP resilience through contract, oversight, and service provision inputs. Policy makers can also provide risk definitions and metrics, including for force majeure[42] events, when such risks and events may jeopardize PPP operations.

International financial institutions can support resilience and climate change adaptation in industrial parks and sectors with a range of financial instruments. Developing countries struggle to finance resilience investments with high capital costs, and require assistance through concessional finance, Climate Funds, Green Bonds, equity and guarantees. In Bangladesh, the World Bank is providing support for the Bangladesh Economic Zone Authority (BEZA) to develop a Green and Resilient Economic Zone (World Bank 2020a). This support includes a technical assessment to embed resilience into the design and costing of basic infrastructure investments in the flagship economic zone. The assessment reviewed: floods and earthquake risks; resilience designs for flood management, roads, buildings and other infrastructure, and life-cycle analysis of cost/benefits for these designs. A conceptual review was undertaken of costs and lifecycle savings for on-site public infrastructure such as river embankments, coastal levees and dikes, drainage, internal roads, bridges, and buildings to inform technical designs and financing of the investment. US$ 416 million will be invested, of which US$ 246 million will be spent on basic infrastructure (e.g., road network, stormwater network, and water and power supply network) including resilience measures (World Bank 2020a). This infrastructure investment will consider flood and seismic risks, and integrate green and resilient economic zone guidelines that the World Bank is developing with BEZA and other government agencies.

6.3.3 Provide Financial Support for Contingency Planning and Advance Disaster Risk Financing

Industry resilience initiatives are difficult to promote in advance of disasters if firms fail to understand their potential returns, or are unable to focus on future risks given the urgency of those they face in the present. This challenge applies particularly to smaller businesses and SMEs. In these contexts, fiscal-incentive-based financing is needed, and governments as well as public and private financial institutions play an important role in providing it. As an example, the Development Bank of Japan (DBJ) offers low-interest loans based on firms' disaster preparations (see World Bank 2020b for more details). DBJ uses regularly updated criteria to assess firms' preparedness levels (table 6.5). Based on these BCM ratings, DBJ evaluates firms' performance in three stages and provides loans with lower interest rates to companies with high ratings. This program encourages businesses of all sizes to design and implement BCM. Between 2006, when the BCM rating system was launched, and in 2019, 261 companies received preferential loans under this program. These companies have formed a networking platform for peer-to-peer knowledge sharing and information exchange. The DBJ has expanded this program, which now provides a more comprehensive risk management service which partners with insurance companies.

42 For more information, see Technical Brief on Resilient Infrastructure Public-Private Partnerships: Policy, Contracting, and Finance. https://openknowledge.worldbank.org/handle/10986/32632.

Table 6.5 Criteria for DBJ's BCM Ratings-Based Loan Program

Category	Evaluation Criteria
Disaster risk reduction (DRR) & prevention	• Corporate disaster prevention system • Employee safety protections • Participation in district and regional disaster prevention • Disaster prevention drills and training (emergency response, first response) • Good practice of DRR initiatives • Compliance
Business Continuity Management	• Crisis management system • Business impact analysis (BIA) • Strategy on business continuity • Good practice of BCP initiatives • Risk management for supply chain and value chain • Business continuity education, training and review • Active risk communication and crisis management publicity • Contribution to sustainable development • Good practice of BCM initiatives

Source: DBJ 2020.
Note: BCM = business continuity management; BCP = business continuity plan.

Governments need to pre-arrange disaster risk finance so that funds are rapidly released when urgent recovery action and financial support is needed. To accomplish this, the following principles are important (box 6.10).

Box 6.10 Principles of Disaster Risk Financing

1. **Release of funding: Speed matters, but not all resources are needed at once.** While liquidity is rapidly needed to support relief and recovery, more time is available to mobilize the larger amounts required for reconstruction programs, and thus, timeframe awareness clarifies funding strategies and plans for longer-term recovery.
2. **Disbursement: How money reaches beneficiaries is as important as where it comes from.** Governments require dedicated mechanisms and expertise to effectively allocate, disburse, and monitor recovery and reconstruction funds. Collaboration between the ministries of finance and the public entities tasked with post-disaster fund allocation—such as local governments and agencies that maintain public infrastructure-is essential. The disbursement system should be also transparent and accountable, balancing various concerns.
3. **Risk layering: No single financial instrument can address all risks.** Disaster risk layering mobilizes different financial instruments, such as budget reserve, mutual funds, contingent finance, and risk transfer instruments, which are applicable to disasters of varying frequency and severity. Layering addresses the evolving needs of recipients in pre- and post-disaster phases, so that less expensive funds are used first, while more expensive ones are used only if needed.
4. **Data and analytics: Decisions demands data.** Financial protection instruments should be keyed to the risk environments in which they are needed; such calibrations require risk and other quantitative data, and the analytics to interpret them. Such information helps to design financial instruments, and also assists aid recipients to choose those best suited to their needs and risk environments.

Source: World Bank Group 2019a.

Pre-arranged financing, structured by layering, also assists national governments to safeguard public infrastructure needed by industries, and to speed its recovery following disruption. In an example from the Philippines Disaster Risk Financing Strategy, retention and transfer instruments were used to protect public infrastructure. Risk transfer instruments, such as insurance for public assets and small businesses, are suitable for low frequency/high severity disasters, while disaster funds and contingency financing come into play for high frequency/low severity events.

While disaster funds are a common risk retention mechanism, their effectiveness depends on a number of preconditions. First among these is the need to define what qualifies as a disaster, as it is this designation which triggers emergency fund activation, and access. Procedures for this activation and access should, ideally, be formalized and documented in advance, so that they are well understood and executed during disasters; and this pertains, too, to legal and institutional frameworks for emergency response, finance for response actions, procurement, and reporting. Once funds are disbursed, fiduciary responsibilities come to the fore. The financial roles of national and local authorities should be clear, and damage evaluations methodical, so that resources can be consistently and transparently allocated.

Contingency financing instruments may be drawn on to establish pre-arranged mechanisms for post-disaster reconstruction. In Japan, pre-arranged agreements between the government and local construction companies minimized infrastructure disruptions following the GEJE. These agreements were made possible through contingency financing from the Ministry of Land, Infrastructure, Transport, and Tourism (World Bank 2014). The quick repair and reconstruction work that was initiated under the pre-arranged agreement enabled the reopening of highways six days after the earthquake.

Risk transfer instruments, such as insurance, add to the suite of pre-arranged financial instruments strengthening industry resilience; this important strategy requires technical and financial support. Globally, only one third of disaster-related losses are insured, and governments need to bridge affordability gaps through risk-sharing and subsidization of premiums. Risk-sharing distributes exposure among insurance companies, businesses and governments, increasing affordability and providing access to proactive measures. This narrowing of the affordability gap ultimately supports business continuity, solvency, and resilience, and generates co-benefits associated with risk-informed planning, investment, and even political accountability (Weingärtner et al. 2017).

In addition to closing the affordability gap, regulatory support also assists firms, especially in risk-prone areas. Understanding that affordability incentivizes preparedness, the US's National Flood Insurance Program (NFIP) offers a good example of this regulatory support.[43] The federally backed NFIP works to reduce flood impacts by providing affordable insurance and incentives for businesses to follow floodplain management regulations. Thus, industrial facilities in high-risk areas which have complied with flood-resistant building requirements qualify for reduced insurance premiums, and receive payouts from NFIP to cover flood damage. Additionally, federal, or federally insured lenders require that the owners of these properties purchase flood insurance. In this way, the government incentivizes both preparedness via insurance, and mitigation via incentivized compliance with building requirements. This, in turn, reduces government spending on disaster aid, and improves post-flood financial recovery, as evidenced after Hurricane Sandy.

Finally, to implement the approaches introduced in this section, it is important to strengthen the financial sector itself, and ability to settle claims because disasters can drain the sector of liquidity and limit its services to its industry clients. To prevent such a scenario, the Bank of Japan's (BoJ) Disaster Preparation Plan is designed to maintain liquidity in the event of significant savings drawdown or deteriorating credit quality following

43 NFIP offers commercial policyholders up to US$ 500,000 in coverage for insured properties, and US$ 500,000 for contents. Under NFIP, this product covers damaged electrical and plumbing systems, water heaters, water tanks, heat pumps; and business contents such as machinery and equipment, merchandise, or in-process goods held in storage or for sale. *Source:* FEMA 2020.

a disaster. Additionally, the BoJ has backup business premises, disaster-proof construction of its headquarters, emergency power, and the means to deploy first responders. After the GEJE, the BoJ opened an alternative office within 15 minutes, communicated via its website, provided cash to local banks, and was able to replace damaged bank notes (World Bank 2020b). In Thailand, the government has implemented a series of insurance development plans, which included actions to improve regulation and supervision of insurance and strengthen supervisory staff (IMF 2019). If large claims or loss events take place, as in 2011 floods in Thailand, the Office of Insurance Commission (OIC) monitors the impacts on the insurers' cash flows. The OIC also monitors the needs for additional capital injections, liquidity positions, reinsurers' financial positions, and so on (IMF 2019). These actions illustrate the importance of maintaining financial sector resilience to support the recovery of its clients.

Table 6.6 Mitigation and Preparedness: Example Projects

Intervention area	Name of intervention	Location	Brief description	Outcomes
Promote business continuity planning and management.	BCP Manuals	Japan	In Japan, the Cabinet Office and METI provided manuals to guide companies to develop BCPs, reflecting lessons learned from previous disasters.	BCP implementation rate increased significantly.
	Continuity Guidance Circulars, NFPA 1600	United States	Manuals and resources were made available online to guide business process analysis, business continuity impact analysis, etc.	BCP implementation rate increased significantly.
	Kyoto BCP	Japan (Kyoto)	A prefecture-wide BCP was applied across industry sectors. Prefecture government, industry associations and companies shared damage scenarios and conducted joint workshops.	Collaboration among a wide range of stakeholders was enhanced, and BCP implementation rate increased.
	REinforce Supply Chain Under Emergency (RESCUE)	Japan	A large car manufacturing company develops a joint BCP with its suppliers based on its supply chain information.	During Kumamoto earthquake, the companies' BCP was activated and parts production shifted and resumed according to their joint needs.
	Istanbul Tuzla Organized Industrial Zone	Istanbul, Turkey	The Istanbul Chamber of Industry and the World Bank partnered with ITOIZ to develop a risk-informed, park-wide BCP.	Industrial park stakeholders jointly developed a risk-informed BCP and confirmed the need to strengthen capacity building of on-site technicians and engineers.
Help industries maintain global value chains.	The Otagai Project	Japan and Thailand	After the GEJE and the floods in 2011, the Governments of Japan and Thailand signed an MoU to initiate the Otagai Project which encourages cooperation between companies in the two countries under the "sister-cluster" concept through a BCP.	The Otagai business network mutually improved competitiveness of the countries' trade and supply chain functions both during disasters and normal operations.
Help industries maintain global value chains.	HOPE II Act	Haiti	Trade preferences (direct shipment and flexible rules of origin clauses) allowed companies to re-route exports through the neighboring Dominican Republic.	The trade preferences helped secure business and reputational continuity of garment manufacturers in Haiti after the earthquake.
Promote resilient industrial park development.	Bangladesh National Building Code, and National Guideline for Green and Resilient Economic Zones	Bangladesh	In Bangladesh, the Government have adopted structural design requirements addressing the risks of floods, cyclones and earthquakes. The National Building Code identifies Cyclone Prone Areas, Surge Prone Areas, Risk Areas (RA) and High-Risk Areas (HRA), and have different building design requirements for these areas.	The National Building Code has guided the master planning and design of green and resilient economic zones.
	Guidelines for Preparing Master Plan of SEZ Area	India (Gujarat)	In Gujarat, India, the SEZ Authority developed guidelines to help firms protect themselves from natural hazards.	The national laws and SEZ master plan development guidelines restricted industrial production in high risk areas.
	Update of river embankment and dike designs for industrial parks	Thailand	Standards are revised and updated to guide the design, construction, and maintenance of flood protection infrastructure in industrial parks.	Revised design standards for embankments were used to increase flood protection for industrial parks, including those affected by the 2011 flood, helping to increase investor confidence.
	Resilient Industry	United States (New York City)	In the US, advisory flood maps produced by FEMA establish flood-resistant construction standards; the Government of New York City integrates these standards into its zoning text which applies to industrial building construction and reconstruction.	Industrial buildings in manufacturing districts of the City were retrofitted to withstand coastal flooding and storm surges.
Minimize infrastructure disruption in industrial parks.	Dike construction in industrial parks	Thailand	Flood dikes in inundated industrial parks were constructed or upgraded to reflect increased flood risks.	Dike construction and improvement of flood-proofing measures helped secure investments.
	Bangladesh Private Investment Digital Entrepreneurship Project (Green and resilient Economic zone)	Bangladesh	Flood-proofing of the economic zone (raising site level to 6.5 meters above mean sea level). An additional list of structural designs to withstand earthquakes, floods, cyclones, etc. is being developed and integrated into the design and costing of various on-site infrastructures, including power and water supply network, road network and wastewater treatment plants.	US$ 60 million worth of adaptation co-benefits are expected from the climate-resilient infrastructure investments.
	Factory-Grid ("F-Grid")	Japan (Ohira Industrial Park)	Tenant firms jointly improved preparedness and reliability of power supply in industrial parks by establishing a back-up power system and diversifying energy sources.	The F-Grid increased both disaster management capacity and energy efficiency of the industrial park. This helped increase the reliability of power supply services and lowered utility costs for tenant firms.
	Reforestation at the Port of Mombasa	Kenya	Nature-based solutions in the port infrastructure area; mangrove forests were also restored to improve the buffering capacity of the port area's coastline.	Kenya Port Authority helped reduce the impacts of frequent floods and landslides on port logistics.
	Investing in green and grey infrastructures	United States (New York City)	The City government invested in "green" (green infrastructure including bioswales) and updated "gray" infrastructure (sewer infrastructure).	The City expects to increase drainage capacity and mitigate impacts of flooding on business operations, while reducing capital costs.
	Post-disaster Emergency Response Partnership Agreements	Japan (Sendai City government)	Pre-arranged agreements can be made among private service providers as part of their BCPs.	Pre-arranged agreements have proven effective in Japan. All roads were quickly cleared and repaired through pre-arranged agreements.
Conduct alternative cost-benefit analyses.	Industrial manufacturing complexes (Gunsan National Industrial Complex 2)	Republic of Korea	Improvements to the detention pond infrastructure were made as a part of the Gunsan Comprehensive Natural Disaster Reduction Plan. The benefits of this investment included an increase in the area of serviced land.	The Industrial Complex was able to increase the area of serviced land and attract private investment in floating solar panels on the retention pond.
	Manual for economic evaluation of flood protection infrastructure investment.	Japan	The manual requires that both physical damage and business disruption costs are considered in the cost-benefit analysis for public infrastructure investment decision-making.	The improved cost-benefit analysis justified investment in flood protection infrastructure.
	Bangladesh Private Investment and Digital Entrepreneurship Project	Bangladesh	A life-cycle cost analysis was used to prioritize resilient infrastructure investments.	The life-cycle cost analysis will inform technical design specifications that optimize capital and operational costs.
Provide financial support for contingency planning and advance disaster risk financing.	BCM Rated Loan Program	Japan	The Development Bank of Japan offers preferential loans for firms with high disaster preparedness ratings.	Firms of different sizes incentivized to implement BCMs. As of 2019, 261 companies received preferential loans.
	National Flood Insurance Program	United States	Industrial property owners complying with flood-resistant building requirements qualify for reduced insurance premiums.	The Program incentivizes preparedness and mitigation by linking compliance with building codes to reduced insurance costs.

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7

Response and Recovery

Disaster response situations often present opportunities to develop and strengthen disaster mitigation and preparedness measures because of the temporarily high profile of disasters. However, agencies supporting disaster response efforts have struggled to design instruments that provide coordination and resources quickly enough, or for long enough to achieve their objectives. Building back industries better during the response stage may require a longer period of implementation, initially focusing on rapid restoration of critical functions and later on mitigation based on lessons learned from previous disasters.

Recommended Actions

- **Activate and refine coordination frameworks for response and recovery.**
- **Conduct rapid assessment of industrial damage and losses.**
- **Provide support to retain investors and boost market demand.**
- **Support safety and employment continuity.**
- **Restore critical infrastructures and services.**
- **Provide financial safety nets targeting SMEs.**
- **Financial investments in building back competitive industries.**

7.1 Activate and Refine Coordination Frameworks for Response and Recovery

During the emergency response stage, there are strong pressures to act quickly to minimize suffering and disruption. However, this imperative should not override stakeholder dialogue and agreement on coordination mechanisms, as these procedures generate multiple benefits. Stakeholder engagement clarifies the needs of industry, incorporates lessons learned into longer-term recovery and preparatory actions, promotes commitment from local partners and other stakeholders, and improves the overall legitimacy and sustainability of emergency measures. Stakeholder dialogue also clarifies roles and responsibilities and avoids delays when project time frames are short.

A number of principles apply when responding to a disaster (World Bank 2018a; World Bank 2020b):

- Practitioners should adopt an evidence-based approach to disaster response and recovery.
- Rapid damage assessment should be conducted to inform first steps.
- Disaster response projects need to engage a broad range of national and local stakeholders, private sector representatives, employees and vulnerable populations that depend on the affected industries. Ideally, the list of these stakeholders, as well as their roles and responsibilities should be included in emergency preparedness and response plans or BCPs so that they are executed in a timely manner.
- Coordination frameworks should be as simple and realistic as possible within what is likely to be a complex implementation environment.

Specialized task forces can contribute substantially to the emergency response stage, streamlining decision-making; providing planning continuity, coordination and monitoring; facilitating PPPs for damage assessment, emergency response and recovery;

and tracking recovery and reconstruction activities. Such teams may be mandated by governments, and may also manage information regarding damage, review funding requests, and manage funding disbursement. In the mid-term, the coordination unit or the task force team may also monitor and evaluate the performance of disbursed funds against long-term industry resilience and competitiveness goals.

Clearly mandated, independent bodies are better able to coordinate efforts across existing national government agencies, ministries and provincial governments. Experience suggests that governments struggle to do this, as evidenced during the Thailand floods. In response to the floods, a number of ad hoc committees were set up, and these worked with fifteen ministries from the Thai government (Kawasaki et al. 2012). But roles and responsibilities were unclear, and coordinating and operating procedures inadequate, and this case flags the importance of pre-disaster procedures to support business continuity and emergency response (World Bank 2012b). It also notes the need to include lessons from previous disasters into these plans, while retaining flexibility to respond to different types and scales of disasters.

In Haiti, a clustered approach was used to coordinate emergency responses. The clustered approach was introduced in 2005 as a part of reform to improve overall coordination and response during crises (Stumpenhorst et al. 2011). In this approach, UN agencies with a particular technical and institutional capacity lead and facilitate coordination at the global and country level, strategically planning, raising funds and supporting the quality of emergency response and so on. In Haiti, this approach and coordination arrangements had been established in 2008 for response to the floods, which were activated quickly after the earthquake. The Joint Operations Tasking Center (JOTC) was established within 10 days of the earthquake by the Department of Peacekeeping Operations (DPKO), United Nations Stabilization Mission in Haiti (MINUSTAH), and the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), and through humanitarian and military inputs from various nations. From the outset, JOTC provided common operating procedures focusing on security, humanitarian, transport, and engineering works; and provided efficient and coordinated use of military and police resources for restoring key infrastructure services. OCHA coordinated a multi-sectoral assessment, enhancing information sharing among emergency response stakeholders during the initial response phase. Although the clustered approach reflects its previous activation during the 2008 hurricane (OECD 2011), and in later contingency exercises, it still required much improvement in terms of collecting data and exchanging and managing information and effectively engaging the national and local governments and civil society groups (Altay and Labonte 2014).

One of the lessons learned in Haiti is that private sector support leads to robust, rapid and cost-effective responses. The Haitian government itself was severely affected by the earthquake, and with little capacity to coordinate relief efforts, it engaged the international humanitarian taskforce and international private sector stakeholders experienced in logistics and infrastructure restoration. With this assistance, the government was able to rapidly resume core functions, reassure investors and help manufacturers stay in business and retain market access.

The Japanese case further shows how agreements and operating procedures with clear criteria for activating EP&R for emergencies arranged ahead of disasters can deliver swift coordinated actions when they strike (World Bank 2020b). Japan's pre-arranged cooperation agreements, with defined roles, responsibilities, and action items, enabled disaster responders to by-pass normal contractual processes, allowing public and private sector stakeholders to mobilize resources and rapidly restore infrastructure services and supply chains, as shown in the Sendai City government example in Section 6.2.

Post-disaster situations provide unique opportunities for national governments to develop action plans that strengthen the capacity of people, the economy and private sectors to better manage disaster risks in the long term. Therefore, it is important for national governments to direct post-disaster responses if possible, and to engage other stakeholders such as local governments, industrial park operators, and industrial associations in stakeholder dialogue and decision-making. While ideal, this approach may not be possible when large-scale disasters cause multiple donors and partners to render assistance at the earliest opportunity, thus overlooking the advantages of inclusion and ownership. Importantly, the need for rapid responses should not be used as a justification for by-passing local institutions and communities who are the ultimate owners and beneficiaries of such responses.

7.2 Conduct Rapid Assessment of Industrial Damage and Losses

In the aftermath of disasters, the speed with which impacts can be assessed affect recovery process, and the mobilization of funds. Damage assessments also flag locations requiring specific assistance, quantify funding requirements, and guide resource allocations. Conventional Post-Disaster Needs Assessment (PDNA) or Damage and Loss Assessment (DaLA) methodologies can take up to 3 months to complete, requiring surveys, field staff, baseline data, and government interaction (World Bank Group 2018a). While they may provide detailed analysis, there is a need to streamline these approaches so that they do not delay the arrival of urgently needed funding. This streamlining can be achieved using dedicated damage assessment teams/organizations which focus on industry sectors.

The importance of rapid assessment was illustrated in the aftermath of the Haiti earthquake, when rapid assessment of the damaged seaport and Parc Industriel Metropolitan (PIM) secured foreign investor commitment and catalyzed investment for retrofitting industrial buildings and restoring port infrastructure. Damage assessment was completed within four days, and allowed the Haitian government to (box 7.1):

- Quickly estimate and cost the scope of repairs and reconstruction required at the PIM;
- Promptly and correctly update buyers on the production capacity and investment potential of recovering garment manufacturing companies;
- Reconnect buyers who had cancelled orders with manufacturers who had resumed operations; and
- Clarify reconstruction needs and guide foreign investors, international donors, and development partners to address these needs.

Box 7.1 Haiti: Rapid Damage Assessment Helped Attract and Inform Investment in Repair and Reconstruction of Industrial Infrastructure

Solution

The World Bank conducted a rapid damage assessment to help the Government of Haiti estimate needs and costs for the repair of industrial parks and facilities, and damage to port infrastructure and logistics services needed for import and export. Remaining production capacity and potential for its expansion were also assessed. Linking with previously designed expansion plans,[44] the assessment of damages at the PIM included the structural analysis of 51 industrial buildings.

The team received initial information from Haiti's public and private sectors soon after the earthquake occurred, confirming that, despite high localized impacts, that manufacturing facilities were not critically damaged. Of 23 companies in the garment sector, 19 were operational within a week, albeit not at full capacity. The team secured a budget for the damage assessment, initiated procurement, and contracted a specialist to develop a plan for industrial park recovery. A similar plan[45] for PIM followed (IFC 2009).

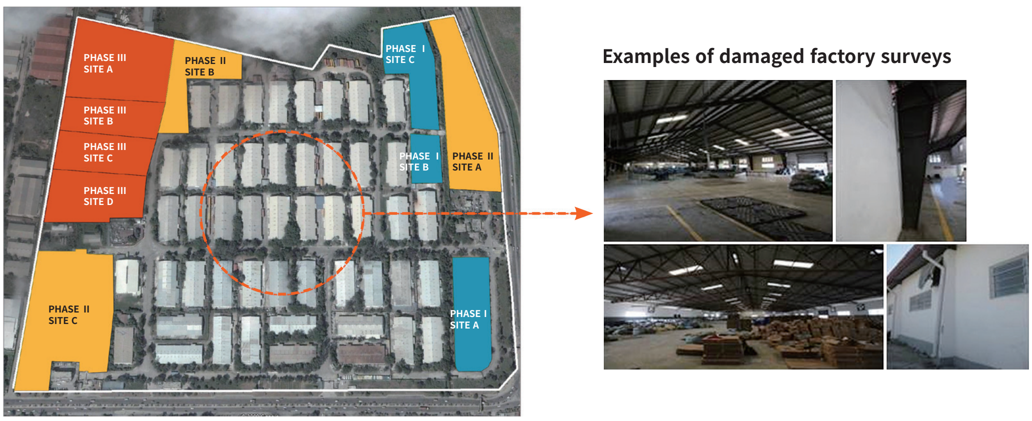
Structural damage to buildings was identified through visual inspection due to time and resource constraints (see also Section 8.2.4). The report also identified local construction companies and locally-sourced earthquake-resistant materials required to reconstruct factory shells.

Results

The assessment confirmed that the garment sector, if supported by investors and development partners, could resume production and continue business. Within the PIM, where most garment manufacturers were based, a number of factory shells were still useable (71 percent, or 35 buildings). Remaining buildings (approximately 22 percent, or 11 buildings) needed major repair, while one had to be demolished (figure 7.1). The estimated cost of repair was approximately US$ 20.6 million. Importantly, the assessment identified 161,000 square meters of industrial land within the PIM for new industrial facilities. The report suggested a phased expansion of production, and found that, if financed, plots marked in green could be developed quickly, at relatively low cost, because they were served by roads, water and power supply networks. The assessment also identified an investment opportunity to upgrade electrical substations, reducing reliance on economically and environmentally problematic back-up diesel generators.[46]

In short, the rapid damage assessment informed an effective recovery strategy that could leverage the remaining production capacity of garment manufacturing industries in the Port-au-Prince area, and expand it.

Figure 7.1 Rapid Damage Assessment of an Industrial Park in Haiti



Source: Ortega et al. 2010; IFC 2009.

44 Ibid.

45 IFC 2009.

46 Using diesel generators during month-long power outages can generate problems such as limited and unequal access to fuel, and large CO_2 emissions. These generators are meant to be used only for brief outages that typically last days.

An important lesson from the Haiti assessment was the need for an industrial infrastructure asset management system. While the park operator provided information on underground services, electricity, water, and sewage, this information had not been systematically documented, or computerized, and this hindered the assessment. To perform rapid damage assessments, ICT-based asset management systems are needed (more details are discussed in Section 8.2.4).

7.3 Policy

7.3.1 Provide Support to Retain Investors and Boost Market Demand

Tax Incentives

Tax regimes are often an important determinant of investor willingness, and governments can use tax incentives as a tool to shape post-disaster responses in favor of resilience. In Thailand, the Board of Investment (BOI) and the Ministry of Industry granted temporary exemptions from import duty/tariffs on machinery (new and old machinery) to encourage firms to replace and/or repair damaged machines, and obtain machine parts and tools (BOI 2011). BOI also extended the incentive period and investment benefits for investors, and assisted them with visa applications and employment licensing. Other measures included permission for temporary production relocation and outsourcing, and lifting of import tariffs on locally unavailable equipment. Additional corporate tax exemption was given to flood-hit companies and tax-free car imports were granted to the automobile industry.

Such tax incentives can encourage affected investors and firms to remain in a disaster-affected country, and/or expand operations, and may also attract new investors. Approximately 3 months after the floods, the BOI provided additional exemption on corporate income tax, targeting investors and tenant firms in flood-affected industrial zones. The tax exemption was applied to the two most flood-affected provinces: Ayutthaya and Pathumthani (table 7.1). Through various reconstruction efforts and tax incentives, the net flow of FDI increased from US$ 2.47 billion in 2011 to US$ 15.936 billion in 2013, although net flows fluctuated between 2011 and 2019 overall.[47]

Table 7.1 Thailand: Corporate Income Tax Exemption Applied to Flood-Affected Industrial Estates

Pathumthani Province	An 8-year corporate income tax exemption with a cap of 150% of the investment (excluding cost of land and working capital) for projects in industrial estates and zones.
Ayutthaya province	An 8-year corporate income tax exemption with a cap of 150% of the investment (excluding cost of land and working capital). **Additional three-year 50% corporate income tax reduction for investments in industrial estates and zones.**

Source: BOI 2011.

Governments can provide similar tax incentives to attract new investments or boost markets for the manufacturing sector during other emergencies. For example, during the COVID-19 lockdown, the Malaysian manufacturing sector has been impacted by disrupted international supply chains and the movement control order (MCO)-related restrictions that

47 The Bank of Thailand. Foreign Direct Investment Classified by Country/Economic territories (US$) https://www.bot.or.th/App/BTWS_STAT/statistics/ReportPage.aspx?reportID=654&language=eng.

resulted in the shutdown of industrial facilities. In response, the government of Malaysia has introduced a series of stimulus packages to encourage the establishment of new businesses through various incentives (Deloitte 2020; Medina 2020), including:

- A zero percent tax rate for 10 years for manufacturing companies with investments in fixed assets between US$ 70.5 million (RM 300 million) and US$ 117.5 million (RM 500 million);[48]
- A zero percent tax rate for 15 years for manufacturing companies with investments in fixed assets exceeding US$ 117.5 million (RM 500 million);
- 100 percent investment tax allowance for three years for an existing company in Malaysia that will relocate its overseas facilities into the country;
- Income tax rebate of up to US$ 4,700 (RM 20,000) per year for the first three years for an SME; and
- Incentives to stimulate the automotive sector and provide financial relief to car buyers through sales tax exemption on both locally assembled and imported cars.

Temporary Relaxation of Regulatory Barriers

Following disasters, some regulatory requirements may be relaxed to facilitate product certification, or reconstruction of damaged industry assets and infrastructure. For example, existing building codes may stand in the way of repair and reconstruction, requiring temporary relaxation. While reconstruction should ideally be guided by existing codes, governments may, in such cases, need to suspend those that block urgently-needed repair work. In New York City following Hurricane Sandy, for example, FEMA updated federal flood maps[49] to revise flood risk information (The City of New York 2013). But the existing zoning restrictions made it difficult for property owners to renovate in compliance with the updated flood maps. In the post-Sandy environment, translation of the FEMA's updated flood-resistant standards into local zonings would have been impractical, and delayed reconstruction. To solve this problem, the NYC government fast-tracked zoning regulation amendments via an Emergency Executive Order[50] so as to avoid these delays (The City of New York 2013), allowing firms to recover quickly and legally, and without jeopardizing their eligibility for the National Flood Insurance Program.

Another way in which governments can aid fast recovery is to relax visa requirements so that foreign investors, engineers and stakeholders from parent companies can quickly enter disaster-affected countries. In the Thailand case, the government relaxed entry requirements for experts in factory rehabilitation including Japanese engineers, technicians and investors in Thai companies, all of whom needed to enter Thailand to assist in the recovery of damaged factories (World Bank 2012b). This rapid entry enabled stakeholders to restore operations in three months, as opposed to the estimated 12 month recovery time (Hammerton 2012). In addition, METI and the Small and Medium Enterprise Agency (SMEA) helped Thai employees from damaged factories to move to factories in Japan through a special visa regulation, which supported the prompt recovery of disrupted supply chains (World Bank 2020b). This reciprocal relaxation of visa requirements helped mitigate GVC disruptions and job losses.

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48 Converted into US dollars ($) at the 2019 annual average exchange rate of $1 = RM 4.14, based on official exchange rate (LCU per US$, period average) provided at: https://data.worldbank.org/indicator/PA.NUS.FCRF?end=2019&locations=MY&start=2019. RM=Malaysian ringgit.

49 FEMA published Advisory Base Flood Elevation Map on January 28, 2013 to provide up-to-date information on safe elevations for flood-resistant construction.

50 Emergency Order to Suspend Zoning Provisions to Facilitate Reconstruction in Accordance with Enhanced Flood Resistant Construction Standards (Executive Order No. 230). http://www.nyc.gov/html/om/pdf/eo/eo_230.pdf.

During the COVID-19 pandemic, governments around the world supported business continuity by streamlining regulatory requirements that would have curtailed the adaptability of firms (World Bank 2020a). Such support focused on:

- Removing the need for applications, permits, and licenses for products posing minimal risk to human health, environmental safety, or consumer protection;
- Streamlining procedures for products requiring authorization, using web-based or automated options for requesting and obtaining documents;
- Prioritizing import approvals for all COVID-19 related medical goods, essential food items and perishables; and suspending fees and charges for the issuance of licenses, permits and certificates required for these products;
- Implementing risk management to allow critical, low-risk supplies to quickly pass clearance controls;
- Allowing flexible working schedules, longer border opening hours and expanded access to telephone and online enquiry points; all of which can increase efficiency of trade logistics and assist social distancing of workers and officials at facilities and border crossing points; and
- Supporting cooperative arrangements among small-scale cross-border traders to organize their supply chains, reducing movement and interaction of people.

Investment Aftercare Program

Investment aftercare programs can also help manufacturers maintain investors and access to markets. The Government of Haiti, with support from the World Bank and Inter-American Development Bank (IDB) tried to increase FDI in the Haitian apparel sector following the 2010 earthquake. These partners re-assured investors to prevent them cancelling orders due to concern about the country's post-earthquake production capacity. Box 7.2 details the investor aftercare program established to accomplish this, showing how this program, in concert with other post-disaster measures, was able to retain investors, and to create new, long-term jobs for economically disadvantaged Haitians stricken by the impacts of the earthquake.

Box 7.2 Haiti: Adaptive Investment Generation Strategy

Solution

In the aftermath of the earthquake, the Government of Haiti, in partnership with the World Bank, formed an adaptive project management strategy to protect firms through investment retention and the creation of new FDI opportunities. Specifically, the program was restructured to maintain access to markets and investors by arranging contracts between global buyers/retailers and local suppliers, and soliciting new orders. With technical support from garment industry experts, the IFC project team conducted a mapping and baseline survey of surviving garment manufacturers' capacity and product lines (IFC 2010), and identified standing contracts from US buyers. The survey showed that, despite the earthquake, the remaining production capacity of garment manufacturers was approximately 16 percent. It was estimated that, with investment support, this capacity could be expanded to generate approximately 1,800 new jobs, with an approximate annualized potential US$ 34 million increase in export sales.

Based on these findings, the team aimed to increase the production and export performance of the surviving garment manufacturers. A consultant was engaged to work with operational factories, maximize their remaining capacity, and maintain business continuity of the garment manufacturing sector.

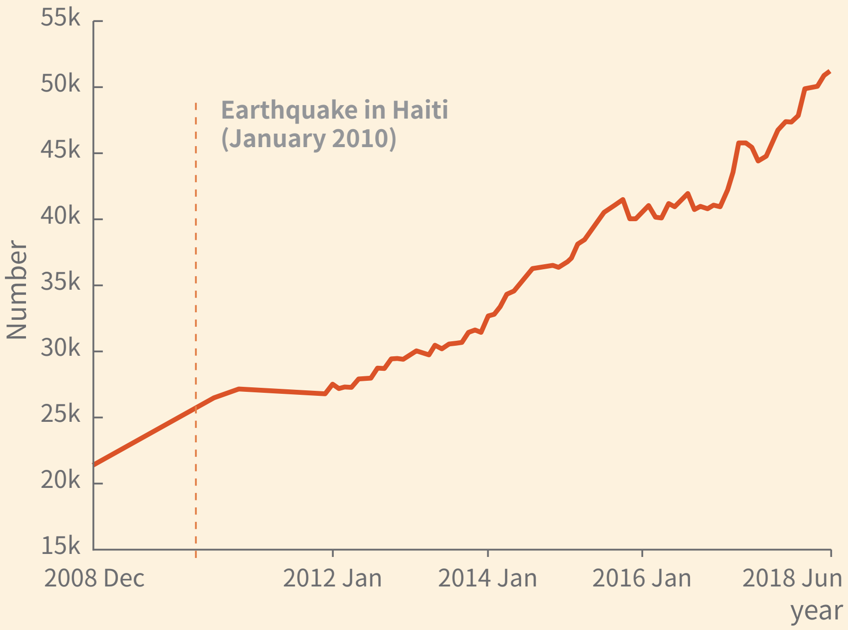
The project also helped garment manufacturers expand their product offerings and leverage the HELP preferential trade treatment. The project also provided support for an FDI promotion campaign.

Results

These adaptive program management strategies helped retain and increase investment, and achieved some tangible results. By helping to maintain existing contracts between international buyers/retailers and garment manufacturers, and soliciting new orders, the apparel sector increased its production capacity from 80 to 92 percent between April and September 2010. The net exports of the sector increased by approximately US$ 51 million during this period. In short, and despite the earthquake, the aftercare program forged new efficiencies, smarter reading of the market, and better buyer-client relations to establish a positive prospectus for the industry.

In contrast to substantial job losses in other commercial sectors in the country, employment losses in the apparel sector were relatively small due to trade preferences and investor aftercare programs that helped garment manufacturers retain their connections with their investors and the GVC. Together with the rapid industrial damage assessment, the ability to retain investors also preserved more than 23,000 pre-earthquake jobs, and created 2,560 new ones (Center for Facilitation of Investment, n.d.). The Government of Haiti's efforts to create jobs by supporting manufacturing industries also contributed to the long-term sustainability of employment. And, in between 2009 and 2018, employment in the garment sector steadily increased by 26,306, from 24,583 to 50,889 jobs, as illustrated in figure 7.2.

Figure 7.2 Employment in the Haitian Apparel Sector



Source: Adapted from Center for Facilitation of Investment, n.d.

Investment aftercare programs can reduce the effects of demand and supply shocks on manufacturing industries during disasters and pandemics (box 7.3). During health emergencies, the output of firms can be significantly reduced, even in the absence of physical damage, through reduced labor productivity and supply and demand shocks. In these cases, governments can support firms and encourage adaptive strategies such as using substitute suppliers from less affected regions, diversifying products, or producing goods that are urgently needed during emergencies.

Box 7.3 Business Strategies to Maintain Market Access in Response to Demand and Supply Shocks During Disasters and Other Emergencies

Shocks to demand and supply:
Disasters often generate supply side shocks through reduced labor productivity, partly because employees cannot commute due to physical and health impacts. Negative working and commuting environments delay transportation and logistics, and disrupt supply chains. Shocks on the demand side also occur following reduced consumer demand, or reputational loss. During pandemics, these shocks may be of longer duration, and may shape consumer behavior in the longer-term. During the COVID-19 pandemic, FDI inflows to developing economies are expected to decrease considerably for an extended period - a consequence that differs from that of a natural disaster in which FDI is relatively unchanged in the long-term as large-scale reconstruction investment offsets other adverse effects (World Bank 2020a).

Business strategies to maintain market access in response to supply and demand shocks during COVID-19:
To stay in business, and at the same time, address the shortage of critical medical supplies, manufacturers have repurposed production lines and diversified products. For example, the European fashion industry adapted its factories to make hand sanitizer, face masks, nonsurgical gowns, and medical overalls (Schatteman, Woodhouse and Terino 2020). Likewise, in developing countries, garment manufacturers are diversifying production to make Personal Protective Equipment (PPE) and nonsurgical masks. For example, in Tajikistan, some textile firms have expanded production to manufacture masks and gowns, obtaining assistance from UNIDO to meet PPE quality requirements (UNIDO 2020). Public-private partnerships have played a vital role in manufacturing critical medical products. Responding to a request from the US federal government, US automotive manufacturers converted production lines to produce ventilators (Albergotti and Siddiqui 2020).

Source: Albergotti and Siddiqui 2020; UNIDO 2020; Schatterman, Woodhouse and Terino 2020; and World Bank 2020a.

Policy makers should design investment incentives and aftercare programs to maintain healthy market structures supporting competition and innovation, while mitigating the impacts of disasters. Poorly implemented investment incentives and aftercare programs can privilege dominant firms, invite the emergence of cartels, prevent innovation (Gramegna et al. 2018) and weaken production. Therefore, public authorities should make sure that industry resilience programs do not facilitate anticompetitive behavior or entrench unfair market dominance.

7.3.2 Support Safety and Employment Continuity

In countries in which social security, safety and healthcare systems are inadequate even under normal conditions, governments and industrial park operators need to provide security and healthcare to firms and their employees. International agencies may also support manufacturing sector recovery through security and logistics interventions. For example, at the time of the 2010 earthquake, Haiti faced security challenges due to prolonged political crisis, and as a result, the Stabilization Mission in Haiti (MINUSTAH) had a strong presence in the country, providing security and humanitarian assistance as part of its mission.[51] Police units formed by the MINUSTAH also had a strong presence in PIM, a public industrial park close to the international airport and long threatened by surrounding social unrest. These threats were exacerbated by the earthquake, alarming the park management authority (SONAPI) and leading to the deployment of a MINUSTAH unit to protect workers and

51 The U.N. Security Council created the U.N. Stabilization Mission in Haiti (MINUSTAH) on April 30, 2004, having determined that the situation in Haiti threatened peace and security in the region, and acting under Chapter VII of the U.N. Charter. MINUSTAH was given a mandate under three broad areas: a secure and stable environment, the political process, and human rights. In 2017, MINUSTAH completed its mission and left Haiti following the Mission’s closure, scheduled for October 2019 (Margesson and Taft-Morales 2010).

industrial assets in the park.[52] MINUSTAH's involvement also supported economic recovery partially by re-assuring investors and buyers that the park remained operational and safe, despite threats to law and order elsewhere.[53] This security support helped tenant firms in the PIM to resume their operations more smoothly, which, in turn, helped workers maintain employment (Wilbes Haitian S.A. 2019).

Job security can be preserved during disasters through working capital support and employee exchange programs with trading partners. In the Thailand case, for example, the Japanese government issued work visas to allow Thai employees from damaged factories in Thailand to temporarily move to Japan. More than 5,300 visas were issued under the special regulation from the Japanese government (Sukegawa 2013). The program benefited Japanese firms needing back-up production in Japan to mitigate supply chain disruptions; it also benefited, at least in the short-term, Thai workers whose jobs might otherwise have been jeopardized (Ranghieri and Ishiwatari 2014).

7.4 Infrastructure

7.4.1 Promptly Restore Critical Infrastructure and Services

Quickly restoring disrupted infrastructure and services is critical for business continuity during disasters; in the absence of pre-arranged disaster responses, emergency contracts become especially important to maintain business continuity and market access. In Haiti, in the absence of pre-arranged agreements, port infrastructure and logistics were restored through fast-tracked emergency contracts with private companies. With limited resources for restoration, the government sought assistance from international donors and private infrastructure service providers who could mobilize resources and technical expertise. Within days of the earthquake, the United States Transportation Command (USTRANSCOM) engaged the services of US-based maritime, transportation, logistics, and wreck removal companies to restore port operations. Supported by USTRANSCOM, a contract was quickly issued for crane-bearing barges which act as temporary piers for rapid resumption of cargo handling. At the same time, with additional support from international organizations, debris on the roads leading to ports and damaged cranes were cleared, and floating containers were removed to clear the port entrance. The Port-au-Prince seaport resumed operating approximately 10 days after the earthquake, allowing import of much-needed aid and supplies, and resumption of import/export-based trade and commerce (Crowley 2010).

52 MINUJUSTH (United Nations Mission for Justice Support in Haiti). Public Security: Two International Police Units Leave Haiti. https://minujusth.unmissions.org/en/public-security-two-international-police-units-leave-haiti.

53 Haiti Earthquake: Crisis and Response, Ibid.

Figure 7.3 Haiti: Barge/Crane for Import and Export from Temporary Piers

Photo Credit: © Etienne Raffi Kechichian

Emergency contracts may be useful when additional resources are rapidly needed to minimize downtime of infrastructures and services critical to industries. When disasters strike, EP&R plans and BCPs need to be activated according to predetermined criteria, and critical infrastructures such as roads, power and water supply networks, ICT and other infrastructure should be restored following clear timelines. Adjustments to what was planned in the BCP may still be needed, requiring additional resources. Governments should work with private sector/industry stakeholders, such as national and local industrial associations, which can be approached at short notice if pre-disaster contracts are not in place, or if additional help is needed. Industrial associations can mobilize member companies, bypass time-consuming contractual procedures, and rapidly deploy technical capacity and resources.

7.5 Finance

Disaster impacts cannot always be anticipated, and for this reason, financial instruments for emergency responses are an essential industry resilience approach, irrespective of pre-disaster preparedness. These instruments include budget redistribution, emergency loans, emergency guarantee programs, tax-related measures, donor support and resource loans. Pre-arranged financial mechanisms allow for quick recovery and have been described in Section 6.3.

7.5.1 Provide Financial Safety Nets Targeting SMEs

Many firms become financially vulnerable following disasters, and SMEs without creditworthiness, working capital, and insurance are particularly at risk. Thus, post-disaster financial instruments are needed to deliver rapid financial assistance and offer safety nets for firms without the need for collateral or particular credit scores. Examples of such instruments may include emergency credit guarantees, emergency loan programs, and loan restructuring programs.

Governments can help SMEs to consolidate their creditworthiness by offering emergency guarantee programs; clear eligibility standards, local-level coordination networks and political will are needed. In Japan, two months after the GEJE, public Credit Guarantee Corporations (CGC) provided guarantees to struggling SMEs to help them borrow from banks under clearly defined eligibility criteria (World Bank 2020b; CGC 2018). Firms that had lost 10 percent of their sales due to the GEJE, firms directly damaged by the earthquake and tsunamis, and those whose businesses were in the warning zones of the nuclear power plant accident, were eligible to apply for the emergency guarantee program. Under the program, SMEs qualified for credit guarantees covering a maximum of US$ 1.82 million (¥200 million),[54] of which US$ 727,000 (¥80 million) required no collateral. In response to the GEJE, CGC provided over 132,000 guarantees, corresponding to a credit exposure of approximately US$ 24.5 billion (¥ 2.7 trillion). These costs show that governments need long-term political commitment and funding strategies to run nationwide public credit guarantee programs (for more details, see World Bank 2020b).

Emergency loans are also suitable instruments for SME recovery if they are timeously disbursed on time. Close partnerships with local banks and credit unions are needed to effect this. In Japan, the Japan Finance Corporation (JFC) partners with regional banks and credit unions as a complementary lender to provide SMEs with long-term, low-interest loans for reconstruction investments (World Bank 2020b). SMEs suffering sales and reputational losses are eligible to apply for the loans on submission of proof of damage; and the interest rates, repayment schedules (from 8 to 20 years) and grace periods (from 3 to 5 years) ease the burden of repayment, helping them to quickly recover.

In addition to loans and guarantees to individual firms, governments can provide group subsidies for regional recovery. In Japan, after the GEJE, the SME Agency and METI supported groups of SMEs to repair damaged facilities (Kashiwagi and Todo 2019; Kashiwagi 2020). This financial support, launched three months after the earthquake, was provided to groups of firms, such as those linked through supply chains and located in the same industrial park or commercial area. As of December 2018, the program provided approximately US$ 4.5 billion to 705 groups of SMEs for various reconstruction actions such as the purchase of production equipment and facilities, relocating plants to different locations and so on. Both sales and ability to take on staff increased significantly for small firms, although these effects were less apparent for medium-sized firms. Furthermore, post-disaster sales for firms that were linked with suppliers that received financial support were significantly higher (5.5 percent) than for those linked with unsupported suppliers, indicating that public sector financial support plays a role in the recovery of small firms and supply chains in disaster-affected regions.

International financial institutions and development partners can play important roles in designing emergency credit guarantee and loan programs. Following the 2010 Haiti Earthquake the World Bank supported the Government of Haiti to establish partial credit guarantee programs (PCGP) (World Bank 2010; World Bank 2015; IDB 2010). The PCGP was designed to guarantee loans in two components. First, it provided loan guarantees to firms whose loans were performing before the earthquake, to those negatively affected by the disaster, and to those deemed by financial institutions to be able to service their loans after a restructuring process. The PCGP provided additional finance to existing borrowers, especially firms, and partial guarantees of 50 percent for loans up to US$ 1 million. Secondly,

54 Converted to US dollars ($) at the 2018 annual average exchange rate of $1 = ¥110, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates.

the PCGP guaranteed new loans, extended to existing borrowers, with a particular focus on SMEs. The program helped SMEs restructure their loans, and revitalized lending from banks and cooperatives. Fonds de Développement Industriel, a financial institution of the Central Bank of Haiti specializing in promoting industrial development, offered US$ 3.3 million in partial credit guarantees to firms through three private banks, benefitting 255 businesses (World Bank 2010). Partial guarantees minimize the effects of deteriorating credit quality by allowing existing borrowers to restructure loans to maximize the probability of repayment. Partial guarantees also catalyze bank lending and maintain liquidity within the economy, contributing to financial sector resilience.

After disasters, government support may be needed to provide risk insurance so that firms are able to attract investment for post-disaster recovery. While insurance and risk-financing are best made available before disasters, private sector insurance for high risk businesses/scenarios may not be available, especially if private insurers have been drained of liquidity by post-disaster claims. Therefore, post-disaster actions by governments are crucial for investments in recovery, risk containment, and the development of insurance products which distribute risk among governments and private stakeholders. This type of support can help firms stay in business and return to disaster-affected countries, regions or industrial parks. The Thailand case shows that the prompt intervention of national governments is crucial to maintain foreign investor confidence when disaster insurance is unavailable, or when the insurance market fails. Disaster insurance supports business continuity, but during the Thailand floods, many businesses, including both foreign and Thai investors in flood-affected industrial parks, struggled to find affordable insurance policies that could cover flood damages and losses.[55] It was critical for the government to alleviate financial barriers to reconstruction, and to restore the confidence of investors who wished to remain, or return to the country. The National Catastrophe Insurance Fund (NCIF) was established within three months to achieve these objectives (OIC 2012). The Government of Thailand enabled domestic insurers to transfer a part of their disaster risk to the NCIF, whose risk is then shared with or transferred to reinsurance companies (box 7.4) (Schanz and Wang 2015).

Box 7.4 Thailand: NCIF Reinsurance Instruments Following the Thailand Floods of 2011

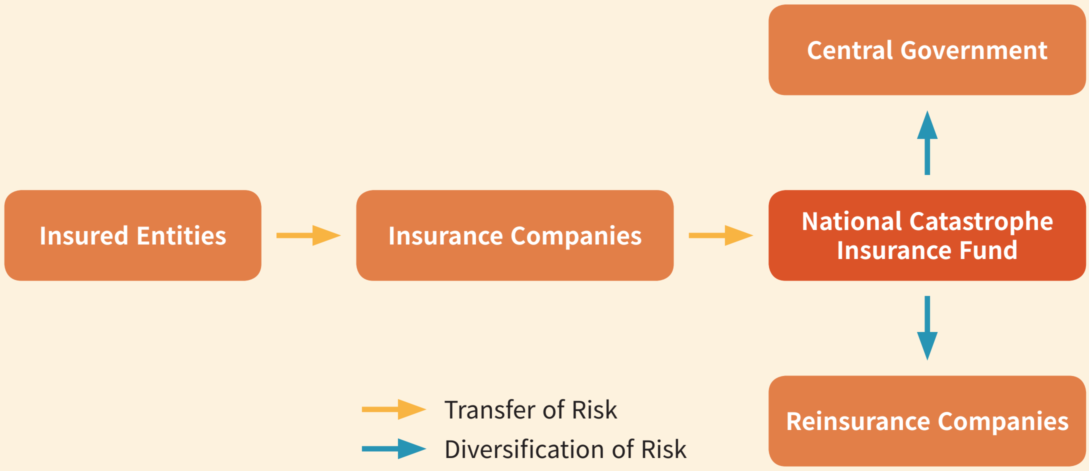
Bringing 70 general insurers together, the NCIF provided additional reinsurance at subsidized rates in order to enable struggling domestic insurers to continue offering coverage against disaster risks at affordable rates. The fund will act as a reinsurer in the event of disasters and will use premiums to secure reinsurance at competitive rates (OIC 2012). Under NCIF, SMEs are eligible for a maximum insured amount of US$ 1.6 million (฿ 50 million)[56] with a 30 percent coverage of the insured amount at a premium rate of 1 percent. Large companies with insured amounts above US$1.6 million are eligible for a 30 percent coverage of the insured amount at a premium rate of 1.25 percent.

Insured type	Coverage	Premium (per annum)
Private households	Up to US$ 3,225 (฿ 100,000) of damage	0.50%
SMEs	Limited to 30% of the insured amount	1.00%
Large companies	Limited to 30% of the insured amount	1.25%

55 Only US$ 10 billion out of US$ 32.5 billion worth of losses were insured (OECD 2015).

56 Converted into US dollars ($) at the 2019 annual average exchange rate of $1 = ฿ 31, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates. ฿ = Baht.

Figure 7.4 Risk-sharing Mechanisms in the National Catastrophe Insurance Fund



Source: Adapted from OIC 2012.

During Covid-19, various financial support programs including tax incentives and wage subsidy programs are being implemented by development partners and governments to increase industry resilience (box 7.5).

Box 7.5 Financial Support Programs for Business Continuity and Recovery During Pandemics

The World Bank has rolled out a US$ 14 billion fast-track package to strengthen COVID-19 responses in developing countries. This package includes US$ 8.9 billion that will be used for:

- Financing loans and equity investments for struggling firms in manufacturing, infrastructure and service sectors;
- Working Capital Solutions Program, which finances banks to extend credit to vulnerable businesses which need working capital to pay utility bills and salaries;
- Supporting local financial institutions to offer trade financing to import-export firms, and to manufacturing SMEs participating in the global value chains; and
- Funding and risk-sharing support for local banks to finance firms, including those affected by the pandemic.

In Vietnam, IFC is supporting the manufacturing and other sectors affected by the pandemic's negative cross-border trade impacts. The beneficiaries, mostly SMEs importing and exporting goods, are credit-constrained, and rely on bank trade facilities to manage cash flows, and purchase raw inputs. To address this challenge, IFC increased trade limits for client commercial banks, thus assisting local banks to provide trade financing for SMEs. In turn, SMEs are better resourced to stay in business and maintain market access.

Source: IFC 2020a; IFC 2020b.

7.5.2 Finance Investments in Building Back Competitive Industries

Disaster response and recovery provide opportunities to expand access to finance; public finance is often used to pay for reconstruction projects. In Thailand, within approximately three months, the Thai government budgeted US$ 9.7 billion (฿ 300 billion) to improve water management systems in the flood-impacted Chao Phraya River Basin (Thailand Strategic Committee for Water Resource Management 2012).[57] As part of this plan, US$ 552 million (฿ 17.1 billion) was allocated to emergency response projects to update physical infrastructure, such as the construction and strengthening of river dikes, repair of flood gates and pumping stations, and discharge pumps to drain priority areas (Thailand Strategic Committee for Water Resource Management 2012). The plan also made US$ 5.7 billion (฿ 177 billion) available to restore and improve dikes and reservoirs, and to enhance the capacity of water drainage systems in flood-prone industrial, commercial and other community areas; it also allocated approximately US$ 32.3 million (฿ 1 billion) to restore and redevelop industrial parks and other important areas.

Resilience-informed financial instruments should stipulate "build back better" requirements. The Mexican Natural Disasters Fund, FONDEN, is an indemnity-based insurer that provides rapid financing to repair federal and state infrastructure damaged by disasters (World Bank 2012a). FONDEN specifically funds reconstruction to higher standards, including relocation of buildings and communities to safer zones (APEC 2018). To access FONDEN resources, the affected federal and state agencies must demonstrate that the magnitude of reconstruction needs exceeds their financial capacity, and file a specific request detailing the extent of the damage and estimated cost of reconstruction.

Governments can also leverage post-disaster financial support programs or existing sustainability initiatives to attract private investments towards resilient infrastructure development. After the GEJE, for example, the Government of Japan set up a US$ 73 million (¥ 8 billion) fund to support businesses in disaster affected areas to develop "smart communities" by using alternative energy.[58] This program financed the feasibility study and pilot-testing of the F-grid system in Ohira Industrial Park, which catalyzed private investment in innovative renewable-based back-up power systems (box 6.6) (METI 2012).

In the long-term, financing greenfield industrial park development in disaster-hit regions can be an effective building-back strategy. Following the Great Hanshin-Awaji earthquake of 1995 in Kobe, Japan, a joint effort between national, city, and private firms led to the establishment of a new medical industry cluster as a key approach in building back its industry. The earthquake was a devastating event, with more than 4,600 deaths, displacement of hundreds of thousands of people, and an estimated US$ 100 billion in damage (World Bank Group 2018b). Prior to the earthquake, Kobe had only a small life sciences industry. However, in light of the strong promotion of the life sciences by the national government during the early 1990s, and as part of the reconstruction process, Kobe initiated the development of a biomedical industry cluster to revitalize its economy, provide health care for the local community, and support the development of medical technology in Japan. Rent subsidies were the main financial instrument used to attract investors. Companies that move into the

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57 Converted into US dollars ($) at the 2019 annual average exchange rate of $1 = ฿ 31, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates. ฿ = Baht.

58 Costs were converted to US dollars ($) at the 2018 annual average exchange rate of $1 = ¥110, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates. ¥ = Japanese yen.

cluster can rent lab space and other facilities at discounted rates of 50 percent reduction of rent for the first three years. The discount applies for three years, after which full market rates apply. By providing financial support for access to lab facilities, this instrument reduces the risk of moving into the cluster for biomedical companies. Over fifteen years it has attracted over 500 companies, of which 344 companies and organizations continue to operate (as of September 2017), and created 8,000 jobs. The total public cost of the cluster is estimated at approximately US$ 3.8 billion (¥ 420 billion), or approximately US$ 472,700 (¥ 52 million) per job (World Bank Group 2018b).

Table 7.2 Response and Recovery: Example Projects

Intervention area	Name of intervention	Location	Brief description	Outcomes
Activate and refine coordination frameworks for response and recovery.	Activating a clustered approach to coordinate emergency responses	Haiti	UN agencies with specific technical and institutional capacity lead and coordinate emergency responses at the global and country levels.	With the activation of the clustered approach, multi-sectoral damage assessment and coordinated emergency responses were quickly launched.
	Activation of EP&R plans and pre-arranged agreements	Japan	During disasters, pre-arranged cooperation agreements are activated immediately based on with pre-defined roles, responsibilities, and action items.	Swift emergency response is possible with quickly mobilized resources and restoration of infrastructure services.
Conduct rapid assessment of industrial damage and losses.	Rapid damage assessment of of Parc Industriel Metropolitan (PIM)	Haiti (Port-au-Prince)	A rapid damage assessment was conducted to estimate the scope of repairs and costs in and outside of the PIM. A consultant was engaged to develop an economic zone recovery plan, and evidence was presented that production could be rapidly resumed. Damage assessments informed recovery plans to expand production capacity.	The port rapidly resumed operations, and the garment manufacturing industry retained investors and employees, and recovered with subsequent industry expansion.
Provide support to retain investors and boost market demand.	Corporate Income Tax Exemption Applied to Flood-Affected Industrial Estates	Thailand	The BOI provided exemption on corporate income tax, targeting investors and tenant firms in flood-affected industrial parks. Import duty/tariff exemptions, incentive periods, and other investment benefits were also offered.	Retention of investors and tenant firms in flood-affected industrial zones; new private investments attracted, and some expansion of plant operations.
	FEMA's role in post-flood reconstruction	United States (New York City)	The NYC Government fast-tracked zoning regulation amendments via an Emergency Executive Order, relaxing existing zoning requirements to facilitate reconstruction. This allowed business owners in manufacturing districts to renovate damaged properties rapidly and legally.	Urgent issues pertaining to the post-flood recovery of manufacturing zones in the City were addressed, allowing property owners to access funds by complying with FEMA requirements and hastening the manufacturing sector's recovery from Hurricane Sandy.
	Fast-tracking visa issuance	Japan/ Thailand	The governments of Japan and Thailand relaxed visa requirements so that investors, engineers, and employees could quickly enter affected countries to restore damaged plants or relocate to less affected factories to continue production.	Rapid visa availability helped mitigate global value chain disruptions and enhanced job security during disasters.
	Investment aftercare program to provide support for increased market access	Haiti	Following the 2010 earthquake, the Government of Haiti and its development partners pursued an investment aftercare program to protect its apparel industry by re-assuring investors. The partners arranged post-earthquake contracts between global buyers/retailers and local suppliers, and solicited new orders in order to maintain the sector's business continuity. FDI promotion and preferential trade agreements were also leveraged.	The retention of existing buyers and securing of new orders saw a post-earthquake increase in the apparel sector's production capacity, a rise in the sector's net exports and jobs, and the emergence of a positive outlook for the industry.

Intervention area	Name of intervention	Location	Brief description	Outcomes
Support safety and employment continuity.	MINUSTAH's work in Haiti's PIM	Haiti	In response to prolonged political crisis MINUSTAH maintained a strong presence in Haiti, based in the PIM, offering both security and humanitarian interventions to prevent social unrest. Workers and industrial assets were protected, and clients and buyers were re-assured that the Park was operational and safe, despite instability elsewhere. PIM tenants also played a role, offering food and shelter to employees until they could safely return home.	The maintenance of security in the PIM allowed for a smooth resumption of operations, despite surrounding unrest.
Promptly restore critical infrastructure and services	Emergency contract agreements for critical infrastructure in Haiti	Haiti	Following the earthquake in Haiti, and in the absence of pre-arranged agreements, Port infrastructure and logistics were quickly restored through post-disaster contracts with private logistics companies. The Haitian Government worked with USTRANSCOM to rapidly issue contracts for recovery work in the Port.	The Port-au-Prince harbor regained operational status approximately 10 days after the earthquake, while debris and damaged infrastructure were rapidly cleared from the harbor area.
Provide financial safety nets targeting SMEs.	Japan's disaster-related emergency guarantee program for SMEs	Japan	A Disaster-related Emergency Guarantee Program was established by the Japanese Government to provide guarantees to SMEs following the GEJE. Substantial portions of the credit guarantees offered required no collateral.	SMEs are particularly vulnerable to disasters, but the program proved effective in providing loans to local SMEs through timely disbursements, thus maintaining their continuity and accelerating recovery.
	Partial Credit Guarantee Program (PCGP)	Haiti	The PCGP provided loan guarantees to firms affected by the earthquake, and helped SMEs restructure their loans.	US$ 3.3 million in partial credit guarantees was offered to 255 businesses to offset the effects of declining credit quality.
	Emergency loans and group subsidies	Japan	The Japan Finance Corporation, regional banks, and credit unions offered SMEs long-term, low-interest loans for reconstruction investments. The SME Agency and METI provided US$ 4.5 billion to 705 groups of SMEs to support reconstruction.	Both sales and job creation increased among small firms.
	National Catastrophe Insurance Fund (NCIF)	Thailand	The NCIF was quickly established to provide additional reinsurance at subsidized rates to restore the confidence of investors who were willing to remain in or return to the country.	The Government of Thailand enabled domestic insurers to transfer a part of their disaster risk to the NCIF. SMEs were able to access insurance at competitive rates.
	Financial support programs for business continuity and recovery during pandemics	Global, including Vietnam	The World Bank has provided a US$ 14 billion package to finance loans, equity investments and working capital for struggling manufacturing firms.	It is expected that SMEs will be better resourced to stay in business and maintain market access.
Finance investments in building back competitive industries.	Government-Private sector partnerships to build back post-earthquake industry	Japan (Kobe)	Following the Hanshin-Awaji earthquake, Kobe drove its recovery by allying with the National Government's support for the Life Sciences, initiating the development of a Biomedical Industry cluster to revitalize the economy and provide local medical care. Rent and lab-space/equipment subsidies were employed to attract companies.	The program has attracted over 500 companies over fifteen years, creating 8,000 jobs, while the cluster is worth approximately US$ 3.8 billion.

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8

Integrating Gender and Technology Solutions

Industry resilience measures should be gender-aware, and open to the many applications of emerging technologies. Diverse gender-sensitive industry resilience measures may be developed based on the assessment of gendered impacts of disasters and the specific needs of women. Technologies—both conventional ICT and emerging technologies—have many industry resilience applications. They help governments and industry practitioners better understand complex, highly connected manufacturing environments, facilitate access to markets, and make risk-informed and evidence-based decisions in a timely manner.

Recommended Actions

Integrating gender-aware approach:
- **Conduct gender-sensitive needs assessment.**
- **Finance women-owned SMEs through disaster risk financing.**
- **Enhance market access for women-led SMEs during disaster response.**
- **Maintain training programs for women entrepreneurs and workers.**

Leveraging technologies:
- **Encourage ICT uptake by firms.**
- **Enhance supply chain resilience and visibility utilizing new technologies.**
- **Minimize industrial infrastructure disruption with new technologies.**
- **Use innovative technologies to fast-track asset damage assessments and insurance claims payouts.**

8.1 Gender-Sensitive Industry Resilience Planning and Actions

Gender equality should be at the core of industry resilience planning and actions. This goal is a reminder that "build back better" encompasses the social dimension of including vulnerable groups. Another meaning of "build back better" is to close the gap between the ideals of gender equality experts and the realities of implementation in disaster risk management and industrial policy arenas. In the gap between theory and practice, efforts toward gender equality are often reduced to afterthoughts, or add-ons that are not meaningfully included in resilience planning and actions. Embedding gender perspectives into the Resilient Industries Framework is needed to start the process of institutionalizing and normalizing industry-wide gender-aware perspectives. This change in corporate culture is especially important in resilience planning, since women are disproportionately affected by disasters.

In general, the following principles and approaches should be considered when developing gender-sensitive responses to disasters (UNDP 2020):

- Ensure women have access to early warning information and are aware of evacuation plans and procedures in the event of a disaster;
- Promote participatory approaches to recovery planning and coordination;
- Increase women's access to economic and financial resources through instruments such as microfinance services;
- Use recovery programming as an opportunity to challenge traditional gender roles; and
- Ensure that women's specific sanitation, safety and security needs are addressed (e.g. curbing the gender-based violence that ensues in the aftermath of disasters, especially in camps and shelters).

Diverse gender-sensitive industry resilience measures may be developed based on these principles, as may the assessment of gendered impacts of disasters and the specific needs of women. These measures include increasing women entrepreneurs' access to finance, credit and markets through targeted cash transfers, alleviating tax burdens, or procuring goods and services for infrastructure and public services from women-owned enterprises. Solutions should also enhance women's capacity-building regarding disaster mitigation and preparedness measures, including purchase of insurance. Retrofitting social infrastructure such as childcare facilities, schools, and shelters in industrial parks with gender-sensitive and disaster-resistant designs may provide additional support for women entrepreneurs and workers affected by disasters. Existing vocational training and social protection programs may be used to help disaster-affected female workers retain their jobs. These targeted approaches, whether they are policy-, infrastructure-, or finance-related, may provide opportunities to address deep-rooted social challenges (Danes et al. 2009; Asgary, Anjum, and Azimi 2012).

Examples and case studies on integrating gender into industry resilience measures are lacking. Thus, the evidence base for successful interventions is limited. While acknowledging this limitation, this section focuses on the following four areas: 1) gender-sensitive needs assessments, 2) increasing access to finance for women-owned SMEs through disaster risk financing, 3) enhancing market access for women-led SMEs during disaster response, and 4) maintaining training programs for women entrepreneurs and female employees during and after disasters.

8.1.1 Conduct Gender-Sensitive Needs Assessment

Gender-sensitive needs assessments are of particular relevance in the context of disasters, but lessons learned in these contexts need to inform broader, generic industry resilience approaches that go beyond disaster response. This mainstreaming requires cross-sectoral efforts to gather baseline data and information on how disasters affect women in industry sectors, and what kinds of responses are most needed. Pre-disaster baselines establish disaster risk awareness, and may inform preparation and mitigation measures among women-owned SMEs and female employees. In post-disaster phases, these analyses may become part of PDNA, which examines damage to infrastructure and physical assets, change in production flows, effects on supply and access to goods and services, disruption of governance services and decision-making processes; and increased risks and vulnerabilities. Governments should be aware of these analyses, and of whether and how they inform recovery actions, including manufacturing sector-specific outcomes. Development partners can provide technical support and training so that the needs of women entrepreneurs, women-owned SMEs, and female employees are planned, monitored and budgeted for, from the outset of industry resilience planning.

Industrial park operators or their social management/occupational health and safety (OH&S) management teams may be well placed to identify gender specific needs and impacts. They can assess gender-specific needs for access to finance, market access/aftercare support programs, capacity building /skills development training, and enhanced safety and security measures.

8.1.2 Finance Women-Owned SMEs Through Disaster Risk Financing

Disaster risk financing can be specifically directed to assist women entrepreneurs or businesses with high percentages of female employees. As an example, MiCRO (Microinsurance Catastrophe Risk Organization), is a natural catastrophe and weather index insurance scheme (World Bank Group 2014) which works in Haiti, one of the most disaster-prone countries in the world. Because of Haiti's vulnerability to flashfloods, hurricanes, and earthquakes, MiCRO insures against damages and losses from these disasters, covering up to 50 percent of insurance premium costs. This coverage is bundled with loans from Fonkoze, Haiti's largest microfinance institution (World Bank Group 2014). Risks are distributed through Fonkoze, insured by the Alternative Insurance Company, and reinsured by the Micro-insurance Catastrophe Risk Organization and Swiss Re. If triggered by a disaster, its payouts can be used to restore the business operations of women-led SMEs and replace destroyed or damaged inventory items.

With these innovative designs, the program provided a financial safety net for both women-owned SMEs and a local microfinance institution which then increased lending to its women-owned microenterprise clients (World Bank 2014). In 2012/2013, a US$ 8.9 million payout was made to help women-owned micro-enterprises repair damages, replace inventory and reopen businesses (World Bank 2014). By 2015, 65,000 female entrepreneurs including shop keepers, traders and market vendors, have enrolled in their micro-loans program (OECD 2015).

Trade finance also needs to target women-owned SMEs so that women entrepreneurs have better access to finance during and post-disasters. The IFC has recently begun to increase trade finance to women-owned SMEs and businesses in emerging markets. This trade finance support has been extended to SMEs affected by the Covid-19 pandemic (see Section 5.5 of this report for more detail). By specifically targeting women-owned SMEs as beneficiaries, trade finance measures have great potential to increase women entrepreneurs' access to finance during and post-disasters.

8.1.3 Enhance Market Access for Women-Led SMEs During Disaster Response

When responding to disasters, governments can support women-led SMEs through procurement. Such approaches provide opportunities for these SMEs to break into markets and to diversify their products. In the United States, the US Small Business Administration Agency (SBA) offers a Women-owned Small Business Federal Contracting program for this purpose. Mirroring this program, in the aftermath of Hurricane Sandy, the New York City government used an existing program to rebuild Minority- and Women-owned Business Enterprises (MWBEs) by certifying these businesses and procuring goods and services for government-led reconstruction from MWBEs. Businesses certified under the program enjoyed access to contracting opportunities through classes, networking events, and targeted bids. For example, the City's Rapid Repairs program employed 10 prime contractors and approximately 185 subcontractors, including 37 MWBEs. As a result, in the 2012 fiscal year, MWBEs won nearly US$ 530 million worth of city prime contracts and sub-contracts (The New York City Special Initivative for Rebuilding and Resiliency 2013).

A number of additional enabling factors were required for the implementation of the program (Glick and Walsh 2013):

- **Defining women-owned business enterprises (WBEs):** A WBE is by law a business enterprise in which at least fifty-one percent (51%) is owned, operated and controlled by women.
- **Formalizing and increasing the pool of viable MWBEs through certification:** NYC Small Business Services (SBS) simplified this process by offering online certification applications and information related to licensing, permits, tax and other requirements.

- **Technical assistance and training:** The city launched the NYC Rapid Repair Program, an emergency assistance initiative to restore power, which provided contractual opportunities for MWBEs. Other initiatives included programs that matched MWBE construction firms with reconstruction opportunities in the city. These capacity building and technical assistance initiatives particularly benefited MWBEs in the construction industry as they pursued post-Sandy recovery work. A technical assistance program, "Compete to Win", helped beneficiaries with city procurement processes, including bid and contract submissions.
- **Upfront capital loans:** The city also provided short-term capital loans to MWBEs to fund labor and equipment costs related to city contracts.
- **Enabling policies:** A 2005 regulation stipulated contract percentages allocated to city-certified MWBEs for contracts capped at US$ 1 million. Following Hurricane Sandy, a subsequent regulation removed this cap for MWBE-targeted contracts, increasing their value from US$ 400 million to US$ 2.2 billion.

In short, the MWBE program mobilized resources for both quick recovery and long-term reconstruction (e.g., rebuilding damaged homes) by proactively matching reconstruction needs with disadvantaged businesses.

8.1.4 Maintain Training Programs for Women Entrepreneurs and Female Employees During and Post-disaster

Awareness raising and skills training programs can help women entrepreneurs and female workers to prepare for disasters. These may include, but are not limited to, training for: mobile banking, risk insurance, e-commerce and digital wage payment methods, location-specific climate change and disaster risk information, BCPs, and EP&R or evacuation plans, to name a few. For women entrepreneurs in the manufacturing sector, these programs can enhance workplace safety, provide early warning information, speed access to finance, and improve supply chain management and competitive ability following disasters. For female workers, these programs can improve workplace safety and help them carry out BCPs.

For example, in Haiti, the United Nations Development Program's (UNDP) entrepreneurship initiative provided training for women affected by the earthquake. The UNDP program assisted 1,000 women from Port-au-Prince's most vulnerable communities, providing them with training, technical assistance, and access to micro-credit to start or consolidate businesses. The project also leveraged platforms and created a network of partners—including community councils, government institutions and civil society—to develop job creation projects in key sectors that supported women's economic integration.

A growing literature advocates for the role of technology as a support for women in resilience contexts. Digital payments and e-commerce can increase access to finance and income in disaster contexts, reduce costs, and save time and resources (Kergroach 2020; OECD 2019). In Bangladesh, research suggests that mobile banking and digital wage payments may increase savings and the ability to cope with disaster-induced financial shocks (Breza, Kanz, and Klapper 2017). Yet, there is still a considerable gender gap in digitization in developing countries, both in terms of access to and actual use of digital devices. For example, in Bangladesh, where female workers account for 80 percent of the workforce in the garment manufacturing sector, only 25 percent of factories pay workers digitally. Most workers, including females, are paid in cash, or with checks, and these methods are unsafe, especially during disasters (Hasan 2017; Breza, Kanz, and Klapper 2017). Evidence suggests that these aspects of financial and technical illiteracy can make women-owned SMEs and female workers vulnerable during disasters, and that these vulnerabilities merit specific consideration.

Industrial park operators are well positioned to meet these needs on-site, where they are easily accessible to women. Park management and firms can develop joint, sector-specific training programs such as automation, 3D printing, and AI-controlled production, which may confer competitive advantages and skill sets for women in post-disaster markets.

Sadly, such programs are harder to maintain during disasters, and are thus often discontinued when they are most needed, retarding both post-disaster recovery and preparedness for future challenges. This situation was largely avoided in Haiti, where the Haitian Development Bank that worked with the World Bank to provide such training programs suffered significant losses and was forced to discontinue funding for six months (Van Daele 2012). Various resources were sought, including in-kind contributions and financial support from international and local organizations to provide managerial training to business owners, including women, who could not afford it. By June 2013, the program was able to provide training for 2,750 SME owners, employees, and entrepreneurs, including over 1,250 women, many of whom reported increased profits and greater access to finance (IFC 2013).

Women may be further supported by paying attention to social and industrial amenities upon which they rely, such as childcare facilities, dormitories, and multipurpose cyclone shelters. In developing countries, these facilities may be of poor quality, and lack gender-sensitive design, as in Bangladesh, where research revealed that only 19 percent of multipurpose cyclone shelters had separate toilet facilities for women (Mahmood, Dhakal, and Keast 2014), making it difficult for women to use them during floods. In response, with support from the World Bank, the government has been upgrading the shelters to provide separate toilets for women, and facilities for pregnant women and the disabled. More than 1,700 women have been consulted during the project design (World Bank 2017), showing that programs can be developed to retrofit and incorporate disaster-resilient designs into industrial facilities and parks that host large numbers of female employees.

8.2 Improving Industry Resilience Through New Technologies

Technologies–both conventional ICT and emerging technologies–have many industry resilience applications. Applications that use ICT, such as early warning systems, digitization of transactions, digital wage systems, digital contracts and supply chain management can boost industry resilience, helping firms maintain links with customers during disasters, and finding new suppliers or markets. However, during disasters, e-commerce systems are also easily disrupted, and thus, jointly confer both advantages and vulnerabilities.

In the context of industry resilience, emerging technologies help governments and industry practitioners better understand complex, highly-connected manufacturing environments, and facilitate access to market, and make risk-informed, data-driven decisions. Together, these technologies offer tools to analyze large amounts of detailed, real-time climate and disaster risk information and data, visualize this information, and guide industries' resilience thinking, planning and response actions. IoT, sensor technologies, and big data analytics promote resilient design, operation, maintenance and monitoring of industrial infrastructures and services. These technologies may be used, for example, to track the structural integrity of infrastructure with sensors, and to share these data rapidly via the cloud. Such data inform quantitative risk assessments which compare real-time readings with known risk threshold values.

8.2.1 Encourage ICT Uptake by Firms

Greater use of ICT can improve business continuity and boost resilience by helping firms maintain access to markets, suppliers and customers during crises. While use of ICT makes businesses more competitive under normal conditions, its use value under the COVID-19 pandemic has been unprecedented, as businesses activities relying on human proximity have been replaced by online, digital platforms. Digital platforms such as e-commerce, which is broadly defined as the sale of goods and services online, are emerging as a new modus operandi to buffer firms and sectors from the effects of COVID-19 (World Bank 2020). E-commerce stands out among digital applications because of its ability to link sellers with buyers, lower transaction costs, and create new niche markets tailored to consumer demand. Increased use of digital platforms for contractual agreements, transactions, trade, and payments may help maintain business continuity and competitiveness during disasters.

With the advent of COVID-19, governments in emerging economies are encouraging firms to adopt ICT and e-commerce in their daily business operations. In Malaysia, for example, the government has allocated grants to 10,000 e-commerce entrepreneurs, and approximately US$ 4.8 million (RM 20 million)[59] has been given to the Malaysian Digital Economy Corporation to turn existing internet centers into e-commerce hubs (Shah et al. 2020). Bank Negara Malaysia (BNM), the Central Bank of Malaysia, has also budgeted US$ 72.5 million (RM 300 million) to support and incentivize SMEs to digitalize their business operations and increase productivity (Shah et al. 2020). The Bank provides finance for the purchase of equipment, machinery, computer hardware and software, and IT services up to US$ 724,640 (RM 3 million) at an interest rate of four percent.

To realize the full potential of ICT for industry resilience, governments in emerging economies still need to promote uptake of existing technologies, especially among SMEs. Structural gaps in socioeconomic and business environments explain much of the lag in e-commerce or other digital technology adoption by developing countries. In addition to a lack of basic infrastructure, such as transportation and logistics infrastructure, developing countries experience poor quality of basic ICT infrastructure, low computer use, and low levels of digital literacy. These further inhibit innovation and the uptake of e-commerce, which in turn constrains competitiveness, especially during disasters that disrupt the physical flow of resources and information. Most micro enterprises in low- and middle-income countries lack information on the possibilities afforded by digital technologies. Small firms may lack the capital required to purchase computer hardware and software, while workforces in such firms are usually not ICT literate, or lack skills such as order handling, quality control, and processing of online payments. Therefore, supporting programs and policies are required to address barriers to technology adoption, such as employee skillsets, capacity for technology management and knowledge acquisition, and access to finance and capital.

Industrial parks may be best placed to effectively offer such training programs for firms and employees. For instance, the International Framework for Eco-Industrial Parks recommends that industrial park operators help establish skills or vocational training centers and programs (UNIDO, World Bank and GIZ 2017). The training centers shall be easily accessible by all employees. Development of training programs, courses, or curriculum that

59 Converted into US dollars ($) at the 2019 annual average exchange rate of $1 = RM 4.14, based on official exchange rate (LCU per US$, period average) provided at: https://data.worldbank.org/indicator/PA.NUS.FCRF?end=2019&locations=MY&start=2019. RM=Malaysian ringgit.

are relevant to the investors in industrial parks are also encouraged to be supported by residential firms and industrial park management entities, including ICT training, mechanical engineering, quality management, etc. Training courses may reflect the latest trends in industry sectors, including technologies such as automation, 3D printing, or AI controlled production processes. For example, in the Republic of Korea, the Ministry of Trade, Industry and Energy, in collaboration with the Ministry of SMEs and Startups, has allocated US$ 160 million (₩ 185.8 billion)[60] for the smart industrial complex project, in which tenant companies and their employees will be provided with training and piloting opportunities to improve their productivity through joint application of both existing and leading-edge technologies that allow for enhanced connectivity of resources and data (Government of Republic of Korea 2019).

8.2.2 Enhance Supply Chain Visibility and Resilience Utilizing New Technologies

Minimizing supply chain disruption is critical for industry, and the advent of Industry 4.0 offers industrial sectors, parks and firms a suite of new tools to inject resilience into their supply chains. There is no agreed definition on Industry 4.0[61] but within the manufacturing context, it generally refers to increased digitization and automation (Oesterreich and Teuteberg 2016; Roblek, Me ko, and Krape 2016; Weyer et al. 2015). These technologies include the IoT platforms, smart sensors, big data analytics, advanced human-machine interfaces, and cloud computing, to name a few, and are transforming the way in which information and capital flow through value chains (World Bank and World Trade Organization 2019). They improve operational efficiency, help firms to integrate their horizontal and vertical value chains (Kagermann et al. 2013), and create new value chain activities, such as product data analytics and data security (Porter and Heppelmann 2014).

In industry resilience context, Industry 4.0 technologies increase the visibility of supply chains, generate insights across complex production networks, and better manage disruption risks. They generate real-time information about suppliers, customers and market demand, warehouses, distribution centers, shipping, and the quality and quantities of inventories; enable smart alerts throughout value chains; improve predictive analytics and forecasting capabilities and bridge organizational and technology silos across value chains (figure 8.1). With such information, Industry 4.0 technologies not only increase visibility of Tier 2 and 3 suppliers in the value chain system, they also reduce the costs of tracking and monitoring complex production processes, thus enabling quick responses to GVC disruptions and lowering coordination and matching costs across different geographies, firms and organizations (World Bank and World Trade Organization 2019). Thus, these technologies have the potential to improve economic competitiveness, guard against disaster impacts, and strengthen the structure of GVCs.

60 Converted to US dollars ($) at the 2019 annual average exchange rate of $1 = ₩ 1,165.70, based on the yearly average currency exchange rate provided at: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates. ₩ = South Korean won

61 The term is drawn from the German government's initiatives on high-tech strategies announced in 2011 (Oesterreich and Teuteberg 2016).

Figure 8.1 Industry 4.0 Technologies Transform and Generate Insights into Supply Chain Networks

Source: Adapted from McKinsey & Company 2016. Background Photo Credit: © NanoStock

Many cloud-based applications for supply chain visibility and resilience are available from global IT corporations and logistics companies, and these new technologies allow global actors to work together to improve industry resilience across borders. Disruptions have become commonplace in manufacturing and supply chains, and the application of technologies such as AI, IoT and blockchain has delivered resilience gains through data analytics, real-time information sharing, scenario modeling and pre-program responses. These gains have enabled business continuity during disasters. For example, IBM's Watson Supply Chain Insights (WSCI) is a supply chain-focused platform powered by AI technology that allows supply chain officers to predict and mitigate disruptions (IBM n.d.).[62] WSCI analyzes weather data, traffic and regulatory reports to generate insights into the global supply chain landscape. These technologies promote a culture of disaster resilience by allowing collaborative planning among supply chain participants based on shared disaster risk forecasting and scenario information.

Blockchain is another new technology that can improve supply chain visibility and resilience (Min 2019). Blockchain technology is a "distributed peer-to-peer linked-structure" which enables a decentralized mode of recording transactions within a system, in which participants share the responsibility of validating transactions without the need of an entrusted intermediary (Casino, Dasaklis, and Patsakis 2019). In the manufacturing sector, blockchain technology has the potential to transform the management of large and complex supply chains. It provides a secure and transparent mechanism for monitoring information exchanged at each level, thus improving visibility and reliability of transactions throughout the supply chain. Among its benefits are enhanced data and information sharing among multiple parties (Brody 2017), transparent verification of actions taken at each level of the supply chain (World Bank Group 2018; Ferguson 2018), improved supply chain efficiency and sustainability, reduced transaction and monitoring costs, and trust between supply chain participants.

62 IBM. n.d. "IBM Sterling Supply Chain Insights with Watson: Capitalize on AI to break free from supply chain visibility challenges and act with confidence." IBM Sterling Solution Brief. https://www.ibm.com/downloads/cas/78GAVDMA.

Big data visualization can also aid in evidence-based policy making that supports industry resilience. In Japan, the Cabinet Office and METI developed the Regional Economy Society Analyzing System (RESAS) database with data and system design partners including Teikoku Databank, Takram, and teamLab in 2015. The system synthesizes and visualizes public and private big data on, for example, industrial structures, population movement, and flows. It supports local governments, aid organizations, and educational institutions and is used for evidence-based policy making. The tool has been widely used, particularly to inform the postdisaster reconstruction planning of local governments and communities; 58 percent of municipalities used RESAS to help develop their five-year Regional Comprehensive Strategy (Cabinet Office 2019). The system continues to be updated and expanded, as illustrated by the recent launch of V-RESAS, which visualizes near-real-time consumer behavior data. This information is being used at both firm and government levels to support business recovery during and after the COVID-19 pandemic.

Box 8.1 Japan: Data Visualization Tools to Promote Policy Making for Industrial Resilience

Data visualization tools utilizing near-real-time big data can provide beneficial information for disaster-preparedness policy making. By helping users to understand disaster risk in the context of interconnected business activities, technology tools can aid in the design of policies that engage various stakeholders to collaborate in designing and implementing solutions for resilient industry. In Japan over the years, various technology tools have been developed and utilized, adapting to the changing social, policy, and technology contexts. Three tools are introduced below:

The **Regional Economy Society Analyzing System (RESAS)** synthesizes and visualizes public and private big data for categories such as industrial structures or population movement and flows. It supports local governments, aid organizations, and educational institutions and is used for evidence-based policy making. The tool has been in wide use among local governments and communities in the creation of better-informed planning tools for postdisaster reconstruction, especially among rural communities facing significant challenges stemming from declining populations. According to a survey conducted by METI in 2017, RESAS has been implemented in 97 percent of municipalities across Japan. These municipalities have utilized the visualization system to discuss policy planning and demonstrate the effectiveness of various measures. In addition, the system is being employed across a wide variety of entities, including financial institutions, commerce and industry associations, chambers of commerce and industry, and educational institutions. By utilizing RESAS, Kasugai City identified that the manufacturing industry has the highest added value and greatest intraregional ripple effect among industries in the region. Kasugai City used RESAS to match buyer and supplier manufacturing companies with local banks to further strengthen the manufacturing industry (METI 2017). For more information, see: https://resas.go.jp/.

The **Local Economic Driver Index (LEDIX)**, developed through collaboration between the Teikoku Data Bank and Takram, visualizes the flow of goods and services between firms and regions, thus identifying key leading companies from various levels and sectors. The partnership is working to incorporate external shocks, including disasters. This project shows how big data and visualization technology can be utilized to map out supply chains in order to understand the impacts of supply chain disruptions and opportunities for economic development, including postdisaster recovery. For more information, see: https://ledix.jp/.

V-RESAS is a new tool provided by the Office for Promotion of Regional Revitalization and developed in partnership with Teikoku Databank and Takram. It brings together high-frequency big data to help local governments, financial institutions, commercial and industrial groups, and businesses better understand the impact of COVID-19 on their regional economies and help them better plan for the future. Having more data and being able to separate fact from fiction is all the more important during these uncertain times, and V-RESAS aims to provide greater clarity in decision making. For more information, see: https://v-resas.go.jp/.

Source: World Bank 2020; METI 2017.

Blockchain and big data have the added potential to reduce supply chain disruptions, especially when used in combination with other technologies such as smart sensors and IoT. Conventional paper-based transaction records are an unsecure way to log data, and do not provide a holistic understanding of where and how problems along the supply chain occur, especially during disasters when rapid responses are required. Blockchain “digitizes” date and location records for all transactions, allowing manufacturers to anticipate risks inherent to complex supply chains. Abnormalities or potential choke points in the supply environment can be detected and addressed, even during disasters. In addition, the use of blockchain together with sensor technologies supports the enforcement of smart contracts, which can reduce transaction costs.

In pharmaceutical manufacturing, for example, blockchain technology, when combined with IoT and sensors, can be used to monitor contractual conditions of transport, and improve cold chain[63] management in the face of extreme weather events (Min 2019; Harvard Business Review 2017). In the pharmaceutical and food processing sectors, temperature control is essential to maintaining product quality. Despite their importance, cold chain infrastructure and technologies are still lacking in many emerging economies, reducing the quality of and demand for pharmaceutical and food products, especially during extreme weather events. Blockchain technologies, combined with Radio-frequency identification (RFID) tags and IoT sensors attached to packages and transport vehicles, allow manufacturers to track temperature, humidity, light, vibration, and tamper information required to ensure the quality of their products. By tracing and visualizing the end-to-end supply/cold chain, the system can automatically send alerts to manufacturers and operators.

Governments can provide R&D support to develop new technologies to help identify supply chain risks before disasters and rapidly assess actual damage and disruptions following disasters. In Japan, policy makers and business owners employed big data and visualization technologies to flag, and proactively address supply chain vulnerabilities following supply chain disruptions in the automotive and petrochemical sectors during the GEJE (box 8.1).

8.2.3 Minimize Industrial Infrastructure Disruption with New Technologies

Governments can also encourage the adoption of innovative sensor technologies to protect industrial infrastructure from the impacts of disasters and improve infrastructure asset monitoring and maintenance systems. Sensors provide real-time climate and disaster risk information, allowing technicians to track the structural integrity of infrastructure during impacts, and in relation to known risk threshold values. Because data are generated in real time, technicians can monitor sequences of stress impacts, or structural deterioration, and are able to respond on the basis of quantitative risk assessments which can guide maintenance actions, contain costs, and minimize disruption. A further advantage is that sensor-generated data can be rapidly shared via cloud-based alert systems to trigger responses. Day-to-day operation, maintenance and monitoring of infrastructure are also improved through these approaches, further supporting resilience. Sensors are used to monitor the structural integrity of bridges, tidal gates, roads and harbor walls, among other industrial assets, and these data can also be used to specify insurable conditions (Sacertis srl 2019).

63 A cold chain is a system of storing and transporting perishable products such as pharmaceutical and food items at recommended temperatures from the point of manufacture to the point of use.

Because of these potentials, ports around the world are increasingly using IoT, sensors, AI and satellite-generated data to guide their operations. These are of particular relevance in coastal industrial areas that often occupy reclaimed, flood prone land. In Japan, for example, these technologies enable automatic operation of over 1,600 flood gates in Miyagi Prefecture (World Bank 2020). During the GEJE, the need for rapid and reliable flood gate control was recognized, so that tsunami and storm surges could be contained. Gate control is now linked to a countrywide, satellite-based, real-time tsunami alert system. Resilience is conferred through a duplicate satellite, and backup control and power systems. Smart CCTV technology allows proactive intervention via remote control during emergencies, and the effects and scheduling of gate closures are shared with local communities and companies for their planning purposes.

Similarly, at the Port of Rotterdam in the Netherlands, IoT sensors, AI, and smart weather data are used to minimize operating risks and service disruption from coastal floods and storm surges, while optimizing shipping and trade logistics. The Port of Rotterdam occupies a flood-prone area and is one of the largest industrial and energy complexes in Europe, with more than 120 industrial sites and over 140,000 ships passing through it annually (see also box 4.4 for challenges and risks faced by the Port of Rotterdam). Therefore, it is critical to minimize operational risks to firms and to maintain logistical efficiency during emergencies. To address this challenge, the port infrastructure operating system has been updated with new technologies (box 8.2).

Box 8.2 The Netherlands, Port of Rotterdam: The Role of Technology in Logistics and Safety

In 2018, the Rotterdam Port Authority, in partnership with IT companies, launched an initiative to digitize port operations and monitoring systems. Under this project, 44 IoT sensors were installed along 42 kilometers of quay walls, gathering data on tides, wind speeds and directions, currents, water levels, and berth availability. The system also receives data on water levels, flow rates, salinity, water temperature, wind, and visibility. This information is compiled by the operational monitoring network of the Port Authority. Their real-time, aggregated information from the port’s sensors are used to identify and prepare for flood risks, and to establish favorable water conditions for docking and port entry. This improves efficiency and safety of port logistics, especially under conditions of stress.

Sensor data also control the operation of the Maeslantkering, a storm surge barrier composed of two floating arms spanning one of the port’s entrances in the Botlek industrial area. The operation of the arms is controlled by computers which receive weather and sea level data from sensors. These data are analyzed using cloud-based technologies, and inform decisions to close the gates. The decision-making algorithm triggering closure is entirely computer driven, as are notifications to ships using the gate.

Figure 8.2 The Maeslant Barrier (Maeslantkering) Uses Sensors on its Automated Storm Surge Barrier to Protect the Port of Rotterdam and Industries

Photo credit: © GAPS

Source: Campfens and Dekker 2018; Port of Rotterdam 2019; Dutch Ministry of Infrastructure and Water Management, Rijkswaterstaat, and Rijkswaterstaat n.d.

Technologies that increase redundancy, decentralization and diversification of infrastructure and services also minimize disruption and support business continuity. Disasters may disable communication systems, power grids, transport networks and other critical infrastructure. These effects are amplified by centralized systems, in which failure of a single, central unit, can cut off power supply and communications. In contrast, distributed infrastructure systems are more resilient and reliable, as they do not rely on single point supply sources, and contain back up options to cover central system failure (Hallegatte, Rentschler, and Rozenberg 2019).

Communication networks that remain connected during emergencies are critical to continued flow of supply chain information, and minimize disruption across value chains. In New York City, following Hurricane Sandy, the city government, the NYCEDC and non-profit organizations established a wireless mesh network-based distributed telecommunication system for small businesses so that they could stay connected when central communication networks were down (box 8.3).

Box 8.3 New York City (United States): Resilience of Small Businesses is Improved Through Increased Redundancy of Telecommunication System Via a Wireless Mesh Network Connecting Firms

Challenge

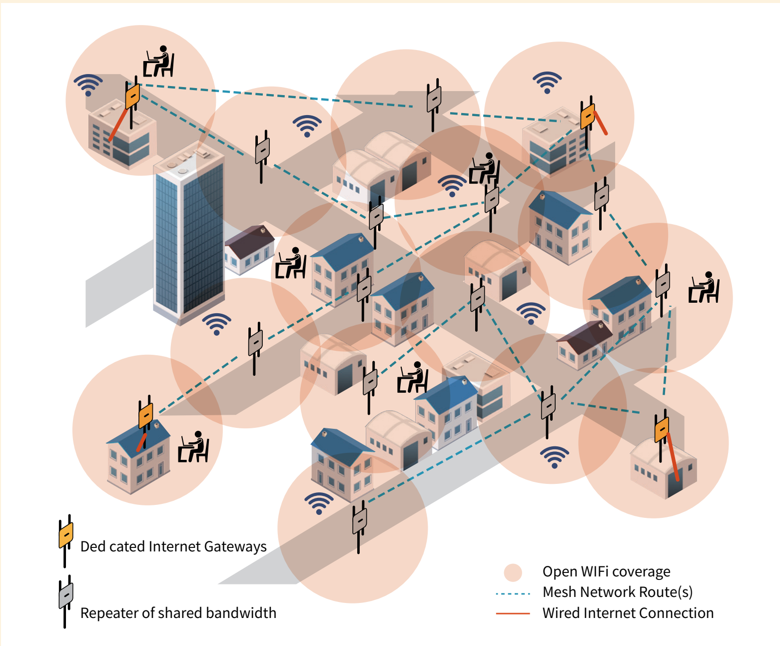
New York City was severely affected by Hurricane Sandy in 2012. In 48 hours, approximately 300 homes were destroyed and hundreds of thousands of residents, and many businesses and retailers were left without power and communication. Industrial businesses were particularly vulnerable to the effects of the hurricane due to the location of manufacturing industries on the low-lying floodplains of the city's coastline. Twenty-four percent of manufacturing zones fall within floodplains (on which there are 3,600 businesses that employ about 87,000 workers (NYC Planning 2018). Improving the disaster preparedness of the power and communication networks was crucial for businesses in these flood-prone manufacturing zones to maintain business continuity.

Solution: Developing storm-ready digital infrastructure in flood-affected manufacturing districts.

In efforts to rebuild the city, the NYCEDC and New America's Resilient Communities launched the "Resilient Innovations for Stronger Economy (RISE: NYC) program, a Hurricane Sandy business recovery and resiliency program. The program tasked community-based projects and organizations to develop storm-ready digital infrastructure in the manufacturing and business districts within the City, such as Queens, Brooklyn, and Staten Island, many of which were severely affected by Hurricane Sandy (Byrum et al. 2016).

The project aimed to improve the resilience of the telecommunication network through a system allowing small businesses, manufacturers, workers and households to stay connected when central communication networks were down. Connectivity can be maintained even during disasters through a distributed telecommunication system supported by individual hand-held devices capable of generating their own radio waves to create a mesh network in the absence of cell service. New America Foundation, a nonprofit organization, is also providing free, open-source meshing software to turn routers and other wireless devices into decentralized Wi-Fi networks around potential choke points (or points of potential disruption) during disasters. This effort leverages existing local initiatives that mobilize digital resources and expand Wi-Fi coverage to local small businesses. It also makes use of existing training programs for affected communities to be more disaster-ready, and actively participate in disaster response and recovery efforts. The cost of establishing distributed communication systems through individually owned devices needs to be further reduced, or financial support would be needed, if these technologies are to be applied in a developing country context.

Figure 8.3 Connectivity Enhancement Through Distributed Communication Systems



Source: Adapted from Braun 2017.

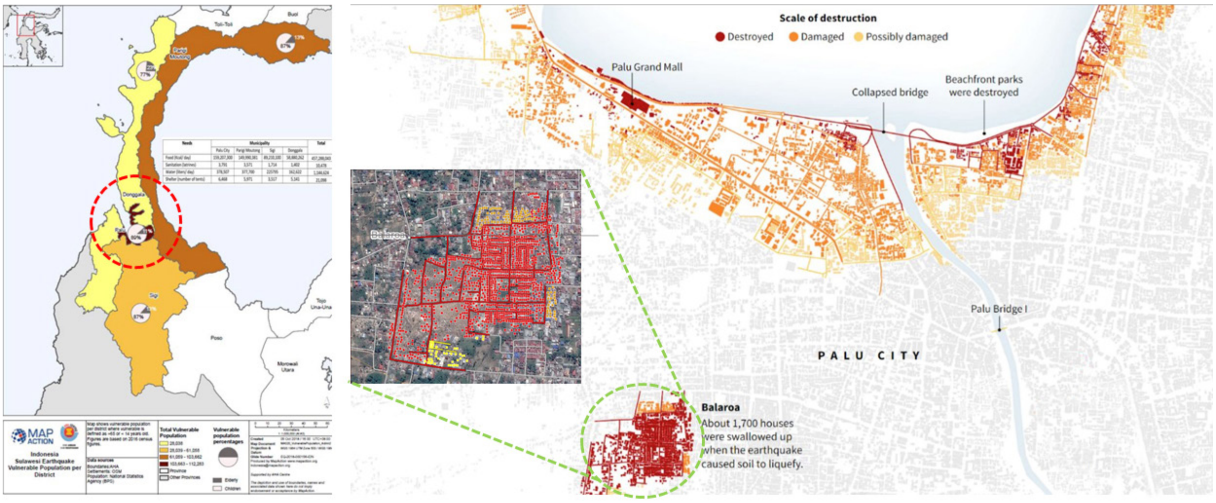
Source: NYCEDC 2016; Byrum et al. 2016; Braun 2017; Coldewey 2017; NYC Planning 2018.

8.2.4 Use Innovative Technologies to Fast-Track Asset Damage Assessments and Insurance Claims Payouts

Satellite mapping unmanned aerial vehicle (UAV)[64] and drone technologies have been extensively used in disaster management, together with the big data analytics and post-disaster damage assessment tools introduced earlier (e.g. GRADE approach by the World Bank). These technologies speed damage assessments by surveying and mapping affected regions, and capturing information required for recovery actions. For example, the International Organization for Migration has been using drones since 2012 to capture the damage in Haiti after the 2010 earthquake (Sharma 2016). During the Palu Earthquake in Indonesia (2018), several agencies used satellite mapping and remote sensing for search and rescue missions, to map devastated infrastructure and buildings, and to produce satellite/ remote-sensing imagery (figure 8.4). The remote-sensing imagery data were used in the World Bank's GRADE assessment, and within 14 days, the team identified commercial/industrial buildings as one of the major affected sectors (World Bank 2018a).[65] The GRADE assessment, making use of satellite and remote-sensing images, consequently informed government-led damage and loss assessment processes, as well as the World Bank's US$ 1 billion financing of the Government of Indonesia's reconstruction actions (World Bank 2018b).

Figure 8.4 Use of Satellite Mapping Technology to Assess Earthquake Damage in Indonesia

Panel a) Panel b)



Source: Panel a) Adapted from AHA Center 2018; Panel b) © European Union, Copernicus Land Monitoring Service 2018, European Environment Agency (EEA).
Note: Panel a) Earthquake/tsunami-affected areas in Central Sulawesi Province, Indonesia; Panel b) Detailed analysis of the affected areas in red dotted circle in Panel a), using satellite mapping technologies. The detailed footage included damaged residential and commercial buildings, road networks and other public infrastructure.

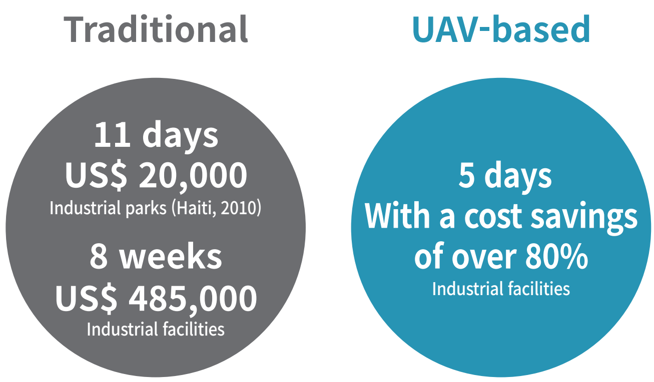
64 An unmanned aerial vehicle (UAV) is an aircraft that carries no human pilot or passengers. UAVs, commonly referred to as "drones", can be fully or partially autonomous but are more often controlled remotely by a human pilot. UAVs have a host of applications such as land surveillance, search and rescue, photography, disaster response and remote tracking.

65 The World Bank's GRADE assessment used remote sensing-imagery available from UNOSAT, COPERNICUS, DigitalGlobe, Google, HOTOSM, and MapAction; and satellite imagery and other ground-collected data from BNPB, Ministry of Education, PUPR, AHA Center, and social media. The total economic damages associated with the 2018 earthquake were estimated at over US$ 500 million. Of this, approximately US$ 185 million was expected to be associated with commercial/industrial buildings (approximately 37 percent); and US$ 165 million with infrastructure (approximately 33 percent) (World Bank 2018a).

In the industry resilience context, satellite mapping technologies, UAV systems and drone technologies can also be used for rapid data collection, monitoring, and assessment of industrial infrastructure and asset damage (Moranduzzo and Melgani 2014). They allow assessors to quickly assess damage without risking the safety of workers and inspectors in dangerous situations typical during disasters (box 8.4). Like sensors attached to infrastructure, UAV/drones can also generate, within a short period of time, accurate monitoring data even during disasters. Because of the speed of data capture and analysis, cost savings of up to 80 percent can be achieved (figure 8.5); and, when combined with other technologies, these tools quickly provide damage assessments accurate enough for insurance claims. Typical use cases include:

- Aerial investigation of disaster-affected industrial parks, facilities, equipment, machinery and inventories
- Produce actionable aerial data, enabling rapid emergency response decisions and actions in industrial parks, business sites, and facilities
- Evacuation monitoring at industrial parks and facilities
- Remote hazard detection

Figure 8.5 Differences in Estimated Savings on Industry Asset Damage Assessment Costs



Source: Industrial Skyworks n.d.

Box 8.4 UAV Systems and Drones for General Industrial Applications

Industrial parks, infrastructure operators and firms require constant monitoring and maintenance of their facilities, machinery, and equipment to ensure productivity, safety, and process efficiency, and to reduce operational risks,[66] security breaches and disruption during disasters. For facility managers at firms and industrial parks, this means overseeing thousands of critical processes, equipment and components such as turbines, boilers, generators and storage tanks. Such inspections require extensive human and financial resources and inspection equipment. At times, they may even require shutdown of plants, with attendant losses, or place inspectors at risk.

UAV systems and automated industrial drones are now increasingly used to address these challenges and reduce monitoring and maintenance costs during daily business operation (figure 8.6) and often come with software to analyze images and numerical data. Typical uses during normal industrial operations include up-close inspection of critical industrial infrastructure, plants and facilities, critical equipment and process monitoring in dangerous, confined industrial spaces and vessels, and tracking inventories.

66 Industries often cite profit losses caused by equipment failure. According to the analysis conducted by FM Global, an insurance company, of the company's 232 large non-natural hazard related losses in 2018 of over US$ 3million, 65 (approximately 28 percent) were the result of equipment breakdown. Major losses due to equipment failure typically occur in turbines (42%), non-rotating electrical (14%), generators (9%), and chemical vessels/process equipment (8%), accounting for over 70 percent of equipment related losses (FM Global 2019).

Figure 8.6 Use of Drones and UAV Technologies to Inspect Industrial Facilities

Panel a)

Panel b)

Panel a) Photo credit: © Dmitry Kalinovsky; Panel b) Photo credit: © Marcin Jozwiak

Source: Airbotics n.d.; Industrial Skyworks n.d.; and McKinsey & Company 2017.
Note: Panel a) drones inspecting indoor spaces in an industrial facility; Panel b) drones locate, generate, automatically organize, and analyze large image data sets on industry properties.

With respect to UAV and drone use, mapping and data capture for disaster management purposes needs to be aligned with the capture of data needed by industries for their recovery. Once the imperative to save lives has been met, it makes sense to integrate DRM and industry recovery needs so that UAVs and drones can capture both data sets simultaneously. For example, the satellite mapping of earthquake-affected areas in Palu, Indonesia, could have also identified impacts on industrial parks and facilities[67] (European Commission 2018). A lesson from this experience is that damage assessments should be refined to include data relevant to industrial damage assessment so that industry sector losses can be quantified.

Streamlining insurance payouts through digital platforms is another example of how new technologies can facilitate industries' response and recovery. Technologies that digitize insurance payouts offer quick access to funds for recovery, and support governments and financial institutions to effectively deliver financing solutions introduced in Section 6.3. Many small businesses are uninsured, but even insured businesses suffer from slow insurance payouts, as was the case in Puerto Rico, after Hurricane Maria, which impacted 77 percent of small businesses (Federal Reserve Bank of New York 2018). Such situations may be resolved by digitizing insurance payouts through new technologies including blockchain (FEMA 2019). FEMA recommended a blockchain technology pilot in Puerto Rico, advocating for a blockchain land/property registry to speed up insurance payouts. The registry would store information required by firms to file disaster-related insurance claims, including various policy documents, land ownership records, and machinery or inventory records. The blockchain registry is expected to reduce disaster response times and speed up insurance payments through automated smart contracts, without the risk of fraud. It can also engage public and private stakeholders, and hold insurance companies liable.

67 Critical industrial infrastructure and buildings included Palu Power Plant, a fertilizer factory, and a multi Nabati Sulawesi palm oil refiner.

In Puerto Rico, digital insurance payment schemes are being tested in which insurance claims are automatically filed and paid in response to hurricane-strength wind speeds (Grzadkowska 2018). Contracts are linked to property addresses, and claims are released when Category 3 Hurricane wind speeds are recorded within 30 miles of a claimant's property. When hurricanes strike, and Category 3 wind speeds are recorded, payouts are sent to claimant's bank accounts within 72 hours.

A number of conditions must be met to leverage digital or other innovative technologies introduced in this section. These include:

- **Training and capacity building for digitization: An important factor in the adoption of innovative technologies is the status of prior technologies, and the systems needed for the uptake of those replacing them.** In order to activate sensor networks and automatic flood gates, for example, regional-level early warning systems should be in place. Technical capacities of governments, industrial park operators, firms and their employees need to be strengthened in concert with the introduction of new technologies. Technicians operating key industrial infrastructure require supercomputing, IoT, big data, and microgrid systems expertise; training and additional infrastructure investments may be required, and need to be budgeted for as an industry resilience cost.

- **Resilience-related IT training, however, creates nodes of competence which may ultimately cater to emerging economy demands for IT skills.** Superior insight from digital technologies does not translate into better corporate performance unless many activities change—for instance, businesses may need to change the way they operate and market their products in order to enhance supply chain resilience. Even when the technological backbone is present, companies cannot generate value from digitization without employees who are alert to, and able to unlock all that it offers. Realizing the full resilience benefits of new technologies may require changes in employee skillsets, and even in corporate culture, as technology alone cannot sustain meaningful change.

- **Building business cases:** As many of them are nascent, integrating new technologies for industry resilience requires piloting and consensus before application. Issues such as technical feasibility or the privacy of proprietary information (such as margins, prices, and customers' information) shared through digital platforms remain as open-ended questions. In the Puerto Rico Case, for instance, the US Department of Energy (DOE), in partnership with national research laboratories, has provided technical support to evaluate the technical and financial feasibility of microgrids in enhancing the resilience of the electricity sector in Puerto Rico (United States Department of Energy 2018). This R&D has assisted Puerto Rico Industrial Development Company (PRIDCO) which operates industrial parks in Puerto Rico, with the pilot application of several microgrid projects for industrial corridors, and facilitated their potential deployment for commercial and industrial customers.

- **Regulatory reform:** Governments should revisit and modify existing regulatory frameworks, or enact new ones, to scale up public and private investment in new technologies to increase industry resilience. This was highlighted in Japan and Puerto Rico where micro-grid systems were piloted or installed in industrial parks to enhance the resilience of power supply (see also box 6.6). Development of microgrid systems in industrial parks may require new regulatory frameworks, or alignment with existing regulations. In Puerto Rico, after Hurricane Irma, prior to piloting microgrid projects in industrial parks by PRIDCO, the Regulation on Microgrid Development of the Puerto Rico Energy Commission (PREC) was adopted, and has set the legal and regulatory framework required for the development of microgrid systems. The regulation has achieved this by defining classes of microgrids, the types of generation they can use, and clarifying the role of utilities, owners and operators of microgrids (Puerto Rico Energy Commission 2018).[68] Regulatory reforms such as these, or regulations that allow for connection to the main grid would help lower barriers to the introduction of microgrids in industrial parks. The regulatory environments required to introduce new technologies may not always mesh with existing regulations, as these regulations may not have anticipated the advent of new technologies, and may not be geared to their accommodation; therefore, regulatory, policy and institutional analyses, in concert with technical and financial feasibility studies, should be conducted to identify gaps.

68 For example, the regulation defines microgrid owners (who purchase, lease, or receive third-party financing for microgrid equipment) and operators (who oversee the system and deliver electricity services to customers), as well as different microgrid systems; it also clarifies interconnection regulations, grid codes and standards.

Table 8.1 Integrating Gender and Technology Solutions: Example Projects

Intervention area	Name of intervention	Location	Brief description	Outcomes
Finance women-owned SMEs through disaster risk financing.	Microinsurance Catastrophe Risk Organization	Haiti	MiCRO covers damage from floods, hurricanes and earthquakes through a natural catastrophe and weather index insurance scheme, and increases women-led SMEs' access to finance post-disaster.	54,000 female entrepreneurs have enrolled in the program, and a US$ 8.9 million payout was made.
Enhance market access for women-led SMEs during disaster response.	Rapid Repair Program	United States (New York City)	Programs were developed by national and local governments to procure goods and services from women-owned enterprises.	Minority- and women-led SMEs won nearly US$ 530 million worth of the City's prime contracts and sub-contracts during the recovery process.
Maintain training programs for women entrepreneurs and female employees during and post-disaster.	Business EDGE	Haiti	The Haitian Development Bank partnered with the World Bank to continue providing a training program for women-owned SMEs in the aftermath of earthquake.	The program provided training for 2,750 SME owners, employees and entrepreneurs, including over 1,250 women. This increased women entrepreneurs' capacity to compete in the post-disaster market.
Enhance supply chain visibility and resilience utilizing new technologies.	IBM: use of AI to integrate end-to-end supply chain management into a single operational framework	Global	IBM's WSCI is a supply chain-focused, cloud-based application which has been used to improve supply chain resilience and visibility in order to manage increasingly vulnerable global supply chains. WSCI's AI technology is used to analyze weather data, traffic, and regulatory reports, and to identify and mitigate disruptions.	This, and similar technologies, support a culture of resilience through predictive analytics and forecasting, increased supply chain visibility, and better management of disruptions.
	Regional Economy Society Analyzing System (RESAS)	Japan	The Cabinet Office, METI, the SME agency, and the Teikoku Databank developed a system to analyze big data on population, business and infrastructure dynamics.	1,706 municipalities (nearly 95% of municipalities in Japan) use RESAS for post-disaster reconstruction planning or promoting inter-industry collaboration across regions.
Minimize industrial infrastructure disruption with new technologies.	Port of Rotterdam: Technologies have a growing role in improving logistics and safety	The Netherlands, Port of Rotterdam	The port infrastructure operating system was updated with new digital technologies. 44 IoT sensors were installed along 42 kilometers of quay walls to analyze weather, flood risks, availability of berths and movement of ships.	Real-time, aggregated information from the port's sensors have reduced operating risks and service disruption from coastal floods and storm surges, and improved shipping and trade logistics, efficiency, and safety, especially under conditions of stress.
	"RISE: NYC" program	New York City	NYCEDC and New America's Resilient Communities have established storm-ready digital infrastructure, which can help businesses stay connected when central communication networks are down. Resilient connectivity may be achieved through wireless, distributed systems that use hand-held devices that generate their own radio waves to create networks in the absence of cell service. Free, open-source meshing software was made available.	These efforts have enhanced redundancy in the telecommunications system, and created storm-ready digital infrastructure for flood-prone manufacturing districts.

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9

A Way Forward

Resilient industries are competitive industries that are prepared for various hazards and able to build back better after disasters. The many case examples in this report paint a picture of what resilient industries may look like in the face of disasters—climate-related and natural hazards, and pandemics and indicate the areas in which government can promote industry resilience. While this picture is still emerging, and remains incomplete, a Resilient Industries Framework is suggested in this report, based on analysis of current case studies in a rapidly emerging field (see table 3.3). A number of lessons have emerged from this global study of industry resilience planning and action.

9.1 Key Lessons

The key message of this report is that risk-informed planning and investment can yield both short-term and long-term competitiveness benefits that make sense for a wide range of stakeholders even before disasters strike. These benefits accrue through positive returns on investments for firms and industrial parks, and through social and job-related improvements for workers and local communities. Costs associated with planning and acting in advance—through risk data collection and analysis, regulatory reform, contingency planning, and risk-informed infrastructure investment and industrial park management—significantly offset recovery costs after disasters. These costs may be offset through avoided damage and losses to industry assets and revenues, and yield benefits even before disasters strike by increasing operational cost savings, industry asset values and reputation, job creation, and through other synergies of social, environmental and economic benefits.

To increase competitive benefits, industry resilience stakeholders can plan for creating synergies with other investments and financing opportunities such as quality and sustainable infrastructure investments or green finance. Integrating nature-based solutions into gray infrastructure helps improve stormwater management capacity of industrial sites at relatively low maintenance costs. Innovative power supply network designs that use renewable energy increase reliability of power supply both during normal operations and disasters. Water supply networks that reuse treated wastewater, rainwater and stormwater can also help create resilience benefits. Climate/sustainable finance can support investments in these green and resilient infrastructures. Pharmaceutical and food processing firms that operate in hot, dry climates can seek green finance to investing in measures that increase energy and water efficiency and lower cooling and refrigeration costs.

Governments and other public sector entities should take a “no-regrets” and risk-informed approach to industry resilience; this approach should be based on the best available information, taking into consideration various types of hazards. This requires reflecting not only on current risks but also considering future and longer-term climate change impacts such as sea-level and temperature rise in the development of industry policy, regulations, and incentives; master planning of industrial parks and infrastructure development including the selection of their locations and design specifications; or financial analysis of direct damages and business interruptions. As illustrated in the UK, the Netherlands and Peru cases (Sections 4 and 5), governments can consider projections of future climate change risks to industrial infrastructure, industrial parks and park operations. Longer-term industry resilience planning and adaptation introduces new challenges, as models and projections involve high degrees of uncertainty, making it difficult to secure financial commitments or arrange risk-sharing mechanisms. While progress is occurring, few governments have been able to fully integrate climate model projections and potential business losses into infrastructure investments.

Collaboration strengthens industry resilience planning and action. Industry resilience requires multi-sectoral and multi-level efforts, including national, local, industrial park and firm levels, and even across countries. The implementation of the Resilient Industries Framework therefore requires inputs and collaboration from a wide range of stakeholders for identifying strategic areas where they can jointly plan for contingencies and prearrange partnerships for support. Strengthening coordination frameworks is essential to scaling up planning and actions across firms, industry sectors, supply chains, industrial parks and regions. Recommended roles and responsibilities of each stakeholder group are summarized below:

- **National and local governments, public agencies, and public infrastructure operators** guide industry resilience initiatives and provide enabling environments through policies and financial support. They are able to work at inter-governmental levels, partner with industries to identify risks and opportunities, seed resilience principles into various policies and plans, advance fiscal incentives, and risk-informed industrial park planning, design standards, tools and other regulations to incentivize disaster mitigation and preparedness. They are also able to streamline recovery from shocks by supporting access to GVCs, boosting market demand through incentives and stimulus packages, and maintaining healthy and competitive market structures.
- **Firms across multiple manufacturing sectors and supply chains** can reduce losses and increase competitiveness by identifying strategic areas of collaboration and jointly investing in low-cost disaster mitigation and preparedness measures. These include both structural and nonstructural measures, such as investments in risk-informed facility designs, purchasing insurance, developing joint BCPs or emergency preparedness plans, re-arranging business operations with suppliers and customers, and/or rethinking business strategies in light of risks.
- **Industrial associations** can support governments to identify sector-specific or cross-sectoral disruption risks, or develop training programs to facilitate BCP implementation and uptake of innovative technological applications across member firms.
- **Industrial park operators** can use park-wide hazard maps and BCPs to secure their parks against risk, prepare business cases for resilience investments, and explore collective access to finance for these investments.
- **Financial institutions** may provide instruments to incentivize firms, infrastructure providers and other stakeholders to increase preparedness. Some measures include integrating disaster resilience benefits into investment analytics, providing financial incentives such as preferential loans, insurance premiums or guarantees; or innovating disaster risk financing mechanisms using new technologies.
- **Development partners** can support client governments to mainstream resilience into industry development/private sector development projects through policy, institutional, technical, and financial support. Development partners can also pilot emerging finance and industry resilience approaches, plan key resilient infrastructure investments, and help firms improve understanding of the risks they face.

Industrial parks offer opportunities to create synergies to enhance resilience. Industrial park operators can improve resilience of park infrastructure, services, and management, and these improvements may collectively benefit tenant firms and broader communities. Such parks can also attract investments in further improvements of common infrastructures such as power supply or flood protection, as in the Japan and Thailand cases. Common infrastructures and services with improved resilience can collectively benefit industrial parks and their tenant firms. Industrial park operators can offer managers and employees skills training on BCPs and the use of ICT, launch site-specific risk assessment studies and develop a park-wide BCPs to guide the mobilization of collective resources from tenant firms when disasters require this, as highlighted in the Japan and Turkey cases. These park-level actions can generate further synergies across different industry sectors and regions if implemented alongside national efforts to improve resilience.

Industry resilience measures should be gender-aware, and open to the many applications of emerging technologies. Diverse gender-sensitive industry resilience measures may be developed based on the assessment of gendered impacts of disasters and the specific needs of women. These measures include increasing women entrepreneurs' access to finance, credit and markets through targeted cash transfers, or procuring goods and services for reconstruction from women-owned enterprises. Technologies—both conventional ICT and emergency technologies—have many industry resilience applications. They help governments and industry practitioners better understand complex, highly connected manufacturing environments, facilitate access to markets, and make risk-informed and evidence-based decisions. Greater use of ICT can improve business continuity and help firms maintain access to markets, customers and suppliers during disasters. Big data and blockchain technologies also help enhance supply chain visibility and resilience, and guide governments and industry practitioners. Satellite mapping, blockchain and drone technologies can also fast-track asset damage assessments and insurance claims payouts, though more empirical testing may be required.

Industry resilience strategies are not one-size-fits-all; for developing countries that are working towards industrial resilience, the strategies should be modified to reflect the capacity for implementation, nuances of local context, countries' participation in GVCs, and hazard profiles in the face of intensifying climate change. For example, developing countries may lack the modeling capacity and data required for long-term industry resilience planning, and the costs of data and multi-hazard early warning systems may be high. Other economic and political priorities may trump resilience considerations even though preparatory actions boost competitiveness by protecting jobs, livelihoods, economies and resources. Countries planning for industrial resilience can consider these local contexts, and the capacities of governments, firms, industrial park and infrastructure operators, industry associations, and the financial sector. The current uptake of new technologies, and the rights and well-being of women and other vulnerable groups should also be considered in order to establish a holistic approach to enhancing industry resilience at the national level.

Governments in developing countries, with support from development partners and international communities, can mainstream resilient industry benchmarks introduced in this report. Specific industry resilience approaches such as collaborative risk assessments, BCPs, insurance, resilient industrial park development, and post-disaster financing are a promising start to establishing multi-sector industry resilience. For example, governments can work with the international community to improve disaster risk information and climate change projections, and to tailor this information to locality- and industry-specific needs. Collaborative risk assessments can be both a key process and tool for engaging industry practitioners and improving their risk awareness, and capacity-building and partnerships with the public sector, as illustrated in Section 4.2. Investment in infrastructure and industrial parks can also embed technical assistance and other knowledge programs to improve risk-informed designs and industry resilience.

9.2 Areas for Further Research, Improvements and Next Steps

The imperative to transition to safer and more resilient industries has gained momentum globally in the face of intensifying and compounding hazards, and, more recently, a global pandemic. In response, this report has provided an initial framework for how governments can strengthen industry resilience; however, the conceptual underpinnings of industry resilience are still emerging, and will continue to evolve. As such, the evidential basis for policies and investments is far from definitive, and will need strengthening in order to integrate new disaster scenarios, industry sectors, specific country contexts, markets and environments; these challenges will be amplified by the inherent uncertainties of climate change and disaster prediction. Furthermore, additional case studies and research are needed to describe the benefits of resilience actions for different hazard environments, both in terms of their efficacy, investment returns, and suitability for different industry participants (Surminski and Tanner 2016). In the absence of this information, perceived trade-offs between the short-term capital costs of resilience investments and their long-term benefits may mitigate against uptake of resilience recommendations, notably for SMEs, and especially if the required financial instruments are not readily available and easily accessible. Such resistance may also reflect the intangibility of many resilience benefits, and new methodologies are needed to capture rewards and services that fall outside of conventional socio-economic evaluation. The usefulness of resilience-incentivizing financial instruments also needs to be clarified, and much work is needed in the arena of gender-informed resilience work, and its incorporation into institutional cultures and frameworks.

In the longer-term, the impacts of climate change and various hazard types on industries, sectors, and industrial parks requires further research and verification. The inherent uncertainties associated with climate models mean that long-term climate change impacts, particularly at smaller scales, will remain difficult to predict. Thus, climate aware designs, policies and loss estimates require ongoing research into how slow onset events will exert location and sector-specific impacts on manufacturing industries, industrial parks, and regions.

Shocks can be transmitted through complex production networks during disasters (Inoue and Todo 2019; Carvalho 2014) but the empirical details of such cascading effects require further study. The supply chains of manufacturing firms are formed by their contractual exchange of goods and services, and aggregations of these exchanges and supply chains forms a production network. In production networks, shocks travel upstream and downstream, and can have multiplier effects. For example, damages to a third-tier supplier may disrupt an entire supply chain, and even other supply chains which may not be in close geographical proximity. Shocks to an industry can impact production activities at the regional level because of these multiplier effects. Facing this situation, manufacturing firms may have to weigh trade-offs between actions to mitigate supply chain disruption such as supply chain redundancy, and the cost efficiencies of these actions during normal times. While studies on interconnected supply chains are increasingly available (Boehm, Flaaen and Nayar 2019; Barrot and Sauvagnat 2014; Inoue and Todo 2019), the role of governments in managing supply chain dynamics remains unclear.

The relationship between market structure and industry resilience also requires investigation. Collective measures to enhance industry resilience, such as park-wide BCPs and pre-arranged agreements, should also support innovation, stabilize market prices, and guard against unfair competition among firms, which may negatively affect consumer welfare. For example, recent research shows that syndicates, which mandate production quotas and encourage firms to share inventories, increase commodity prices and reduce consumer welfare; however, they also help stabilize supply in the wake of disasters (Gnutzmann, Kowalewski, Spiewanowski 2020). Deeper understanding of how market structure transmits shocks or encourages the private sector to develop resilience measures can guide governments to design market-based rules and standards that can incentivize improved resilience of manufacturing firms and sectors.

While the Resilient Industries Framework presented in this report is primarily focused on geological and hydrometeorological hazards, the concept of industry resilience has significant transferability to health emergencies such as pandemics. Many of the solutions introduced under this framework may be applied to public health emergencies. As an example, BCP responds to situations in which disruptions are widespread, and demand collective action. Such cultures of mitigation and preparedness, and their advanced cooperation and information sharing agreements may be well-suited to public health challenges. Policies and financial instruments introduced in this report are suited to the provision of liquidity to SMEs impacted by COVID-19. The pandemic's impacts have been severe in already vulnerable communities, and this report's recommendation to support women in industry may do much to foster resilience in such communities, increasing their adaptive capacity in the face of other shocks and emergencies. Indeed, the many policy recommendations to explicitly include women in resilience planning arguably lay a strong foundation for responses to a range of challenges, including public health emergencies. Pandemics, for example, may be included in BCPs and risk analyses, allowing for planned responses to both industry and community impacts. Firms and industrial parks may consider structural modifications such as improved ventilation, handwashing stations, and production systems allowing for social distancing. These responses should harmonize with national frameworks to promote resilient industries, including green recovery. The Resilient Industries Framework should be expanded to integrate public health emergencies so that it offers a deeper understanding of the impacts of the pandemic on industries, and the effectiveness of various measures.

While enhanced preparedness is essential, the scope of future disasters and their impacts cannot be precisely specified. Thus, stakeholders must plan both for resilience across multiple disaster scenarios, and to build back better when they strike. COVID-19 invites this possibility, and may prove an important driver of resilience thinking. As firms, and the public and private sectors adapt to a changing global health landscape, new dimensions of resilience will come to the fore, and inform ongoing resilience thinking and planning.

Gender and social dimensions of industry resilience should be championed but knowledge gaps remain. Gender is a key dimension of these emerging industry resilience paradigms, as shown by this report's advocacy for the rights and well-being of women in the resilient industry contexts of preparedness, disaster response and recovery. While there is growing support from governments to address the needs of women workers, business owners and entrepreneurs, it remains limited, and the social, institutional and cultural barriers faced by women and other vulnerable groups require constant emphasis in resilient industry policies and programs. Additional research is required to better understand how disasters affect women differently, and what kinds of responses are most needed for women in industry sectors in disaster contexts.

On this front, the World Bank is working with a number of countries to advance resilience awareness. By targeting various stages of the industrial park development process, the World Bank aims to address challenges and concerns, build countries' knowledge and capacity, and help develop green and resilient industrial parks in these countries. In Bangladesh, the World

Bank is already incorporating the lessons learned from this global study into its programs to support industrial park operators/economic zone authorities, other coordinating agencies and investors.

Finally, *Resilient Industries in Japan: Lessons learned in Japan on Enhancing Competitive Industries in the Face of Disasters Caused by Natural Hazards* provides a detailed account of how the concept of industry resilience has been implemented in Japan, which has strong and competitive manufacturing sector, and a long history of learning from disasters (World Bank 2020). Numerous national resilience legislations, as well as BCPs, EP&R Plans, and infrastructures, have been developed and updated incorporating lessons learned from previous disasters. These policies and actions have proven effective during subsequent disasters. *Resilient Industries in Japan* examines how and why they have been effective, as well as key motivations and remaining challenges. The report will therefore provide detailed guidance for policy makers, industry stakeholders, financial institutions, and development partners on how to mainstream industry resilience strategies into public policy and business management and build back better.

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Appendix

Overview of Country-specific Examples Featured in the Report

Examples of Resilient Design and Operating Standards for Various Hazards

Appendix I Overview of Country-specific Examples Featured in the Report

Industry resilience timeline		Intervention area	Country (Specific locations if applicable)	Hazard type	Section	Number of boxes and pages
Actions before disasters	Understanding risks to industries	Enhance national understanding of disaster risks to industries.	United Kingdom	Multiple hazards and climate risks including floods, high temperatures, water scarcity	4.1	Box 4.1
		Develop frameworks and tools to assess risks to firms, value chains and industrial parks.	Egypt	Multiple hazards including floods and droughts	4.2	Box 4.2
			Turkey	Multiple hazards including earthquakes		Box 4.3
			Morocco	Floods, droughts, and water scarcity		
		Promote public-private partnerships to enhance sector-and location-specific risk assessments.	The Netherlands (Port of Rotterdam)	Floods, and coastal storm surges	4.3	Box 4.4
	Planning and prioritization	Identify national priorities for industry resilience.	United Kingdom	Multiple hazards and climate risks including floods, high temperatures, and water scarcity	5.1	Box 5.1
			Peru	Floods, extreme temperatures, and landslides		Box 5.2
		Develop a national resilient industries framework and coordination structures.	United States	Multiple hazards	5.2	Box 5.3
	Mitigation and preparedness	Promote business continuity planning and management.	Japan	Multiple hazards including earthquakes, volcanic eruption, tsunamis, tsunami, and floods	6.1.1	pp. 70-74
			United States	Multiple hazards		p. 71
			Turkey	Multiple hazards including earthquakes		Box 6.3
		Help industries maintain global value chains.	Japan and Thailand	Floods	6.1.2	Box 6.4
			Haiti	Earthquakes		pp. 77-78
		Promote resilient industrial park development.	India (Gujarat)	Earthquakes and floods	6.1.3	p. 79
			Thailand	Floods		p. 80
			Bangladesh	Multiple hazards including earthquakes, floods, tropical cyclones, and coastal storm surges		pp. 81-82
			United States (New York City)	Floods, hurricanes, and coastal storm surges		Box 6.5
		Minimize infrastructure disruption in industrial parks.	Thailand	Floods	6.2.1	p. 84
			Bangladesh	Multiple hazards including earthquakes, floods, tropical cyclones, and storm surges		p. 84
			Japan	Multiple hazards including earthquakes, volcanic eruption, tsunamis, floods and storm surges		Box6.6
			Kenya	Droughts and floods		Box 6.7
			United States (New York City)	Floods, hurricanes, and coastal storm surges		Box 6.8
			Japan (Sendai City)	Multiple hazards including earthquakes, volcanic eruption, tsunamis, floods and storm surges		pp. 90-91
		Conduct alternative cost-benefit analyses.	Republic of Korea	Floods and coastal storm surges	6.2.2	Box 6.9
			Japan	Multiple hazards including earthquakes, volcanic eruption, tsunamis, and floods		p. 93
			Bangladesh	Multiple hazards including earthquakes, floods, tropical cyclones, and coastal storm surges		pp. 94-95
		Support up-front resilient infrastructure investment.	Bangladesh	Multiple hazards including earthquakes, floods, tropical cyclones, and coastal storm surges	6.3.2	p. 97
		Provide financial support for contingency planning and advance disaster risk financing.	Japan	Multiple hazards including earthquakes, volcanic eruption, tsunamis, and floods	6.3.3	pp. 97-98
			United States	Floods		p. 99

Industry resilience timeline		Intervention area	Country (Specific locations if applicable)	Hazard type	Section	Number of boxes and pages
Actions during and after disasters	Response and recovery	Activate and refine coordination frameworks for response and recovery.	Haiti	Earthquakes	7.1	p. 111
			Japan	Multiple hazards including earthquakes, volcanic eruption, tsunamis, floods and storm surges		pp. 111-112
		Conduct rapid assessment of industrial damage and losses.	Haiti	Earthquakes	7.2	Box 7.1
		Provide support to retain investors and boost market demand.	Thailand	Floods	7.3.1	p.114
			Malaysia	Pandemics		pp. 114-115
			United States (New York City)	Floods, hurricanes, and coastal storm surges		p. 115
			Japan and Thailand	Floods		p.115
			Haiti	Earthquakes		Box 7.2
		Support safety and employment continuity.	Haiti	Earthquakes	7.3.2	pp. 118-119
			Japan and Thailand	Floods		p. 119
		Promptly restore critical infrastructures and services.	Haiti	Earthquakes	7.4.1	pp. 119-120
		Provide financial safety nets targeting SMEs.	Japan	Multiple hazards including earthquakes, volcanic eruption, tsunamis, floods and storm surges	7.5.1	p. 121
			Haiti	Earthquakes		pp. 121-122
			Thailand	Floods		Box 7.4
			Global	Pandemics		Box 7.5
		Finance investments in building back competitive industries.	Japan (City of Kobe)	Multiple hazards including earthquakes, floods, tropical cyclones, and coastal storm surges	7.5.2	pp. 124-125
Integrating gender and technology solutions	Gender-sensitive resilience planning and actions	Finance women-owned SMEs through disaster risk financing.	Haiti	Floods, hurricanes, and earthquakes	8.1.2	pp. 133-134
		Enhance market access for women-led SMEs during disaster response.	United States (New York City)	Floods, hurricanes, and coastal storm surges	8.1.3	p. 134-135
		Maintain training programs for women entrepreneurs and female employees during and post-disaster.	Haiti	Earthquakes	8.1.4	p. 135-136
	Improving resilience through technology	Encourage ICT uptake by firms.	Malaysia	Pandemics	8.2.1	p. 137
		Enhance supply chain resilience and visibility utilizing new technologies.	Global	Multiple hazards	8.2.2	p. 139
			Japan	Earthquakes		Box 8.1
		Minimize industrial infrastructure disruption with new technologies.	The Netherlands (Port of Rotterdam)	Floods and coastal storm surges	8.2.3	Box 8.2
			United States (New York City)	Floods, hurricanes, and coastal storm surges		Box 8.3
		Use innovative technologies to fast-track asset damage assessments and insurance claims payouts.	Indonesia	Earthquakes	8.2.4	p. 145
			United States (Puerto Rico)	Multiple hazards including floods and hurricanes		pp. 147-148

Note: Specific case examples are not included for the following intervention areas identified in this report: analyze financial impacts and needs (section 6.3.1), and conducting gender-sensitive needs assessment (section 8.1.1).

Appendix II Examples of Resilient Design and Operating Standards for Various Hazards

National /local governments

Structural measures	
Type of hazard	**Description**
Flood	***Mitigate by:*** Developing levees to contain coastal/river flood waters. Developing stormwater management reservoirs or green spaces. Procure sandbags. ***Prepare through:*** Installation of river and/or rain gauges, flood early warning systems (e.g. sirens).
Tropical storms (cyclones/ hurricanes/typhoons)	***Mitigate by:*** Developing beach nourishment and other shoreline erosion control measures. Locating industrial parks in low risk sites, and construction of breakwaters, groins and gabions. Use of nature-based options (e.g. green and open spaces, green roofs, mangroves) in coastal protection measures. ***Prepare through:*** Developing multi-purpose cyclone shelters that serve as emergency response and operation centers.
Droughts and extreme heat	***Mitigate by:*** Diversify water resources through the use of rainwater storage and harvesting measures, wastewater reuse technologies (for reuse of treated rainwater), and on-site storage. ***Prepare through:*** Smart water metering systems which allow for monitoring.
Earthquake	***Mitigate by:*** Seismic proofing critical infrastructure. ***Prepare through:*** Development of earthquake early warning systems (i.e. sirens), etc. Procurement and pre-positioning of spare parts and repair equipment for critical public infrastructure servicing firms and industrial parks.
Non-structural measures	
Multi-hazard	***Prepare through:*** • Develop regulations and building codes that require site-specific multi-hazard risk assessments for industrial parks, and consider climate change risks and site-specific characteristics such as topography, vicinity to the coastline, and drainage etc. • Develop coastal protection/restoration plans to mitigate future impacts of storm surges, cyclones and floods. • Work with industry practitioners and other private sector stakeholders to develop location-specific hazard maps that identy key industry assets and infrastructure services. Develop manuals, guidelines, certification systems, incentives and other financing mechanisms for local governments, industrial park operators, and firms to develop BCPs and/or emergency response plans. Put in place restoration procedures for on-site infrastructure in advance (i.e. post disaster checklists, external communication protocols, etc.). • Pre-arrange agreements with other firms, industry associations, and stakeholders for alternative mechanisms for production and/or critical infrastructure service delivery including cleaning up roads, power supply, etc.

Industrial park developers and/or operators

Structural measures	
Type of hazard	**Description**
Flood	***Mitigate by:*** Avoid flood-prone areas when siting industrial parks. Use flood-resistant materials for infrastructure works. Strengthen levees, increase dike heights, and replace overhead lines with underground cables. Develop improved stormwater network and drainage infrastructure such as stormwater management reservoirs. Elevate low-lying sites. Develop flood-resilient road network including arterial and non-arterial roads, footpaths, and plot entry culverts. Install elevated waterproof barriers. Increase drainage capacity for sewage and road networks. Increase green/open spaces and use permeable materials to increase drainage capacity. Use of sandbags. ***Prepare through:*** Water monitoring systems with river and/or rain gauges. Flood early warning systems (e.g. sirens), etc. Spare pumps and boats for evacuation.
Tropical storms (cyclones/ hurricanes/typhoons) and storm surges	***Mitigate by:*** Risk-aware site selection avoiding coastal sites prone to storm surges. Coastal protection measures such as breakwaters, groins and gabions. Integrate nature-based approaches such as green and open spaces, green roofs and mangroves for coastal protection. ***Prepare through:*** Multi-purpose cyclone shelters in or near industrial parks that serve as emergency response and operation centers, and can be shared with local communities.
Drought and water scarcity	***Mitigate by:*** Water efficiency measures. Diversify water resources through the use of rainwater storage and harvesting, wastewater reuse technologies and on-site storage. ***Prepare through:*** Smart water metering systems which allows for monitoring.
Extreme heat	***Mitigate by:*** Cold storage facilities, energy efficiency measures for warehouses; green buildings. Integrating nature-based solutions into grey infrastructure to manage energy consumption.
Earthquake and liquefaction	***Mitigate by:*** Seismic proofing of critical infrastructure (e.g. higher threshold seismic designs for pumping system components of water and wastewater treatment plants, water distribution pipes, etc.). Improve soil and provide seismic reinforcement, compact underlying material. ***Prepare through:*** Infrastructure monitoring sensors. Pre-positioning of spare parts and repair equipment for infrastructure. Periodic maintenance and construction inspection (e.g. replacing drainpipes) Installation of seismometer, earthquake early warning systems.

Multi-hazards	***Mitigate by:*** Conducting rigorous construction inspection, soil testing and procuring quality engineers and contractors. ***Prepare through:*** Developing site-specific multi-hazard map and developing early warning systems and evacuation plans. Investing backup power and water supply systems. Procuring post-disaster road and site clearing machinery, and back-up transport vehicles. Off-site data and ICT backup systems. Disaster-proof and inclusive evacuation centers. • Work with park users to develop evacuation plans and protocols, including for post-disaster damage and loss assessment. These plans and protocols should include roles and responsibilities, and identify evacuation routes, location of shelters, emergency operation centers, and communication and decision-making protocols. • Education and capacity development of tenant firms and employees on emergency preparedness and response plans and protocols. Conduct periodic evacuation and response drills.
Non-structural measures	
Multi-hazard	***Prepare through:*** Work with national and local governments to develop hazard maps which integrate disaster and climate change risks. Introduce risk-informed master planning. Develop area- or industrial park-wide BCPs which involve infrastructure operators, service providers, industrial park operators and firms; and which include back-up plans and critical infrastructure restoration plans. Develop evacuation plans and protocols which locate shelters and emergency operation centers; define control towers, staff roles, evacuation routes and communication and decision-making protocols; include list of staff members and key contact and post-disaster checklists such as post-disaster damage assessment methods. Education and capacity development of tenant firms, staff, and employees on emergency preparedness and response plans and protocols, as well as disaster and climate risk assessment tools. Conduct periodic evacuation and response drills. Pre-arrange agreements with other firms and stakeholders for alternative production and/or service delivery mechanisms. Put in place restoration procedures for critical on-site infrastructure in advance (i.e. post disaster checklists, external communication protocols, etc.

Firms

Structural measures	
Type of hazard	**Description**
Flood	***Mitigate by:*** Elevating floor levels of critical facilities, mechanical and electrical systems (e.g. electric substations, electrical panels, boilers, heating, and air conditioning systems), and equipment and storage spaces above design flood levels. Install watertight doors and obtain sandbags. Enhance rainwater retention and infiltration at industrial sites and factory buildings, combined with nature-based solutions such as green roofs, bioswales, porous pavements, etc. ***Prepare through:*** Elevate mechanical and electrical equipment above design flood levels, positioning key equipment or high value products on higher floors or shelving. Safety pumps and boats for evacuation.
Tropical storms (cyclones/ hurricanes/typhoons)	***Mitigate by:*** Building designs (and using construction materials) that can withstand high winds, floods and lightning. ***Prepare through:*** Developing IT systems such as project and product management platforms or IT-based supply chain management systems and back-up systems, which can protect and recover data, and support business operation during emergency situations.
Droughts and water scarcity	***Mitigate by:*** Water efficiency measures and improve wastewater and re-use technologies, and smart water metering systems. ***Prepare through:*** Installing/developing smart water monitoring systems.
Extreme heat	***Mitigate by:*** Utilizing green building designs such as reflective/green roofs and facades, cross-ventilation, trees and vegetation to provide shading. ***Prepare through:*** Energy-efficient cooling systems including those powered by renewables.
Earthquake	***Mitigate by:*** Investing in earthquake-resistant buildings and facilities. Distributed warehouses. Equip with emergency shutdown systems in factories. ***Prepare through:*** Installing seismometers and earthquake early warning systems, etc. Pre-positioning spare parts and repair equipment.
Multi-hazard	***Prepare through:*** Installing backup power and water supply equipment. Prepare post-disaster road and site clearing machinery, and back-up transport vehicles. Off-site data and ICT backup systems.
Non-structural measures	
Multi-hazards	***Prepare through:*** Advance preparation of recovery plans for factories (i.e. post disaster checklists, external communication protocols, etc.). Pre-arrange agreements with clients, suppliers, group companies, etc. for post-disaster coordination and response mechanisms including information collection, sharing, and decision-making protocols. Understand potential financial losses from business disruptions (one week, one month, and six months, etc.). Consider various disaster risk finance instruments such as insurance, pre-arranged post-disaster low-interest loans, pre-arranged loan repayment grace period arrangements, subsidies, grants available for resilience investments and actions.

Source: GIZ 2016; Hallegatte, Rentschler, and Rozenberg 2019; World Bank 2020a; World Bank 2020b.

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Hallegatte, S., J. Rentschler, and J. Rozenberg. 2019. *Lifelines: The Resilient Infrastructure Opportunity.* Washington, D.C.: World Bank. https://openknowledge.worldbank.org/handle/10986/31916.

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Glossary

***Note:** The key terms in this glossary have been developed through referencing various sources including the United Nations Disaster Risk Reduction (UNDRR) report, ISO, and various studies. They have been adapted for the purpose of this document to serve as a reference for its readers, and are not intended to be universal.*

Acceptable risk: the extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen, tolerable level. This determination of acceptable risk often relies on codes or "accepted practice" which are based on known probabilities of hazards and other factors.[69]

Business continuity: "ability to continue the delivery of previously agreed products and services within acceptable time frames at predetermined capacity during disruption."[70]

Business continuity management (BCM): a management system which "aims to prepare for, provide, and maintain controls and capabilities for managing an organization's overall ability to continue to operate during disruptions."[71]

Business continuity plan (BCP): documented information that guides an organization to respond to a disruption and resume the delivery of products and services (such as manufactured items) consistent with its business continuity objectives. BCPs are often related to a firm's management systems and processes.[72]

Contingency planning: a management process that analyzes disaster risks and establishes advance arrangements for timely and appropriate responses. Contingency planning is an important part of overall preparedness. Contingency plans need to be regularly updated and

69 https://www.undrr.org/terminology/disaster-risk.

70 ISO 22301:2019(en) Security and resilience — Business continuity management systems — Requirements (https://www.iso.org/obp/ui/#iso:std:iso:22301:ed-2:v1:en)

71 ISO 22301:2019(en) Security and resilience — Business continuity management systems — Requirements (https://www.iso.org/obp/ui/#iso:std:iso:22301:ed-2:v1:en)

72 ISO 22301:2019(en) Security and resilience — Business continuity management systems — Requirements (https://www.iso.org/obp/ui/#iso:std:iso:22301:ed-2:v1:en)

implementation of the plans need be practiced before disasters.[73]

Critical infrastructure: utilities and public works essential to economic security, productivity of firms, public health and safety. Key lifeline infrastructures include water, sanitation, electricity, transportation and communication[74] [75] (Hallegatte, Rentschler, and Rozenberg 2019). The report uses lifeline infrastructure interchangeably with critical infrastructure.

Disaster: a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and reduced capacity, leading to losses and impacts in one or more of the following realms: human, material, economic and environmental.[76] The effect of the disaster can be immediate and localized, but is often widespread and could last for a long period of time. Disasters create emergency situations.

Disaster damage: damage occurring during and immediately after a disaster. Disaster damages are usually measured in physical units (e.g., square meters of housing, kilometers of roads, etc.), and describe the total or partial destruction of physical assets, the disruption of basic services, and damages to sources of livelihood in the affected area.[77]

Disaster impact: the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster.[78] The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being.

Disaster mitigation: "the lessening or limitation of the adverse impacts of a particular incident caused by hazards and related disasters."[79] [80] Disaster mitigation measures include engineering techniques and hazard-resistant construction as well as improved environmental and social policies and public awareness. It should be noted that in climate change policy, "mitigation" is defined differently, being the term used for the reduction of greenhouse gas emissions that are the source of climate change.

Disaster risk: "the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity."[81]

Disaster preparedness: "knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions." Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response to sustained recovery.[82] Also known as readiness,

73 undrr.org/terminology/contingency-planning.

74 https://www.cisa.gov/critical-infrastructure-sectors.

75 https://www.law.cornell.edu/definitions/uscode.php?width=840&height=800&iframe=true&def_id=42-USC-1066716883-1185975015&term_occur=999&term_src=.

76 https://www.undrr.org/terminology/disaster.

77 https://www.undrr.org/terminology/disaster.

78 https://www.undrr.org/terminology/disaster.

79 https://www.undrr.org/terminology/mitigation.

80 https://www.iso.org/obp/ui/#iso:std:iso:22300:ed-2:v1:en:term:3.146.

81 https://www.undrr.org/terminology/disaster-risk.

82 https://www.undrr.org/terminology/preparedness.

disaster preparedness measures include activities decided on prior to an incident which support prevention of, protection and recovery from disasters.[83]

Disaster recovery: "the restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and 'build back better', to avoid or reduce future disaster risk."[84]

Disaster response: "actions taken ***directly before, during or immediately after a disaster*** in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected."[85]

Emergency preparedness: "measures and action taken ***in advance*** to mitigate the effects of possible destructive events. This includes drawing up a disaster response plan."[86]

Emergency response: "immediate phase in the aftermath of an event, consisting of gaining control, limiting the extent of the emergency and minimizing further damage."[87]

Emergency preparedness and response plan (EP&R): documented information that guides an organization to manage emergencies by emergency preparedness and response.[88]

Firm: a discrete entity that operates and creates value based on the collection of resources, capabilities, or routines that generates value, and buys and sells good and/or services in the market to make a profit. A firm is predicated on systems of law governing contract and exchange, property rights and incorporations. It generally takes one of three forms: individual proprietorships, partnerships, or limited-liability companies (or corporations). In this report, firm is interchangeably used with business, business enterprise, and business organization.

Global value chain (GVC): refers to the "series of stages required to produce a good or service that is sold to consumers, with each stage adding value and with at least two stages conducted in *different countries*" (World Bank 2020). A manufacturing eco-system of a bike, which is assembled in Finland with parts from Italy, Japan, and Malaysia and exported to the Arab Republic of Egypt, is an example of a GVC. By this definition, a country, sector, or firm participates in a GVC if it engages in (at least) one stage in a GVC (World Bank 2020).

Geological or geophysical hazards: natural hazards which originate from internal earth processes. Examples are earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapse and debris or mud flows. Hydrometeorological factors are important contributors to some of these processes. Tsunamis are difficult to categorize; although they are triggered by undersea earthquakes and other geological events, they manifest as oceanic processes and cause

83 https://www.iso.org/obp/ui/#iso:std:iso:22300:ed-2:v1:en:term:3.172.

84 https://www.undrr.org/terminology/recovery.

85 https://www.undrr.org/terminology/response.

86 ISO 21110:2019(en) Information and documentation — Emergency preparedness and response https://www.iso.org/obp/ui/#iso:std:iso:21110:ed-1:v1:en.

87 ISO 21110:2019(en) Information and documentation — Emergency preparedness and response https://www.iso.org/obp/ui/#iso:std:iso:21110:ed-1:v1:en.

88 Definition developed by authors based on ISO21110:2019 terms and definitions used in the World Bank operations. http://documents.worldbank.org/curated/en/895671585952003880/text/Ghana-COVID-19-Emergency-Preparedness-and-Response-Project.txt.

coastal water-related hazards.[89]

Hazard[90]: refers to a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation. Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Several hazards are socio-natural, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change. According to the Sendai Framework on Disaster Risk Reduction 2015–2030, hazards include (in alphabetical order) biological, environmental, geological, hydrometeorological and technological processes and phenomena.

Hydrometeorological hazards: hazards of atmospheric, hydrological or oceanographic origin. Examples are tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; drought; heatwaves and cold spells; and coastal storm surges. Hydrometeorological conditions may also be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics and in the transport and dispersal of toxic substances and volcanic eruption material.

Industrial parks: also known as economic zones, industrial areas, industrial zones, industrial investment regions, special economic zones, industrial corridors, etc. Industrial parks are planned, developed and managed for the purpose of industrial and associated commercial, infrastructure, and service activities. Through the grouping of firms in a defined location, industrial parks offer collaborative and efficiency gains.[91]

An industry: formed through various sectors that consist of firms or organizations that produce goods or services. Many sectors make up a country's industry, which contributes to the economy. Industries and sectors are not discrete entities, whereas a firm is. Sector refers to the classification or high-level grouping of the (changing) composition of economic activities based on the types of goods and services produced.[92]

Industry sector: corresponds to the industrial activities related to mining and quarrying, manufacturing, electricity, gas, water supply, and construction.[93]

Industry competitiveness: the ability to compete in national or international markets, which can be measured at firm, sector or country level in terms of productivity, skills, innovations, reputation, net exports and investment flows, that affect economic performance (Deloitte 2016; Kechichian et al. 2016; UNIDO 2019; McKinsey & Company 2012). Industry competitiveness can be expressed and assessed at various levels, including:

- **Firm-level competitiveness:** a firm or business is considered competitive if it can innovate, and produce better and higher quality products or services at more competitive prices, and more reliably than its domestic and international competitors

89 https://www.undrr.org/terminology/hazard.

90 From: https://www.undrr.org/terminology/hazard.

91 For more information, see UNIDO, World Bank Group and GIZ. 2017, "An International Framework for Eco-Industrial Parks." http://documents1.worldbank.org/curated/en/429091513840815462/pdf/122179-WP-PUBLIC-AnInternationalFrameworkforEcoIndustrialParks.pdf.

92 http://pubdocs.worldbank.org/en/538321490128452070/Sector-Taxonomy-and-definitions.pdf.

93 https://data.worldbank.org/indicator/NV.IND.MANF.KN.

both during normal times and disasters, thereby increasing trust from customers, market demand, revenues and reputation in the long-term. Firm-level competitiveness can be measured in terms of sales values or global market size.

- **Sectoral-level competitiveness:** how attractive different countries are for a particular sector. This is often measured in terms of tangible economic performance in international trade such as net exports, investment flows, and so on, as well as intangible performance measures such as brand recognition, reputation and attractiveness. Industrial policy, supply chain linkages, standards and the availability of raw materials are among the key drivers of sector-level competitiveness.
- **Country-level competitiveness:** the capacity of countries to compete in international or domestic markets, expand their market opportunities, and help private/industry sectors innovate and create jobs.[94]

Industry resilience: the ability of industry (including manufacturing sectors) and industrial parks to increase competitiveness by minimizing losses and damages, and achieving continuity and growth in the face of ever more frequent and intensifying disasters.

Manufacturing: the making of goods or wares through manual labor or with machinery, especially on a large scale.[95] ***Manufacturing sector*** includes industrial activities related to manufacturing of automobiles, food products and beverages, textiles and apparel, electronic products, electrical machinery, wood products, refined petroleum products, and chemicals and chemical products, etc. The scope of manufacturing sector activities varies by country.[96]

Multi-hazard: the range of hazards that a country faces. It also means the specific contexts in which hazardous events may occur simultaneously, cascadingly, or cumulatively over time, and takes into account potential interrelated effects.[97]

Non-structural measures: in the context of disaster mitigation and preparedness, non-structural measures are those which do not involve physical construction, but which use knowledge, practices or agreements to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education. Common non-structural measures include building codes, land-use planning laws, research and assessment, information resources and public awareness programmes.[98]

On-site infrastructure: infrastructure provided by a developer inside an industrial park. Types of infrastructure may vary but generally include internal roads, utilities (captive power plants, common effluent treatment plants (CETP), sewage treatment plants (STP), and water supply networks, telecommunications, etc.) coastal defense, common facilities such as warehousing, factory buildings, emergency response facilities such as fire stations and disaster/emergency shelters, and so on. On-site infrastructure also includes social infrastructure, childcare facilities and services, medical facilities, schools, and safety and security systems.

Off-site infrastructure: the infrastructure and utilities provided outside an industrial park by government authorities, including public utility, transport, and other infrastructure

94 https://www.worldbank.org/en/topic/competitiveness/overview.

95 http://pubdocs.worldbank.org/en/538321490128452070/Sector-Taxonomy-and-definitions.pdf.

96 The World Bank's definition of the manufacturing sector follows the International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 3, Divisions 15–37.

97 https://www.undrr.org/terminology/hazard.

98 https://www.undrr.org/terminology/structural-and-non-structural-measures.

connections. Off-site industrial infrastructure often provides services to surrounding cities and communities. Ports are often located close to industrial parks, and also considered important off-site infrastructure that services industries.

Risk transfer: the process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.[99]

Small and medium enterprises (SMEs): Definitions of SMEs vary by country. The World Bank Group defines a firm as an SME if it meets two of the following three requirements: (i) has fewer than 300 employees, (ii) has less than US$ 15 million in assets, and (iii) has less than US$ 15 million in annual sales. As some financial institutions are unable to report data based on any of these three criteria, loan size is also used as a proxy. In such cases, a firm is considered an SME if the size of its outstanding loan from a financial institution is less than US$ 1 million.[100]

Structural measures: in the context of disaster mitigation and preparedness, structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Common structural measures for disaster risk reduction include dams, flood levees, ocean wave barriers, earthquake-resistant construction and evacuation shelters.[101]

Supply chain: a network of connected and interdependent firms and business organizations mutually and cooperatively working together to control, manage and improve the flow of products, services, finances, and/or information from suppliers to end customers/users (Sheffi 2005; Christopher 2011; Mentzer et al. 2001). Supply chains include all production activities, functions, and facilities of upstream (firms that are distant from end users) and downstream suppliers (firms that are close to customers and end users), including multinational manufacturing firms and global buyers/retailers.

Value chain: a term coined by Michael Porter (Porter 1985), which refers to the full range of value-adding activities required to bring a product or service through different phases of production, including design, production (e.g. procurement of raw materials and other inputs, assembly, and physical transformation), marketing, distribution (e.g., acquisition of required services such as transport or cooling), and ultimately response to consumer demand (Webber and Labaste 2009).

Vulnerability: “the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.”[102]

99 https://www.undrr.org/terminology/risk-transfer.
100 https://databank.worldbank.org/data/download/g20fidata/G20%20Set%20Methodology.pdf.
101 https://www.undrr.org/terminology/structural-and-non-structural-measures.
102 https://www.undrr.org/terminology/vulnerability.

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RESILIENT INDUSTRIES

Competitiveness in the Face of Disasters