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A Review of Measurement Methods for the Recovery of Businesses After Disasters: An Annotated Bibliography

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Abstract

Business recovery after disasters is a complex process influenced by various factors. By compiling research on business recovery, this work seeks to support researchers and practitioners in identifying research on effective approaches to measuring and promoting business resilience. This bibliography brings together studies on various disaster types, business sectors, and methodologies, demonstrating the complexity of business recovery. The objectives of this work are to: 1) report and summarize academic studies on business recovery after disasters, 2) provide a concise presentation of each study's context and methodology, and 3) highlight the significance of each study's findings to inform future research and practice. The compilation of 39 peer-reviewed studies demonstrates the multifaceted nature of business recovery, revealing that factors such as access to financial resources, business characteristics, and owner demographics play a crucial role in determining recovery outcomes. The studies also emphasize the importance of considering the built environment, lifeline services, and production inputs in understanding business recovery. While the research has made significant contributions, a notable limitation is the lack of validation efforts in many studies, underscoring the need for continued research to develop more robust and validated methods for measuring business recovery. By documenting the various approaches to measuring recovery, this work sheds light on the challenges and opportunities in measuring business recovery and promoting community resilience.

Keywords

Business continuity; Business recovery; Community resilience; Disaster resilience; Disaster risk reduction; Economic recovery; Methodology; Natural hazards; Recovery measurement.

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1. Introduction and Objectives

The resilience of businesses in the face of hazards is a critical component of community resilience, particularly recovery and economic stability [1, 2]. Disasters, whether arising from natural processes, technological failures, human activities, or complex interactions among these factors, can have profound impacts on businesses, disrupting immediate operations and threatening long-term viability. Understanding how to measure business recovery, and recognizing the complex factors that influence it, is critical for designing strategies that effectively support businesses and communities after disasters.

Measuring business recovery after a disaster is a complex task due to the diverse range of circumstances that can affect the recovery process. The type of business, its size, and sector, as well as economic conditions, can all influence the speed and effectiveness of recovery. Additionally, the level of damage to the built environment, such as important business facilities, surrounding infrastructure, and utilities can significantly hinder or enable recovery [3, 4]; so, incorporating infrastructure condition, and business reliance on this infrastructure, into recovery measures is essential for a comprehensive assessment. Furthermore, the type and severity of the disaster itself can also impact the recovery trajectory, with different disasters presenting unique challenges and opportunities for businesses. For instance, a business affected by a hurricane may face different challenges than one affected by a pandemic or earthquake. The interplay between these factors creates a complex landscape that makes it difficult to develop a one-size-fits-all approach to measuring business recovery, highlighting the need for nuanced and context-specific research methodologies. This annotated bibliography draws together academic research involving methods for measuring business recovery after disasters, providing concise yet detailed summaries of each study's methodological approach. By presenting these methods alongside their contexts, the bibliography serves as a comparative tool to help researchers and practitioners identify and select measurement strategies best suited to their specific objectives and circumstances. It also serves as a starting point for future work aimed at improving and refining the methods used to measure business recovery in post-disaster contexts in ways that are comparable and replicable.

The objectives of this annotated bibliography are to:

- Report and summarize studies from the academic literature that include the measurement of recovery at the individual business level after a disaster.
- Provide a concise presentation of each study's context, including its purpose, the type of businesses and disaster examined, the measurement methods' consideration of the built environment, the timeframe assessed, and key methodological aspects, so that researchers and practitioners can use the bibliography as a comparative resource for selecting and improving upon recovery measurement methods.
- Highlight the significance of each study and its findings to provide a context for future method selection.

2. Article Selection

This annotated bibliography focuses on studies from peer-reviewed literature that include measurements of business recovery at the single entity level. Although household and business recovery processes are interdependent—given that households supply labor and demand for businesses, while businesses provide income, goods, and services to households—there remain critical distinctions that warrant separate examination. Treating these domains as analytically distinct, while acknowledging their intersections, facilitates a more precise understanding of the mechanisms that shape community resilience and long-term recovery trajectories.

The nature of peer-reviewed scientific research often leads to the development of novel methods as researchers address limitations in existing approaches or adapt tools to explore questions from new angles [5]. These innovations extend beyond the individual study, providing techniques and perspectives that other researchers can build upon. Peer-reviewed studies are often assessed for validity, reliability, and methodological rigor, helping ensure that results are not only credible but reproducible [6]. Disaster recovery research is generally more applied in nature. Because of this, beginning with an exploration of peer-reviewed studies is particularly valuable, as they are typically more systematic than other forms of measurement inquiry. They provide a stronger foundation for comparison and for guiding future research and the development of more robust measurement methods. An important distinction between peer-reviewed research and other measurement inquiries is that the former typically provides theoretical context that connects methods to the broader body of knowledge in a field. Understanding why a particular approach was chosen, and how it aligns with existing theory, can guide researchers toward more informed and effective methodological choices in their own projects [7].

Academic articles were retrieved through a Web of Science search using the following terms and Boolean operators: “ALL=((household OR business) AND (recovery) AND (disaster OR emergency)).” The search initially returned 1,899 articles. After individually reviewing articles and removing irrelevant results, 315 articles remained that addressed the measurement of either household or business recovery following disasters. Studies focused on household recovery were then excluded, as these will be addressed in a separate bibliography; the present work is limited to business recovery.

The remaining 130 articles were screened against three inclusion criteria:

- The study must directly measure the recovery of a business or businesses.
- Measurement must be conducted at the individual business level (excluding analyses conducted solely at county, sector, regional, or other aggregate levels).
- Business recovery must be measured following a disaster, whether originating from natural or technological hazards.

A total of 39 studies met all criteria and were included in this annotated bibliography.

3. Annotated Bibliography of Business Recovery Studies

This section provides an annotated bibliography of the peer-reviewed papers selected for review. The studies are organized alphabetically by first author. The collection encompasses 14 earthquake studies, 7 hurricane/typhoon studies, 5 flood studies, 3 pandemic studies, 2 tsunami studies, and 1 volcanic eruption study, conducted across different countries in Asia, North America, Oceana, and Europe. The methodologies employed in these studies include 25 studies utilizing surveys, 10 studies conducting interviews, 6 studies incorporating field observations, and 20 studies applying statistical modeling and recovery prediction techniques. While the studies offer valuable insights into the complex processes of business recovery, they are not without limitations. The variability in measurement approaches, lack of validation efforts in some studies, and limited generalizability across different contexts highlight the need for further research to develop and validate more robust methods for assessing business recovery.

Each study in this review is summarized by categorizing information in a way that provides a concise yet comprehensive understanding of its context, methodological approach, and theoretical contributions:

Study Purpose: The objectives or goals of the study

Type of Business: Information on the businesses included, such as sector, industry, or size.

Disaster: A single-word description of the disaster type affecting the businesses (e.g., Hurricane, Earthquake, Flood, Pandemic)

Built Environment: Indicates whether aspects of the built environment[1] were included in the recovery measurement (Yes/No).

Timeframe Measured: The period after the disaster during which business recovery was assessed.

Measurement of Recovery: The specific approach or metric used to evaluate business recovery.

Methodology: The research methods and procedures employed in the study.

Validation: The steps taken to verify or validate the measurement approach or model.

Significance: The study's relevance to disaster recovery measurement and research and the key theoretical contributions asserted by the study.

1. Aghababaei M, Koliou M, Watson M, Xiao Y (2021) Quantifying post-disaster business recovery through Bayesian methods. *STRUCTURE AND INFRASTRUCTURE ENGINEERING* 17(6):838–856. https://doi.org/10.1080/15732479.2020.1777569

[1] The built environment is defined as: "All buildings and infrastructure systems. Also referred to as built capital." [8]

Study Purpose: The study aims to develop a probabilistic modeling approach to quantify and predict business recovery after a disaster using Bayesian linear regression.

Type of Business: Construction, manufacturing, and retail sectors, as well as other types of businesses.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: Approximately 13 months after the hurricane. Single data collection in January 2018.

Measurement of Recovery: The study measures business recovery through four attributes:

- **Cease operation days** - the number of days a business was out of operation after the disaster.
- **Revenue recovery** - the change in business revenue compared to its pre-disaster status, measured on a Likert scale from 1 to 5.
- **Customer retention** - the percentage of customers retained compared to pre-disaster conditions.
- **Employee retention** - the ratio of employees retained compared to pre-disaster numbers.

Methodology:

- Use of data from a survey of 164 businesses from a separate study [9]. The survey asked questions about damage and utility interruption, recovery status, business characteristics, owner and manager characteristics, and financial assistance.
- The study employs a Bayesian linear regression modeling approach to develop predictive models for the four business recovery attributes.

Validation: Cross-validation – Comparison of predicted recovery outcomes from the model to actual recovery outcomes from the survey.

Significance: This study adds to the overall measurement of business recovery by providing a probabilistic modeling framework that can be used to predict business recovery trajectories after disasters. The study considers the interplay between household and business recovery, particularly through the customer retention attribute.

2. Asgary A, Anjum M, Azimi N (2012) Disaster recovery and business continuity after the 2010 flood in Pakistan: Case of small businesses. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 2:46–56. https://doi.org/10.1016/j.ijdrr.2012.08.001

Study Purpose: The purpose of this study is to explore the impacts of the 2010 flood in Pakistan on small businesses and the factors that influenced their disaster recovery and business continuity.

Type of Business: Trade and services, manufacturing, and personal and social services sectors, as well as others such as real estate, transport, and financial services.

Disaster: Flood

Built Environment: Yes

Timeframe Measured: Up to 6 months after the flood. Single data collection between February and March 2011.

Measurement of Recovery: The study measures recovery through various indicators:

- **Re-opening status** - percentage of businesses that re-opened after the flood.
- **Time to re-open** - The length of time taken by businesses to re-open after the flood.
- **Current economic performance**: The study compared the current economic performance of businesses with their pre-flood performance, categorizing them as "better off," "same," or "worse off," based on their self-reported sales and profits.
- Role of various factors in recovery such as access to financial resources, customer retention, availability of human resources, and restoration of critical infrastructure in facilitating business recovery.

Methodology:

- Survey of 500 small businesses impacted by the flood. The survey was designed to gather information on business characteristics, disaster preparedness, flood impacts, and recovery processes.

Validation: Pilot Study.

Significance: This study adds to the overall measurement of business recovery by providing insights into the recovery processes of small businesses in a developing country context, where formal institutional support for post-disaster recovery may be limited. It highlights the importance of factors such as access to financial resources, personal savings, and support from family and friends in facilitating business recovery.

3. Brown C, Seville E, Hatton T, Stevenson J, Smith N, Vargo J (2019) Accounting for Business Adaptations in Economic Disruption Models. *JOURNAL OF INFRASTRUCTURE SYSTEMS* 25(1). https://doi.org/10.1061/(ASCE)IS.1943-555X.0000470

Study Purpose: The study aims to develop an empirically derived business behaviors model (BBM) that can be applied to economic models to improve the estimation of economic impacts of infrastructure disruptions. The BBM is designed to account for business adaptations and recovery trajectories following disasters.

Type of Business: Organizations across various industry sectors, including but not limited to healthcare, manufacturing, retail, and finance.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 2.5 years after the earthquakes. Single data collection between July and December 2013.

Measurement of Recovery:

- **Operability** - defined as the ability of businesses to meet demand. Operability is assessed at different time points following the earthquakes using a scale that categorizes businesses as *completely* (80 % to 100 %), *mostly* (60 % to 80 %), *partially* (40 % to 60 %), *limited* (20 % to 40 %), or *unable* (0 % to 20 %) to meet demand.

Methodology:

- Survey of 541 organizations after the February 2011 earthquakes in Canterbury, New Zealand. The survey asked questions about organization demographics (size, sector, ownership structure), impact measures (infrastructure and non-infrastructure disruptions), pre-event mitigation measures, post-event business changes and adaptations, and financial information.
- Factor analysis was used to group disruption types into meaningful categories. Regression analysis was employed to develop infrastructure disruption functions for each industry sector, relating the duration of infrastructure disruption to the level of disruption experienced. Stepwise linear regression was used to identify predictors of operability.

Validation:

- None described for survey.
- "Qualitatively tested for applicability to other infrastructure disruptions" – No details provided.

Significance: This study contributes to the overall measurement of business recovery by providing a model that accounts for the dynamic nature of business recovery following infrastructure disruptions. The BBM offers a nuanced understanding of how different industry sectors recover over time, influenced by factors such as overall disruption and suppliers' ability to meet demand.

4. Costa R, Baker J (2021) Smote-Lasso Model of Business Recovery over Time: Case Study of the 2011 Tohoku Earthquake. *NATURAL HAZARDS REVIEW* 22(4). https://doi.org/10.1061/(ASCE)NH.1527-6996.0000493

Study Purpose: The study aims to introduce a methodology to identify business characteristics correlated with recovery within selected time windows after a disaster, addressing challenges of imbalanced data and collinear predictors.

Type of Business: Manufacturing, construction, contracting, services, wholesale, retail, finance, insurance, and real estate sectors.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 180 days after the earthquake. Single data collection between October 2011 and February 2012.

Measurement of Recovery:

- **Time to recovery** - time needed for businesses to regain their pre-disaster operation levels, with possible recovery times being 0, 7, 14, 30, 90, 180, and more than 180 days.
- Correlations between recovery status and business characteristics, physical damage, utility disruptions, preparedness, and recovery financing.

Methodology:

- Survey of 930 businesses. The survey asked questions about physical damage, utility disruptions, business characteristics, disaster preparedness, recovery financing, and recovery time.
- Correlations with recovery status were calculated using novel statistical techniques (Smote-Lasso) to handle imbalanced data and collinear predictors.

Validation:

- Cross-validation – Comparison of predicted recovery times from the model to actual recovery times.
- The survey was developed externally, and no documentation is provided about survey validation efforts.

Significance: This study adds to the overall measurement of business recovery by introducing a methodology that can handle imbalanced data and identify significant predictors of recovery. It highlights the importance of considering different time windows when analyzing business recovery and demonstrates that factors such as physical damage, utility disruptions, industry sector, and disaster preparedness are correlated with recovery.

5. Craig H, Wilson T, Stewart C, Villarosa G, Outes V, Cronin S, Jenkins S (2016) Agricultural impact assessment and management after three widespread tephra falls in Patagonia, South America. NATURAL HAZARDS 82(2):1167–1229. https://doi.org/10.1007/s11069-016-2240-1

Study Purpose: The study aims to evaluate the impacts of tephra falls on agricultural systems and assess the effectiveness of response and recovery strategies after three significant volcanic eruptions in Patagonia, South America.

Type of Business: Pastoral farms (cattle and sheep farming) and horticultural farms (fruit and vegetable production).

Disaster: Volcanic Eruptions

Built Environment: Yes

Timeframe Measured:

- 1991 Hudson eruption – 16 years after the event. Single data collection.
- 2008 Chaitén eruption – 9 months and 3 years after the event. Multiple data collections.
- 2011 Cordón Caulle eruption – 9 months after the event. Single data collection.

Measurement of Recovery:

- **Performance-based damage state scale** - categorizes the impacts and recovery of farms:
    - Pastoral farms - the scale considers factors such as pasture availability, animal condition, and the need for supplementary feed. The scale ranges from DPS0 (no disruption) to DPS4 (total loss of capabilities), with intermediate states reflecting varying levels of disruption and impact.
    - Horticultural farms - the scale assesses production losses, damage to crops, and the need for mitigation measures. The scale also ranges from DPS0 to DPS4, with a focus on the specific challenges faced by horticultural farmers, such as damage to crops and infrastructure.

Methodology: The study employs a mixed-methods approach:

- Field observations: The research team conducted field visits to areas affected by the three tephra fall events, observing the impacts on farms and gathering data on tephra thickness, grain size, and other relevant factors.
- Interviews with farmers and agricultural agencies: Semi-structured interviews were conducted with farmers and production managers to gather information on the impacts of tephra fall and the recovery strategies employed.
- Development of the damage/production state scale: Using the data collected from literature review, field observations, and interviews, the researchers developed a damage/production state scale that categorizes the impacts and recovery of farms into five states (DPS0 to DPS4). The scale is based on theoretical steps in damage, impacts, and production losses observed in previous studies and the specific experiences of farmers in the Patagonia region.

Validation:

- Cross-validation – Comparison of the assigned damage/production state values with actual production changes (horticultural) and animal deaths (pastural) reported by farmers.
- None described for semi-structured interviews.

Significance: This study contributes to the understanding of business recovery after disasters by providing insights into the impacts of tephra falls on agricultural systems and the effectiveness of response and recovery strategies. The development of a performance-based damage state

scale offers a tool for assessing and comparing the impacts of tephra falls on farms. The study's findings on the importance of vulnerability characteristics, such as climate, farm type, and access to 'improvement' assets, can inform pre-event mitigation and preparedness efforts, ultimately enhancing the resilience of agricultural businesses to tephra fall hazards.

6. Dahlhamer J, Tierney K (1998) Rebounding from disruptive events: Business recovery following the Northridge earthquake. SOCIOLOGICAL SPECTRUM 18(2):121–141. https://doi.org/10.1080/02732173.1998.9982189

Study Purpose: The purpose of this study is to explore the determinants of business recovery following the 1994 Northridge earthquake. The authors develop and test a model that predicts business recovery based on various factors.

Type of Business: Firms from various sectors such as wholesale and retail, manufacturing, construction, and contracting, business and professional services, and finance, insurance, and real estate. The sample includes both small (fewer than 20 employees) and large (20 or more employees) firms.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 18 months after the earthquake. Single data collection in May 1995.

Measurement of Recovery:

- **Self-reported recovery status** - categorized as either "recovered" or "not recovered." Businesses that reported being "better off than before the earthquake" or "about the same as before the earthquake" were considered recovered, while those that were "worse off" were classified as not recovered.

Methodology:

- Survey of 1,110 businesses. The survey asked questions about business characteristics, disaster impacts, loss containment measures, previous disaster experience, and recovery status.
- Logistic regression techniques were used to analyze the data, testing a model that included various predictors of business recovery, gathered from survey data.

Validation:

- None described for survey.
- Cross-validation – Comparison of model predictions of recovery outcomes to actual self-reported recovery outcomes.

Significance: This study contributes to the overall measurement of business recovery by suggesting key factors that influence the ability of businesses to recover from disasters. The findings highlight the importance of business size, disruption of operations, and earthquake shaking intensity in predicting recovery outcomes. The study also underscores the complex

relationship between the use of post-disaster aid and business recovery, suggesting that aid may not always lead to better recovery outcomes due to factors like increased indebtedness.

7. de Vries H, Hamilton R (2021) Smaller businesses and the Christchurch earthquakes: A longitudinal study of individual and organizational resilience. INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION 56. https://doi.org/10.1016/j.ijdrr.2021.102125.

Study Purpose: The study aims to explore the nature of small businesses' resilience following the Christchurch earthquakes, examining the interplay between individual and organizational resilience and its influence on recovery outcomes.

Type of Business: Small businesses (fewer than 100 employees): Retail, wholesale, and service sectors, including manufacturing, construction, food manufacturing/retail, advertising services, and hospitality.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 7 years after the earthquake. Multiple data collections every (12 to 18) months from 2012 to 2018.

Measurement of Recovery:

- **Annual sales data** – ranging from 2010 to 2016 to track the financial recovery of the businesses.
- **Recovery outcomes** – businesses were categorized into three groups based on their recovery outcomes – detailed in semi-structured interviews:
    - "Fast recoverers" – businesses that demonstrated strong recovery, with sales increasing significantly post-earthquake.
    - "Survivors" – businesses that managed to stay afloat but with more modest growth.
    - "Exiters" – businesses that eventually closed or were sold.

Methodology:

- Semi-structured interviews with 52 business owners at regular intervals (every 12 months to 18 months) from 2012 to 2018. The interviews were structured around six analytical questions that explored the consequences of and responses to the earthquakes, the restart of business operations, reasons for staying in business, events and changes that occurred in the ensuing years, the lingering impact of the earthquakes, and the current status of the businesses.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by providing a nuanced understanding of the complex interplay between individual and organizational resilience in the face of a major disaster. The longitudinal design allows for a detailed

examination of the recovery processes and outcomes over an extended period, offering insights into the factors that influence business survival and recovery. The study's findings suggest the importance of business model resilience and adaptability in post-disaster recovery, suggesting that individual resilience is necessary but not sufficient for business recovery.

8. Endendijk T, Botzen W, de Moel H, Slager K, Kok M, Aerts J (2024) Enhancing resilience: Understanding the impact of flood hazard and vulnerability on business interruption and losses. *WATER RESOURCES AND ECONOMICS* 46. https://doi.org/10.1016/j.wre.2024.100244.

Study Purpose: The study aims to understand the impact of flood hazard and vulnerability on business interruption duration and losses using firm-level survey data from the 2021 flood event in the Netherlands.

Type of Business: Various types of businesses, including those in the hospitality, manufacturing, retail, public, health, and service sectors.

Disaster: Flood

Built Environment: Yes

Timeframe Measured: (6 to 8) months after the flood. Multiple data collections in December 2021 (6 months), February 2022 (8 months), and an unspecified time after February 2022.

Measurement of Recovery: The study measures recovery through two main indicators:

- **Business interruption** – measured in duration (days).
- **Revenue loss ratio** – revenue losses relative to the firm's 2019 annual revenue.
- The role of various factors, including flood hazard characteristics (inundation depth, flow velocity, contamination, and access difficulty), firm characteristics (number of employees, sector, and building age), and flood damage mitigation (FDM) measures, in influencing business interruption duration and revenue losses.

Methodology:

- Survey of 215 businesses in the flooded area distributed in three waves of data collection. The survey asked businesses about business characteristics, flood impacts, flood characteristics, flood damage mitigation measures, and insurance and compensation.
- Multivariate regression analysis to examine the relationship between flood hazard characteristics, firm characteristics, and business interruption duration and revenue losses. The study also applied propensity score matching (PSM) to assess the impact of FDM measures on business interruption duration.

Validation: None described.

Significance: The study adds to the overall measurement of business recovery by examining the relationship between flood hazard characteristics and business interruption duration, which can

be used to calibrate flood damage models that capture indirect firm impacts. The findings also suggest the importance of quick damage compensation in reducing business interruption duration and revenue losses. Furthermore, the study emphasizes the role of a firm's connection to its region in determining the impact of business interruption on revenue losses, suggesting that firms with weaker regional connections are more vulnerable to revenue losses during business interruption.

9. Helgeson J, Lin B (2025) Adaptive resilience of Asian American, Native Hawaiian and Pacific Islander businesses in the face of COVID-19 and complex events. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 116. https://doi.org/10.1016/j.ijdrr.2024.105118.

Study Purpose: The study aims to understand the impacts of complex events, including the COVID-19 pandemic and concurrent disasters, on small and medium-sized businesses (SMBs) operated by members of the Asian American, Native Hawaiian, and Pacific Islander (AANHPI) community.

Type of Business: Small and medium-sized businesses (SMBs), with a particular emphasis on those owned or operated by individuals identifying as AANHPI.

Disaster: Hurricane, Wildfire, Pandemic

Built Environment: No

Timeframe Measured: Single data collection (survey and follow-up interviews) between July and October 2022.

- 2 years after the start of the pandemic.
- Approximately 1 year after wildfires.
- Approximately 1 year after the hurricane.

Measurement of Recovery: The study measures recovery through a combination of quantitative and qualitative methods:

- **Perceived time to full recovery from COVID-19** – Survey respondents were asked to report their perceived time to full recovery from the impacts of COVID-19, with options ranging from "already fully recovered" to "unlikely to resume to pre-COVID level or at all."
- **Adaptive strategies and resilience** – Follow-up interviews provided qualitative data on the specific challenges faced by AANHPI-operated SMBs, the adaptive strategies they employed to mitigate damage, and their plans for future disaster preparedness.

Methodology: The study employed a mixed-methods approach:

- Online surveys conducted with 31 SMB operators, the surveys collected data on business characteristics, the impacts of COVID-19 and natural hazards, forms of support received, and future plans and concerns.

- Follow-up interviews conducted with 28 survey respondents (and an additional 6 non-survey respondents). The interviews explored topics such as supply chain disruptions, employee retention, and the role of community support in recovery.

Validation: None described.

Significance: The study emphasizes the importance of considering socioeconomic stressors and demographic factors in understanding business recovery. The findings suggest that AANHPI-operated SMBs faced persistent stressors, such as unspoken discrimination and barriers to industry entry, which may have influenced their resilience during the pandemic and natural hazards. By examining the compound impacts of COVID-19 and natural hazards, the research contributes to a more comprehensive understanding of how businesses respond to and recover from multiple, concurrent disruptions.

10. Himaz R (2022) Business recovery in Aceh and North Sumatra following the Indian Ocean Tsunami. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 73. https://doi.org/10.1016/j.ijdrr.2022.102868.

Study Purpose: The study investigates the impact of the 2004 Indian Ocean tsunami on household business assets and business continuity in Aceh and North Sumatra, Indonesia, with a focus on understanding the factors influencing business recovery in the medium term.

Type of Business: Various types of businesses, including rice farming, other farming, and non-farm businesses.

Disaster: Tsunami

Built Environment: Yes

Timeframe Measured: Approximately 2 Years after the tsunami. Multiple data collections in May 2005 to February 2006 (5 months to 14 months after the tsunami), and May 2006 to May 2007 (17 months to 29 months after the tsunami).

Measurement of Recovery:

- **Business continuity** – the probability of households discontinuing businesses two years after the tsunami.
- **Asset accumulation** – changes in business asset stocks between pre-tsunami levels and two years after the event.
- **Business diversity** – a business diversity index to capture the extent to which households engage in multiple business activities.

Methodology:

- Survey of heads of 2879 household businesses, collected in two waves: (5 to 14) months and (17 to 29) months after the tsunami. The survey collected data on income and consumption patterns, business characteristics, health and education, tsunami impact, and aid and assistance received.

Validation:

- Pilot study
- The use of standardized modules of survey questions from other surveys.

Significance: The study adds to the overall measurement of business recovery by examining the impact of a large-scale disaster on household business assets and business continuity in the short and medium terms. The study's findings suggest that businesses in heavy damage areas were more likely to discontinue, and that asset recovery patterns played a crucial role in business continuity. The findings suggest the importance of business asset growth, infrastructure rebuilding efforts, and the role of aid, livelihood interventions, and financial support networks in supporting household business recovery. The study also underscores the need for different approaches to recovery for larger businesses compared to micro and small-scale enterprises.

11. Hsu C, Liu C, Stearns L, Brody S, Mostafavi A (2025) Spillover effects of built-environment vulnerability on resilience of businesses in urban crises. *SUSTAINABLE CITIES AND SOCIETY* 127. https://doi.org/10.1016/j.scs.2025.106376.

Study Purpose: The study aims to investigate the spillover effects of residential built-environment vulnerability on the resilience of businesses in urban crises, with a focus on understanding how damage to residential properties affects the recovery trajectories of nearby businesses.

Type of Business: Essential businesses, including grocery stores, gasoline stations, physicians' offices, and health and personal care stores.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: 2 weeks before and 9 weeks after the hurricane. Continuous data collection of an 11-week observation period between August and October 2017.

Measurement of Recovery:

- **Human mobility data** – weekly visitation patterns to points of interest (POIs), as a proxy for business activity. The measurement involves several steps: (1) establishing a baseline visitation level for each POI using data from two weeks before the hurricane's preparation phase; (2) comparing post-disaster weekly visitations to this baseline to assess recovery progress; and (3) determining a recovery threshold, where a business is considered recovered when its visitations reach at least 85 % of the baseline level, with subsequent weeks not deviating more than ±5 % from this threshold. Businesses not meeting this threshold within the 11-week observation period are classified as "did not recover."

Methodology: The study integrates multiple data sources and employs a comprehensive analytical framework:

- Utilizing location-based mobility data to track weekly visitations to POIs, which are associated with specific business types.
- Assessing property damage using existing records.
- Calculating a distance-weighted property damage metric within a 2-mile radius of each business to quantify the extent of surrounding property damage.
- Analyzing the relationship between this damage metric and business recovery duration across different business types and socio-demographic contexts.

Validation: None described.

Significance: The study adds to the overall measurement of business recovery by suggesting the sensitivity of different business types to surrounding property damage. It suggests that businesses like physicians' offices are highly sensitive to residential flood damage, while others, such as gasoline stations, are less so. Moreover, the study underscores the amplified sensitivity of businesses located in low-income areas, indicating a negative feedback loop that hinders community recovery. By exploring the relationship between built-environment vulnerability and business resilience, this study provides insights emphasizing the need for targeted interventions that support vulnerable businesses and neighborhoods.

12. Huang L, Wang L, Song J (2018) Post-Disaster Business Recovery and Sustainable Development: A Study of 2008 Wenchuan Earthquake. *SUSTAINABILITY* 10(3). https://doi.org/10.3390/su10030651.

Study Purpose: The purpose of this study is to investigate the recovery of small businesses after the 2008 Wenchuan earthquake in China, with a focus on sustainable development.

Type of Business: Small businesses: Specialty stores (e.g., local products like embroidery and wine), catering services, garment stores, and others.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 4 years after the earthquake. Multiple data collections once a year in July 2014, July 2015, August 2016, and August 2017.

Measurement of Recovery: Three indicators were used to categorize businesses into five levels of recovery and sustainable development: not good, not very good, good, relatively good, and very good:

- **The operating rate** – measures the proportion of businesses that are operational at a given time.
- **The sustainable operating rate** – measures the proportion of businesses that remain operational over a certain period.
- The rate of sustainable operating numbers in 2017 relative to the number in 2014.

Methodology: The study employed a mixed-methods approach to collect data on 538 businesses:

- Field observations: The research team conducted four trips between 2014 and 2017, recording the operational status of all 538 stores and collecting basic geographical characteristics, such as sample ID, section area, location, shop name, administrative and business features, and survey time.
- Repeat photography: The team took photos of the businesses during each trip, collecting a total of 2195 photos over the four-year period. The photos were coded for analysis, providing visual evidence for a temporal analysis.
- Semi-structured interviews: The authors conducted semi-structured interviews with business owners and citizens, covering topics such as business operating history and status, owner characteristics, and the impact of the tourism industry on their business.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by providing a longitudinal analysis of small business recovery after a major earthquake. It suggests the importance of considering the specific context and needs of local businesses in post-disaster reconstruction planning. The findings suggest that top-down planning without sufficient public participation can lead to unsustainable business development, and that a stable local customer base is crucial for business recovery.

13. Katare B, Marshall M, Valdivia C (2021) Bend or break? Small business survival and strategies during the COVID-19 shock. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 61. https://doi.org/10.1016/j.ijdrr.2021.102332.

Study Purpose: The study investigates how small businesses in the United States were affected by the COVID-19 pandemic. It examines the impact of the pandemic on small business resilience and the adjustment strategies used by small businesses to survive.

Type of Business: Small businesses defined as non-employer businesses and those with less than 100 employees: A variety of sectors such as service, manufacturing, and construction, with a significant proportion being direct-to-consumer businesses.

Disaster: Pandemic

Built Environment: No

Timeframe Measured: Approximately 3 months after the start of the pandemic. Single data collection between June and July 2020.

Measurement of Recovery:

- **Estimated time to recovery** – business owners were asked to estimate the time it would take for their sales/revenue to return to pre-pandemic levels. This measure provides insight into the expected duration of the recovery process.

- **Estimated income loss** – the percentage of business income lost due to the pandemic was estimated by business owners. This measure quantifies the financial impact of the pandemic on small businesses.
- **Business resilience** – a resilience scale was constructed using three items that asked business owners to rate their business's future success, growth, and profitability as compared to pre-pandemic levels. The scale ranges from 0 (worse off) to 2 (better off), with higher values indicating greater resilience.

Methodology:

- Survey of 463 small business owners across the United States. The survey collected detailed information on: business characteristics, such as number of employees, sector, and whether the business was family-owned or operated from home; financial well-being, including business revenue and profit before and during the pandemic; current responses to the crisis, such as changes in business operations (e.g., shifting to online sales, changing supply procurement, or increasing social media presence); beliefs about future business survival and success; and demographic information about business owners.
- Linear probability models to examine the predictors of business losses (income loss and time to recovery) and the impact of adjustment strategies on business outcomes.

Validation: Use of established constructs and pre-existing questions in the survey.

Significance: The study adds to the overall measurement of business recovery by providing insights into the impact of a global health crisis on small businesses. It suggests the importance of business model changes, digital presence, and access to financial assistance in enhancing business resilience during crises. The study's focus on non-employer businesses, which are often overlooked, also contributes to a more comprehensive understanding of small business recovery.

14. Khamisabadi M, Ghafoury-Ashtiany M, Motamed H (2025) A probabilistic approach for modeling the empirical economic loss impacts of data surveys on small and medium-sized enterprises; A case study of the November 2016 Sarpol-e Zahab earthquake. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 116. https://doi.org/10.1016/j.ijdrr.2024.105002.

Study Purpose: The study aims to identify and categorize the loss impacts on small and medium-sized enterprises (SMEs) after a severe earthquake and to develop an empirical economic impact model (EIM) using real surveyed time-dependent business interruption loss data.

Type of Business: SMEs across various industrial sectors, including construction-related businesses and non-construction sectors such as chemical products and food industries.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 2 years after the earthquake. Multiple data collections occurring once a month from November 2017 to November 2019.

Measurement of Recovery: Recovery is measured through several detailed metrics:

- **Mean Sale Ratio (MSR)** – the ratio of mean sales after the earthquake to mean sales before the earthquake, calculated for each time step (monthly) over the 24-month recovery period.
- **Downtime** – measure of the cumulative loss of sales/profits over time, normalized to allow comparison across businesses of different sizes.
- **Restoration Curve** - represents the probability of full economic performance for the businesses after the earthquake, derived from the downtime values. It illustrates the likelihood of businesses returning to their pre-earthquake functionality levels at different earthquake intensities.
- **Recovery Rate** – indicates an estimate for how quickly businesses are recovering over time, with a decreasing recovery rate indicating progress towards full recovery.

Methodology:

- Time-Interval Questionnaire (TIQ): A specially designed questionnaire to collect detailed data on Direct Loss (DL) and Business Interruption Loss (BIL) monthly over a 24-month period post-earthquake. The TIQ captures various aspects, including structure type, physical damage, repair costs, and monthly sales data, allowing for a thorough analysis of the economic impacts.

Validation:

- None described for survey.
- Cross-validation – Comparison of Direct Loss (DL) estimates with actual data collected from the survey.

Significance: The study contributes to the overall measurement of business recovery by introducing and utilizing several metrics to quantify recovery, including Mean Sale Ratio, downtime, restoration curves, and recovery rates. These metrics capture both the extent of business interruption and the rate of recovery over time. The study also suggests that the type of structure (e.g., Moderate Code vs. Low Code structures) and the business activity sector (Construction Sector vs. Non-Construction Sector) significantly influence the recovery process of SMEs: Businesses with Moderate Code structures and those in the Construction Sector tend to recover faster and more effectively.

15. Kim S, Chandrasekhar D (2024) The impact of social networks of historically underrepresented group operators (HUGOs) business recovery. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 108. https://doi.org/10.1016/j.ijdrr.2024.104540.

Study Purpose: The study aims to investigate the role of social networks in the recovery of Historically Underrepresented Group Operators (HUGOs) businesses after disasters, with a focus on accessing financial aid and information.

Type of Business: Small businesses, particularly those owned by historically underrepresented groups such as women, racial minorities, and veterans, across various industries.

Disaster: Pandemic

Built Environment: No

Timeframe Measured: (1.5 to 2) years after the start of the pandemic. Single data collection between December 2021 and March 2022.

Measurement of Recovery:

- **Self-reported recovery status** – business owners' perceptions categorizing businesses as either "Recovered" or "Not Recovered." The original survey question about recovery perception was framed as a 5-point Likert scale question ranging from "Fully recovered" to "In survival mode." This data was then processed into a nominal variable, with the "Recovered" category only including "fully recovered" respondents and the "Not Recovered" category including all other recovery statuses.

Methodology:

- Survey of 200 businesses. The survey questionnaire addressed various aspects of business operations, recovery actions, financing sources, interactions with recovery resources, and future disaster preparedness.
- Logistic regression analysis was used to examine the impact of different types of social networks (bonding, bridging, and linking) on business recovery perceptions, controlling for various business characteristics and disaster impacts.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by suggesting the importance of social networks, particularly linking networks, in facilitating the recovery of HUGO businesses. The findings suggest that while bonding and bridging networks may not be as effective, linking networks (ties with institutional actors such as government agencies and financial institutions) are crucial for HUGO business recovery.

16. Kuwata Y, Takada S (2010) Business Restoration Related to Lifeline After Tsunami Disaster. *JOURNAL OF EARTHQUAKE AND TSUNAMI* 4(2):73–81. https://doi.org/10.1142/S1793431110000789.

Study Purpose: The study aims to evaluate the functionality of businesses the 2004 Indian Ocean tsunami that affected southern Sri Lanka, focusing on the impact of lifeline services on business restoration.

Type of Business: Various industries such as fishery, manufacture (including construction and others), wholesale and retail trade, financial services, and tourism (including hotels and non-hotels).

Disaster: Tsunami

Built Environment: Yes

Timeframe Measured: 9 months after the tsunami. Single data collection in September 2005.

Measurement of Recovery:

- **Restoration ratio of businesses** – the percentage of functionality restored over time after a tsunami disaster.
- **Damage States** – classified facilities into five discrete categories, ranging from A (no damage) to E (severe damage).
- Assessment of the restoration processes of business facilities (buildings and equipment) and lifeline services (water supply, electric power, and telephone).

Methodology:

- Interview survey of company owners and relevant individuals. The survey gathered data on tsunami inundation heights, damages to buildings and equipment, damages to lifeline services and restoration times in days, and business restoration processes with respect to time since the tsunami.
- Development of business restoration model, which considers the damage estimation of business bases, restoration ratio-to-time models for business bases, and the functionality of businesses introduced by facility restoration and its influence on business operations.

Validation: None described.

Significance: The study adds to the overall measurement of business recovery by suggesting the importance of both business facilities and lifeline services in the restoration process. The study estimates importance factors for lifeline systems (i.e., water supply, electric power, and telephone service), all of which were generally high, especially when business facilities and multiple lifelines were disrupted simultaneously. The findings also suggest that business restoration depends more heavily on business facilities than lifeline restoration when tsunami inundation is higher than 1m.

17. Lam N, Arenas H, Pace K, LeSage J, Campanella R (2012) Predictors of Business Return in New Orleans after Hurricane Katrina. *PLOS ONE* 7(10). https://doi.org/10.1371/journal.pone.0047935.

Study Purpose: The purpose of this study is to identify significant predictors of business reopening and their changing dynamics after Hurricane Katrina in New Orleans.

Type of Business: The study includes a wide range of businesses, with data derived from the Louisiana Department of Labor Micro File for Economic Development, which contains information on approximately 11,000 businesses across various industries, as classified by the North American Industry Classification System (NAICS) codes.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: 26 months after the Hurricane. Multiple data collections in December 2005, June 2006, and October 2007.

Measurement of Recovery:

- **Operating status** – business owners were asked if their business closed following Hurricane Katrina and, if so, how long it remained closed.

Methodology:

- Survey of 1 400 business owners. The survey was asked during three different time periods leading up to 26 months after the hurricane. The survey included questions about the businesses' experiences and responses to Hurricane Katrina, as well as their opening statuses.
- Probit regression analysis to model the probability of a business being open or closed given a set of explanatory variables, including business size (measured by total wages in a logarithmic form), flood depth at the business location, neighborhood characteristics (such as population density, percent non-white population, and median household income), and a spatial spillover variable. The spatial spillover effect was calculated using an inverse distance-weighting method based on the opening statuses of neighboring businesses within a 1-km threshold.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by suggesting the importance of factors such as flood depth, business size, and spatial interdependence among businesses. The findings underscore the need for flood protection measures and targeted support for small businesses in the aftermath of a disaster. The study's incorporation of spatial analysis and examination of the temporal dynamics of business reopening provide insights into the complex process of business recovery.

18. Lee J (2019) Business recovery from Hurricane Harvey. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 34:305–315. https://doi.org/10.1016/j.ijdrr.2018.12.004.

Study Purpose: The purpose of this study is to examine the factors that affected the progress of post-disaster business recovery in Aransas County, Texas, after Hurricane Harvey made landfall in August 2017.

Type of Business: Small businesses in various industries, including retail trade, accommodation and food services, construction, and real estate, finance, and insurance.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: 6 months to 1 year after the Hurricane. Multiple data collections including a single survey in January 2018, and continuous field data collection from November 2017 to August 2018.

Measurement of Recovery:

- **Operating status** – whether the business was open or closed at six months and one year after Hurricane Harvey, using a combination of survey data and field data.

Methodology: The study employed a mixed-methods approach, combining:

- Survey of 152 businesses to gather information on business demographics, damage, financing sources, and operating status.
- Field data on business reopening rates.
- Property damage data formed by the differences in appraised values before and after the hurricane.
- Probit maximum likelihood estimation to analyze the binary response data, specifically the probability of businesses being open at six months and one year after Hurricane Harvey.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery as it suggests some of the complex factors that may influence business recovery after a disaster and underscores the need to consider multiple variables when assessing recovery outcomes. The findings suggest the significance of property damage, business characteristics, and owner demographics in determining business recovery outcomes, and the importance of social networks, such as local chamber membership, in facilitating recovery.

19. LeSage J, Pace R, Lam N, Campanella R, Liu X (2011) New Orleans business recovery in the aftermath of Hurricane Katrina. *JOURNAL OF THE ROYAL STATISTICAL SOCIETY SERIES A-STATISTICS IN SOCIETY* 174:1007–1027. https://doi.org/10.1111/j.1467-985X.2011.00712.x.

Study Purpose: The study aims to analyze the decisions of business establishments to reopen in the aftermath of Hurricane Katrina, focusing on the role of spatial dependence in their decisions.

Type of Business: Various types of businesses (retail, wholesale, services, etc.) visible from the street on three major commercial corridors.

Disaster: Hurricane

Built Environment: No

Timeframe Measured: (0 to 3) months, (0 to 6) months, and (0 to 12) months after the hurricane. Multiple data collections occurring weekly from October 2005 to August 2006.

Measurement of Recovery:

- **Operating status** – firms' status was recorded as "still closed", "open", "partially open", "new", or "moved."
- Additional data from the Census Bureau, Federal Emergency Management Agency, State of Louisiana, and Army Corps of Engineers were used to record the median household income of the surrounding neighborhood, the area's topographic elevation, and depths of flood after Hurricane Katrina.

Methodology:

- 673 businesses were visually surveyed by bicycle weekly for one year. Follow-up phone calls or local inquiries were made when business status proved difficult to discern visually.
- Spatial auto-regressive (SAR) probit model to analyze the reopening decisions of businesses. This methodology allows for interdependence between firms' decisions, capturing the spatial dependence in their reopening choices.

Validation: None described.

Significance: This study contributes to the overall measurement of business recovery by suggesting the importance of spatial interdependence in firms' decisions to reopen after a disaster. The findings suggest that factors such as flood depth, median household income, firm size, socio-economic status of customers, and type of ownership influenced the probability of businesses reopening. The study's use of a spatial probit model provides a nuanced understanding of how businesses are interconnected in their recovery processes.

20. Li F, Hong J (2019) A spatial correlation analysis of business operating status after an earthquake: A case study from Lushan, China. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 36. https://doi.org/10.1016/j.ijdrr.2019.101108.

Study Purpose: The study aims to explore the spatial correlation of business operating status after the 2013 Lushan earthquake in China and its variability over time.

Type of Business: Small retail businesses.

Disaster: Earthquake

Built Environment: No

Timeframe Measured: 4 years after the earthquake. Multiple data collections from July 2013 to July 2017, occurring at 3 months, 1 year, 2 years, 3 years, and 4 years after the earthquake.

Measurement of Recovery:

- **Operating status** – categorized into three statuses: open (businesses that were open before the disaster and remained open during the observation period), newly opened

(new businesses that opened during the observation period), and closed (businesses that were open before the disaster but closed during the observation period).

Methodology:

- Onsight observations, and local inquiries, when necessary, of 951 businesses annually.
- Spatial correlation of business operating status: Firstly, they tested for the presence of spatial autocorrelation in business operating status across the study area. Secondly, they applied a spatial Tobit model to examine the significance and intensity of the spatial correlation business operating status. The authors also used LISA (Local Indicators of Spatial Association) cluster maps to identify local patterns of spatial correlation and to visualize the distribution of business operating status across different street regions.

Validation: None described.

Significance: This study contributes to the overall measurement of business recovery by suggesting the importance of spatial correlation. The findings suggest that the operating status of businesses exhibits a significant positive spatial dependence, suggesting that businesses are more likely to recover if their neighbors are also recovering. The study also reveals that the spatial correlation follows an inverted "U" trend over time, peaking in the third year after the earthquake. The use of LISA cluster maps further reveals that the spatial correlation varies across different street regions, with some areas experiencing a decline in business recovery over time.

21. Li F, Rubinato M, Zhou T (2024) Identifying effective measures to enhance the recovery of small and micro enterprises after multiple waves of COVID-19-A case study from Dongguan, China. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 106. https://doi.org/10.1016/j.ijdrr.2024.104427.

Study Purpose: The purpose of this study is to identify effective measures that can enhance the recovery of small and micro enterprises (SMEs) after multiple waves of the COVID-19 pandemic.

Type of Business: SMEs in the manufacturing, wholesale/retail, and service sectors, which are defined as businesses with revenue from $147 800 to $738 800 and 10 to 50 employees for small businesses, and less than $147 800 revenue and less than 10 employees for micro businesses.

Disaster: Pandemic.

Built Environment: No

Timeframe Measured: 3 years after the start of the pandemic. Multiple data collections in July 2021, and July 2023.

Measurement of Recovery:

- **Survival status** – (open or closed) determined by whether a business was still operating at the time of the second field investigation in July 2023, with a business considered closed if it had not been open for more than three months.
- **Operational status** – changes in the level of average profitability assessed by comparing the average profitability of the business before the pandemic (before 2020) to its profitability after the pandemic (2023).
- **Recovery performance** – categorized into four levels: closed (0), worse performance after the pandemic (1), similar performance after the pandemic (2), and better performance after the pandemic (3).

Methodology:

- Surveys conducted among 592 SMEs. The surveys collected data on business and owner characteristics, response measures taken during the pandemic, and recovery performance. The data was collected on two occasions in July 2021 and July 2023.
- Spatial probit model to analyze the effectiveness of various response measures on SMEs' recovery performance. Additionally, a Local Indicators of Spatial Association (LISA) cluster map is generated to visualize the local spatial correlations of the post-pandemic recovery performance of SMEs.

Validation: None described.

Significance: This study contributes to the overall measurement of business recovery by suggesting the importance of considering spatial correlations and business characteristics in the development of recovery strategies. The study presents findings on the effectiveness of measures such as self-media marketing, borrowing money from family or friends, bank loans, and tax relief in facilitating business recovery. The study's focus on SMEs and the pandemic provides insights into the recovery of businesses in the face of prolonged disruptions.

22. Li F, Wang L, Jin Z, Huang L, Xia B (2020) Key factors affecting sustained business operations after an earthquake: a case study from New Beichuan, China, 2013-2017. *NATURAL HAZARDS* 104(SUPPL 1):101–121. https://doi.org/10.1007/s11069-019-03597-1.

Study Purpose: The study aims to examine the changes in business operating statuses after the initial survival of a large earthquake and identify the factors influencing sustained business operations during the long-term recovery process.

Type of Business: Manufacturing, wholesale/retail, and service-related businesses.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 5 years after the earthquake. Multiple data collections occurring once a year from July 2013 to July 2017.

Measurement of Recovery:

- **Operational status** – classified into two categories: continued operation (1) or closed/moved (0). The business operating rates were calculated for each year.

Methodology:

- Field investigations and surveys conducted among 256 businesses in over the course of 5 years. The survey collected data on various factors, including owner characteristics, business characteristics, disaster impact, and enabling factors for business recovery.
- Binomial logistic regression was used to identify the significant factors influencing the sustained operation of businesses.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by suggesting that the reopening of businesses after a disaster cannot be equated with long-term recovery. It suggests key factors influencing sustained business operations, including the business owner's gender, pre-disaster financial conditions, post-disaster monthly average profit, borrowing money from family or friends, and government subsidies. The study's findings have important implications for understanding the long-term recovery of businesses after earthquakes, particularly in relocated and reconstructed areas.

23. Liang D, Ewing B, Cardella E, Song L (2023) Probabilistic Modeling of Small Business Recovery after a Hurricane: A Case Study of 2017 Hurricane Harvey. *NATURAL HAZARDS REVIEW* 24(1). https://doi.org/10.1061/(ASCE)NH.1527-6996.0000602.

Study Purpose: The purpose of this study is to examine the micro-level foundation of small business resilience and recovery after a hurricane, with a focus on identifying key drivers of survival and recovery.

Type of Business: Small businesses with various industry categories, including construction, manufacturing, trade, transportation, and warehousing, among others.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: 3 years after the hurricane. Multiple data collections occurring in November 2019, and between October and November 2020.

Measurement of Recovery:

- **Time to recovery** – respondents selected from categorical choices (e.g., 1 month to 3 months, 4 months to 6 months, etc.) to report their recovery time. The authors then converted these categorical responses to numerical values by using the midpoint of each category. For example, a response of "(1 to 3) months" was converted to 2 months, and a response of ">12 months" was approximated to 18 months.

Methodology:

- Survey of small business representatives conducted in two waves, resulting in a total sample of 620 respondents. The survey included questions on general demographic characteristics, business characteristics, financial operations, impact of Hurricane Harvey, level of preparedness, and investments in resilience.
- Stochastic process identify which factors were linked to the time it took for businesses to recover. The researchers then used this information to create a model that simulated the recovery process of small businesses.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by providing a nuanced understanding of the recovery process of small businesses after a hurricane. The study highlights the importance of investment in resilience and preparedness in accelerating recovery and reducing uncertainty.

24. Liu H, Tatano H, Kajitani Y (2021) Estimating lifeline resilience factors using post-disaster business recovery data. *EARTHQUAKE SPECTRA* 37(2):567–586. https://doi.org/10.1177/8755293020952455.

Study Purpose: The study aims to estimate lifeline resilience factors (LRFs) for different business sectors using post-disaster business recovery data from the 2011 Great East Japan Earthquake. The authors propose a modeling framework to quantify the impact of lifeline disruptions on business recovery.

Type of Business: Various sectors, such as manufacturing (materials, processing and assembly, and life-related sectors) and non-manufacturing (construction, transportation, wholesale/retail, finance, insurance, and real estate, and service sectors).

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 2 years after the earthquake. Single data collection between November and December 2012.

Measurement of Recovery:

- **Production Capacity Recovery Rate Under Facility Damage (FPCRR)** – represents the recovery of production capacity due to facility damage only.
- **Total Production Capacity and Recovery Rate Under Facility Damage and Lifeline Disruptions (TPCRR)** – represents the recovery of production capacity due to both facility damage and lifeline disruptions.

The authors use these measures to quantify the impact of lifeline disruptions on business recovery. Specifically, they analyze the ratio differences between FPCRR and TPCRR to estimate the LRFs, which represent the remaining proportions of production capacity after lifeline disruptions.

Methodology:

- Survey of 424 businesses. The survey collected data on the recovery processes of businesses, including the restoration of lifeline services and the recovery of production capacity.
- Regression analysis to estimate the coefficients representing the impact of lifeline disruptions on business production capacity. The authors then use these coefficients to calculate LRFs for different lifeline services in various business sectors.

Validation: Cross-validation – Comparison of predicted outcomes from the survey instrument to real outcomes was conducted in a previous study [10].

Significance: This study adds to the overall measurement of business recovery by providing a quantitative framework for estimating the impact of lifeline disruptions on business production capacity. The estimated LRFs can be used to inform disaster risk reduction and management strategies, particularly in terms of prioritizing lifeline service restoration after a disaster. The study's findings highlight the importance of electricity supply in business recovery, followed by gas and water supply. The results also vary across different business sectors, emphasizing the need for sector-specific disaster risk management strategies.

25. Liu H, Tatano H, Kajitani Y, Yang Y (2021) Modelling post-disaster recovery process of industrial sectors: A case study of 2016 Kumamoto earthquakes. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 61. https://doi.org/10.1016/j.ijdrr.2021.102385.

Study Purpose: The study aims to understand the post-disaster recovery process of industrial sectors by developing a recovery function that integrates the impact of initial damage rates and lifeline service supply status.

Type of Business: Firms in industrial sectors, including both manufacturing and non-manufacturing sectors.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: Not described.

Measurement of Recovery:

- **Production capacity of firms** – defined as the maximum possible output of a firm, categorizing it into five distinct states based on the percentage of pre-disaster production capacity: 0 % (productivity stopped), 25 %, 50 %, 75 %, and 100 % (full production capacity).

Recovery is assessed based on the operational status of facilities and the availability of lifeline services such as electrical power, water, and gas supply.

Methodology:

- Survey of 960 business managers. The survey asked questions about facility damage, production capacity, and the time taken for firms to reach different percentages of production capacity.
- Semi-Markov model to describe the stochastic recovery process of firms. Additionally, the study analyzed the impact of influencing factors such as sector type (manufacturing vs. non-manufacturing) and firm size (measured by the number of employees) on the sojourn time using regression models.

Validation:

- None described for survey.
- Cross-validation – Comparison of the estimated sojourn time curves to actual sojourn times from the survey.

Significance: This study adds to the overall measurement of business recovery by providing a quantitative framework that estimates the recovery probability of firms at any post-disaster time, conditional on initial production capacity damage rates and lifeline service availability. The findings highlight the importance of considering sector type and business size in recovery processes.

26. Liu H, Tatano H, Kajitani Y, Yang Y (2022) Analysis of the influencing factors on industrial resilience to flood disasters using a semi-markov recovery model: A case study of the Heavy Rain Event of July 2018 in Japan. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 82. https://doi.org/10.1016/j.ijdrr.2022.103384.

Study Purpose: The study aims to evaluate the dynamic resilience of industrial sectors after flood disasters by developing a parametric semi-Markov recovery model. The model estimates the production capacity recovery rate (PCRR) at any post-disaster time and investigates the impact of various influencing factors on business recovery.

Type of Business: Businesses within the manufacturing sector (lifestyle-related industries, basic material type industries, and processing and assembly type industries) and non-manufacturing sector (construction, information and communication, transport and postal services, wholesale and retail, finance and insurance, real estate, and services).

Disaster: Flood

Built Environment: Yes

Timeframe Measured: Not described.

Measurement of Recovery:

- **Production capacity rate (PCR)** – categorized into six discrete states: 0 % (productivity stopped), re-open (production capacity restarted), 25 %, 50 %, 75 %, and 100 % (full recovery). The re-open state is defined as the restart of production capacity after full disruption, even with only 1 % PCR.

Methodology:

- Survey of 535 business managers. The survey asked about damage to facilities and lifelines, business production capacity recovery rate, and availability recovery resources.
- Semi-Markov process framework to model the stochastic recovery process of firms. The model integrates the sojourn time in each state and the transition probabilities between states, allowing for the incorporation of covariates into the sojourn time distribution. The covariates included in the model are inundation depth, deposited sediment, lifeline disruptions (electricity, water, and gas), and transportation disruption.

Validation:

- None described for survey.
- Cross-validation – Use of samples with missing data as a "validation dataset" – no further details provided.

Significance: The study adds to the overall measurement of business recovery by providing a parametric model that estimates the PCRR at any post-disaster time. It highlights the significance of considering various influencing factors, such as lifeline disruptions and transportation disruption, in understanding business recovery.

27. Liu H, Tatano H, Kajitani Y, Yang Y (2022) Modeling post-disaster business recovery under partially observed states: A case study of the 2011 great East Japan earthquake. *JOURNAL OF CLEANER PRODUCTION* 374. https://doi.org/10.1016/j.jclepro.2022.133870.

Study Purpose: The purpose of this study is to develop a novel analytical methodology for estimating post-disaster business recovery processes under partially observed recovery states. It aims to incorporate the impact of sector types, initial damage, and financial resource availability after disasters into the recovery model.

Type of Business: Businesses belonging to the manufacturing sector (including mining, construction, food, and other manufacturing industries) and firms belonging to the non-manufacturing sector (including communication, transportation, wholesale and retail, financial and insurance, and other services).

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 6 months after the earthquake. Multiple data collections between November and December 2011, and between November and December 2012.

Measurement of Recovery:

- **Facility production capacity rate (FPCR)** – represents the maximum percentage of productivity a firm's facility could still maintain after the disaster. FPCR is categorized

into five distinct states: State 1 (0 % to 25 % FPCR), State 2 (25 % to 50 % FPCR), State 3 (50 % to 75 % FPCR), State 4 (75 % to 100 % FPCR), and State 5 (100 % FPCR).

Methodology:

- Survey of 2052 businesses. They survey asked businesses about their FPCR at 0, 14, 31, 61, and 184 days after the earthquake, financial conditions, reasons for financial difficulty, and business characteristics.
- Multi-state Markov process to model the recovery process. By using this methodology, the study estimates the conditional recovery rates based on initial damage, sector types, and post-disaster financial conditions.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by providing a novel methodology for estimating recovery processes under partially observed states (where the actual state transitions or improvements in a firm's production capacity are not fully observed or recorded during inspections). By incorporating the impact of sector types, initial damage, and financial conditions, the study provides insights into the factors influencing business recovery. The findings suggest the importance of financial assistance in facilitating recovery speed, particularly for firms suffering from more severe damage.

28. Liu H, Tatano H, Pflug G, Hochrainer-Stigler S (2021) Post-disaster recovery in industrial sectors: A Markov process analysis of multiple lifeline disruptions. *RELIABILITY ENGINEERING & SYSTEM SAFETY* 206. https://doi.org/10.1016/j.ress.2020.107299.

Study Purpose: The study aims to investigate the impact of multiple lifeline disruptions on business production capacity recovery after a disaster, with a focus on identifying optimal lifeline restoration strategies to minimize economic losses.

Type of Business: Industrial sectors including materials, processing, assembly, and life-related sectors, as well as non-manufacturing sectors such as finance, insurance, and real estate.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 90 days after the earthquake. Single data collection between November and December 2012.

Measurement of Recovery:

- **Production capacity** – the maximum volume of products that can be generated by a production plant or enterprise in a given period using available resources. Production capacity is measured in percentages, with 100 % representing pre-disaster productivity.

Methodology:

- Survey of 376 businesses. The survey asked questions about business characteristics, restoration of lifeline services, and production capacity recovery.

- Non-homogeneous Markov process model to analyze the recovery of lifeline services (electricity, water, and gas supply) and their impact on business production capacity recovery. The model estimates the transition probabilities between different lifeline service states, which are defined by the availability of electricity, water, and gas supply. The model also assesses the impact of lifeline restoration on production capacity recovery by estimating the reduction factor associated with different lifeline service states.

Validation: None described.

Significance: The study adds to the overall measurement of business recovery by providing insight on the impact of multiple lifeline disruptions on business production capacity recovery. The findings suggest the importance of prioritizing lifeline restoration strategies, with electricity supply being the most critical factor in supporting business productivity.

29. Liu H, Tatano H, Samaddar S (2023) Analysis of post-disaster business recovery: Differences in industrial sectors and impacts of production inputs. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 87. https://doi.org/10.1016/j.ijdrr.2023.103577.

Study Purpose: The study aims to empirically investigate the business recovery process following the 2011 Great East Japan Earthquake, examining differences in recovery among various industrial sectors and the relative influencing factors.

Type of Business: Businesses across eight industrial sectors, including both manufacturing (basic material, processing and assembly, and lifestyle-related sectors) and non-manufacturing sectors (construction, transportation, wholesale/retail, finance, insurance, and real estate, and service sectors).

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 9 months after the earthquake. Single data collection between November and December 2012.

Measurement of Recovery:

- **Production capacity rate (PCR)** – represents the productivity of businesses relative to their pre-disaster levels with values ranging from 0 % to 100 %.
- **Total recovery time** – the number of days needed for the production capacity to return to 100 %.

Methodology:

- Survey of 434 businesses. The survey asked about PCR as well as restoration days for critical production inputs including electrical power supply, water supply, communication, transportation, gasoline supply, facility availability, employee attendance, and raw materials supply.

- Survival analysis to estimate the recovery curves for different sectors and compare the recovery times.
- Regression model is applied to quantify the impact of production input availability on business recovery. The model examines the relationship between the PCR and various production inputs.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by providing insight on the differences in recovery processes among various industrial sectors and the significant role of production input availability in influencing business recovery. The study's focus on the impact of sector type and production inputs on recovery contributes to a more nuanced understanding of business recovery.

30. Mao Q, Li N, Fang D (2021) Modeling the Multisector Business Interruption Ratio in Earthquake-Struck Regions. *JOURNAL OF MANAGEMENT IN ENGINEERING* 37(6). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000964.

Study Purpose: The purpose of this study is to develop an analytical framework for modeling the Business Interruption Ratio (BIR) of individual businesses in multiple economic sectors in earthquake-struck regions. The BIR is a significant indicator of the overall disaster-induced economic impacts on businesses.

Type of Business: Businesses in the manufacturing and retailing sectors.

Disaster: Earthquake

Built Environment: Yes

Timeframe Measured: 10 years after the earthquake. Single data collection between October 2019 and January 2020.

Measurement of Recovery:

- **Business Interruption Ratio (BIR)** – defined as the maximum of the production capacity loss ratio and the final demand loss ratio. To estimate BIR, the authors considered various operation factors, including land, buildings, equipment, infrastructure services, raw materials or goods supplies, and workforce. For manufacturing businesses, the production capacity was modeled using the Cobb-Douglas production function, which was found to be the most applicable form. For retailing businesses, the BIR was estimated based on the amount of goods supplies and the loss ratio of average individual demand.

The actual BIR of each business was calculated based on survey responses, including questions about average monthly production/sales before the earthquake, monthly production/sales when the business reopened, and the percentage of monthly production/sales compared to the pre-earthquake level.

Methodology:

- Surveys of 227 manufacturing and retailing businesses to collect data on the impacts of the earthquake on business operations and final demand. The surveys included questions about business characteristics, damage to buildings and equipment, expenditure on essential infrastructure services, changes in workforce, and production or sales when the business reopened.
- Survey data was used to test and validate the proposed framework for estimating BIR.

Validation:

- Expert evaluation and pilot testing of survey.
- Cross-validation – Comparison of the estimated BIR with the actual BIR reported by survey respondents.

Significance: This study adds to the overall measurement of business recovery by providing a framework for estimating BIR. It addresses limitations in existing methods by considering both production capacity and final demand changes, as well as the recovery of operation factors during business closure. By examining multiple economic sectors and considering sector-specific factors, the study contributes to a more nuanced understanding of business recovery after earthquakes.

31. Marks D, Thomalla F (2017) Responses to the 2011 floods in Central Thailand: Perpetuating the vulnerability of small and medium enterprises? *NATURAL HAZARDS* 87(2):1147–1165. https://doi.org/10.1007/s11069-017-2813-7.

Study Purpose: The study aims to investigate how the 2011 floods affected small and medium enterprises (SMEs) in the Bang Bua Thong (BBT) market community, how successfully they have recovered, and what actions they and the state have taken to reduce their vulnerability to future floods.

Type of Business: A range of SMEs, including retail businesses (e.g., electronics, food, clothing), service providers (e.g., hair salons), and suppliers of agricultural products.

Disaster: Flood

Built Environment: Yes

Timeframe Measured: (3 to 4) years after the floods. Single data collection (survey and interviews) between January and March 2015.

Measurement of Recovery: The study measures recovery through a combination of qualitative and quantitative indicators:

- **Economic recovery** – losses incurred by SMEs, compensation received from the government, and whether SMEs had flood insurance.
- **Perceptions of recovery** – SME owners' perceptions of their recovery, the challenges they faced, and the actions they took to reduce their vulnerability to future floods.

- **Government response** – the government's response to the disaster and its impact on SME recovery.

Methodology: The study employs a mixed-methods approach:

- Key informant interviews conducted with local, provincial, and national government officials, politicians, and the market community leader and deputy leader. The interviews aimed to gather information on the government's response to the 2011 floods, the challenges faced by SMEs, and the actions taken by the government to support SME recovery.
- Survey conducted with 26 SME owners. They were designed to gather data on their demographic and socioeconomic profiles, community characteristics, effects of the floods, their response, recovery, and views about future flooding.

Validation: None described.

Significance: The study adds to the overall measurement of business recovery by highlighting the complex interplay between social, economic, and political factors that influence the recovery process. The findings emphasize the need for more effective government support and disaster risk reduction measures to support SME recovery and reduce their vulnerability to future floods. The study's focus on the political economy drivers of vulnerability and recovery provides a nuanced understanding of the challenges faced by SMEs in recovering from disasters.

32. Marshall M, Schrank H (2020) Sink or Swim? Impacts of Management Strategies on Small Business Survival and Recovery. *SUSTAINABILITY* 12(15). https://doi.org/10.3390/su12156229.

Study Purpose: The study examines the impact of management strategies on the recovery status of small businesses affected by Hurricane Katrina, with a focus on resource exchanges and interpersonal transactions between businesses, households, and communities.

Type of Business: Small businesses (with 200 or fewer employees) across various industries, including service businesses, retailing, manufacturing, agriculture, and forestry.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: (8 to 11) years after the hurricane. Multiple data collections occurring 3 times over the course of 3 years, beginning in 2013.

Measurement of Recovery:

- **Operating status** – categories, including "demised," "survived," "recovered," and "resilient." Recovery is defined as businesses operating with revenues at a similar level to what they generated prior to Hurricane Katrina.

Methodology:

- Interviews with 499 small business owners. The interviews gathered information on business, owner, and household demographics, hurricane preparations, financial information, and post-disaster outcomes.
- The authors use a framework developed by Marshall and Schrank in 2014 [11] to categorize businesses into operating status categories, and a Heckman probit model was used to examine the factors that influenced business recovery.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by highlighting the importance of management strategies, resource exchanges, and interpersonal transactions between businesses, households, and communities in determining business recovery outcomes. The study's findings provide insights into the factors that influence business recovery after a disaster, including the role of financial management strategies, household adjustments, and community resources.

33. Pathak S, Ahmad M (2016) Flood recovery capacities of the manufacturing SMEs from floods: A case study in Pathumthani province, Thailand. *INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION* 18:197–205. https://doi.org/10.1016/j.ijdrr.2016.07.001.

Study Purpose: The purpose of this study is to examine the flood recovery capacities of manufacturing Small and Medium Enterprises (SMEs) in Pathumthani province, Thailand, after the 2011 floods. It aims to identify the factors that influence the recovery process and to analyze the coping mechanisms adopted by these businesses.

Type of Business: Manufacturing SMEs.

Disaster: Flood

Built Environment: Yes

Timeframe Measured: 3 years after the floods. Single data collection (survey, interviews, and focus group), beginning in 2014.

Measurement of Recovery:

- **Recovery time** – time taken by SMEs to resume their business activities after the floods. The recovery time is categorized into various intervals, including less than a month, (1 to 6) months, (6 to 12) months, and over a year. The study also notes instances where businesses were unable to recover
- **Financial losses** – incurred by the SMEs, including losses in production days, sales, and other miscellaneous expenses.

Methodology: The study employs a mixed-methods approach, combining both qualitative and quantitative research methods:

- A survey of 200 manufacturing SMEs was conducted to gather data on their profiles, the impacts of the 2011 floods, and the coping mechanisms adopted.

- Interviews were conducted with 20 key informants, including government officials, emergency response team personnel, and representatives from non-governmental organizations. These interviews provided additional insights into the experiences of the SMEs and the support mechanisms available to them.
- Focus group discussions were held with officials from various organizations, including the Pathumthani police headquarters, electricity department, and district administration. These discussions helped to triangulate the data collected through the survey and interviews.

Validation: Triangulation of data from survey, interview, and focus groups.

Significance: This study adds to the overall measurement of business recovery by highlighting the critical factors that influence the recovery of manufacturing SMEs after a flood disaster. It underscores the importance of business continuity planning, risk perception, and financial resilience in facilitating faster recovery. The findings also emphasize the need for effective government policies and support mechanisms to aid SMEs in their recovery efforts.

34. Podesta C, Coleman N, Esmalian A, Yuan F, Mostafavi A (2021) Quantifying community resilience based on fluctuations in visits to points-of-interest derived from digital trace data. *JOURNAL OF THE ROYAL SOCIETY INTERFACE* 18(177). https://doi.org/10.1098/rsif.2021.0158.

Study Purpose: The study aims to establish a methodological framework for quantifying community resilience based on fluctuations in population activity during a disaster, using visits to points-of-interest (POIs) as a proxy for community activities.

Type of Business: Various types of businesses categorized into 16 POI groups, including: Emergency preparedness (grocery and merchandise stores, gasoline stations, health and personal care stores); Emergency response (medical facilities, public order); Recovery activity (religious organizations, building material and supplies dealers, postal service, banks, insurance agencies); Lifestyle and well-being (self-care services, stores and dealers, restaurants, recreation and gym centers, entertainment, education).

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: Approximately 1 month after the hurricane. Single data collection of existing data from a time period between August (before the hurricane) to September 2017 (1 month after the hurricane).

Measurement of Recovery: The study measures recovery by analyzing the fluctuations in POI visits before, during, and after Hurricane Harvey. To quantify recovery, the researchers employed several metrics:

- **Systemic Impact** – the maximum percentage drop in POI visits, indicating the severity of the disruption caused by the hurricane.

- **Duration of Impact** – the number of days taken for POI visits to return to pre-disaster levels, reflecting the time required for recovery.
- **General Resilience (GR) Values** – a dimensionless metric that integrates systemic impact, slope ratio, time-averaged performance loss, and recovery ability to provide a comprehensive assessment of resilience. GR values enable comparison of the relative resilience of different POI categories.

Methodology: The research used digital trace data related to unique visits to POIs in the Houston metropolitan area. The methodology involved:

- Data Categorization: Filtering 55 537 business entities into 16 categories based on the North American Industry Classification System (NAICS).
- Establishing a Baseline: Calculating average daily POI visits for each category during pre-disaster periods to serve as a baseline for comparison.
- Calculating Percentage Change: Determining the percentage change in POI visits relative to the baseline.
- Resilience Curve Analysis: Plotting the percentage change in POI visits over time to create resilience curves, which were used to derive systemic impact, duration of impact, and GR values.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by providing a novel approach to quantifying community resilience and business recovery using location-intelligence data. By examining the fluctuations in POI visits, the research offers insights into the resilience of various business sectors and community services during and after a disaster. The findings suggest the importance of certain businesses, such as religious organizations and building material and supplies dealers, in community recovery.

35. Schrank H, Marshall M, Hall-Phillips A, Wiatt R, Jones N (2013) Small-business demise and recovery after Katrina: rate of survival and demise. *NATURAL HAZARDS* 65(3):2353–2374. https://doi.org/10.1007/s11069-012-0480-2.

Study Purpose: The purpose of this study is to present a methodology for tracking demised small businesses after a disaster, specifically Hurricane Katrina, and to provide data on the rate of survival and demise of these businesses. The authors aim to address the challenges of post-disaster research, including the displacement of subjects, loss of infrastructure, and disruption of communication.

Type of Business: Small businesses with 0 to 200 employees operating in a ten-county geographic area.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: 1 year before and 5 years after the hurricane. Single data collection of existing data from a time period between 2004 (1 year before the hurricane) and 2009 (5 years after the hurricane).

Measurement of Recovery:

- **Rate of survival and demise** – classifying businesses into three categories: (1) in continued operation, (2) not in operation (demised), or (3) unknown/ unverified status.

Methodology: The study employed a mixed-methods approach, combining desktop research, phone verification, and fieldwork to track and verify the status of small businesses. The authors used record linkage techniques to identify and locate business owners, utilizing various data sources such as:

- Dun & Bradstreet (D&B) listings for 2004 and 2009
- Phone books and online directories (e.g., Pipl.com, ReferenceUSA)
- Property tax records maintained by county assessors
- State corporate entity search databases
- Professional licensing lists (e.g., attorneys, physicians, contractors)
- Online maps and street view images (e.g., Google Maps)
- Social Security Death Index and obituary records

The authors created a tracking sheet to record information gathered from these sources and to document the search process. Phone verification was used to confirm the operating status of businesses and to update owner contact information. Fieldwork was conducted to generate leads to owners of businesses that were not found through desktop research and phone verification.

Validation: Cross referencing of multiple data sources.

Significance: This study adds to the overall measurement of business recovery by providing a novel methodology for tracking demised businesses and estimating the rate of survival and demise. The findings challenge earlier estimates of business closure rates after disasters, suggesting that the actual rate of demise may be lower than previously thought.

36. Tyler J, Sadiq A (2019) Business Continuity and Disaster Recovery in the Aftermath of Hurricane Irma: Exploring Whether Community-Level Mitigation Activities Make a Difference. *NATURAL HAZARDS REVIEW* 20(1). https://doi.org/10.1061/(ASCE)NH.1527-6996.0000323.

Study Purpose: The purpose of this study is to examine the impact of community-level mitigation activities on business continuity and disaster recovery in the aftermath of Hurricane Irma, specifically exploring whether businesses located in communities participating in FEMA's Community Rating System (CRS) program experienced less impact and recovered faster.

Type of Business: Various types of businesses, such as contractors, financial services, gas stations, health services, manufacturers, recreational services, real estate, and veterinary services.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: Approximately 2 months after the hurricane. Single data collection in late 2017, occurring over a 4-week period.

Measurement of Recovery:

- **Self-rated recovery** – respondents were asked to rate the extent to which their business had recovered from Hurricane Irma on a scale of 1 to 5, where 1 represents "has not recovered at all" and 5 represents "has completely recovered".

Additionally, respondents were asked to provide contextual information about their business's recovery through open-ended questions.

Methodology:

- Semi-structured interviews with 19 business owners or representatives and 6 local government staff members. The interviews gathered information on business characteristics, preparedness for Hurricane Irma, challenges associated with recovering from the storm, and the resources available to businesses. The authors analyzed the interview transcripts, coding the data according to preliminary themes and then searched for additional themes within the initial codes.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by exploring the relationship between community-level mitigation activities and business disaster recovery. The findings suggest that businesses in higher CRS-participating communities experienced less impact and recovered faster, highlighting the importance of community-level mitigation efforts in enhancing business resilience. The study also suggests additional factors influencing business recovery, such as dependence on other businesses, stress and emotional reactions, financial considerations, personnel issues, and challenges with contractors and insurance companies.

37. Wang A, Marinova D, Wang F, Wei J (2020) Corporate investor confidence in the aftermath of a mega natural disaster: An empirical study of the 2008 Wenchuan earthquake. *SAFETY SCIENCE* 125. https://doi.org/10.1016/j.ssci.2020.104620.

Study Purpose: The purpose of this study is to investigate how corporate investor confidence is influenced by the distance from a disaster, specifically the 2008 Wenchuan earthquake, and to examine the moderating effects of firm performance and industry risk on this relationship.

Type of Business: Companies headquartered in the disaster-affected areas of the 2008 Wenchuan earthquake. Businesses across 11 different industries, with a particular focus on companies that are publicly listed.

Disaster: Earthquake

Built Environment: No

Timeframe Measured: 6 years after the earthquake. Single data collection of existing data from a time period between 2008 and 2013.

Measurement of Recovery: The study measures recovery through the lens of corporate investor confidence. Specifically, it uses the

- **Value of shareholdings** – Total value of shareholdings of the top ten shareholders as a proxy for investor confidence. This variable is standardized to correct for skewness, ensuring that the data is normally distributed and suitable for analysis. The use of shareholdings as a measure allows the researchers to capture the financial aspect of investor confidence, providing insight into how investors perceive the prospects of companies affected by the disaster.

Methodology: Analysis of a balanced panel of 98 listed companies over 588 firm-year observations from 2008 to 2013. The sample consists of companies headquartered in Sichuan, Gansu, Shanxi provinces, and Chongqing municipality, which were severely affected by the Wenchuan earthquake. The researchers used regression models to test the hypotheses.

Validation: None described.

Significance: This study adds to the overall measurement of business recovery by suggesting the importance of investor confidence in the recovery process. It demonstrates that geographical and temporal distances from the disaster area significantly influence investor confidence. Furthermore, it shows that firm performance and industry risk moderate this relationship.

38. Watson M, Xiao Y, Helgeson J (2024) Using Disaster Surveys to Model Business Interruption. *NATURAL HAZARDS REVIEW* 25(1). https://doi.org/10.1061/NHREFO.NHENG-1807.

Study Purpose: The purpose of this study is to explore how to use survey data efficiently and effectively in business interruption models after disasters. The authors investigate the impact of variable choice, variable measurement, and measurement timing on modeling business interruption.

Type of Business: A range of businesses in the retail or wholesale sector and manufacturing or construction.

Disaster: Hurricane

Built Environment: Yes

Timeframe Measured: 15 months after the hurricane. Single data collection in January 2018.

Measurement of Recovery:

- **Business interruption** – operationalized as the number of days businesses were closed.

- **Binary status of businesses** – (open or closed) at weekly intervals, starting from Week 1 and ending at Week 6 after the hurricane.
- **Damage states** – ranging from DS0 to DS4 for building structural damage, content and inventory damage, and machinery and equipment damage.

Additionally, the study considers various other factors that influence business interruption, including utility disruptions such as electricity, water, and natural gas losses.

Methodology:

- Use of data collected from surveys [9] of businesses conducted in Lumberton, North Carolina, approximately 15 months after Hurricane Matthew. The survey instrument was designed to capture detailed information on business and owner characteristics, damage and losses, operations, financial assistance and insurance coverage, and recovery status. The survey data were analyzed using linear regression models.

Validation:

- Expert review.
- Pilot testing.

Significance: This study adds to the overall measurement of business recovery by highlighting the importance of comprehensive survey design, including the use of detailed damage and utility variables, and capturing recovery dynamics through time. The findings suggest that using more precise measures, such as days of utility loss and damage states, can significantly improve business interruption models.

39. Yang L, Chen Y, Jiang X, Tatano H (2022) Multistate Models for the Recovery Process in the Covid-19 Context: An Empirical Study of Chinese Enterprises. *INTERNATIONAL JOURNAL OF DISASTER RISK SCIENCE* 13(3):401–414. https://doi.org/10.1007/s13753-022-00414-5.

Study Purpose: The purpose of this study is to examine the recovery process of Chinese enterprises during the Covid-19 pandemic, focusing on the determinants and dynamics of enterprise recovery.

Type of Business: manufacturing and non-manufacturing industries, with further sub-categorization into services, wholesale and retail, raw materials manufacturing, processing and assembly, and livelihood-related manufacturing.

Disaster: Pandemic

Built Environment: No

Timeframe Measured: 6 months after the start of the pandemic. Single data collection between July and September 2020.

Measurement of Recovery:

- **Operational capacity** – proportion of its post-disaster operation capacity recovered to the pre-disaster normal level. The recovery states are categorized into four distinct categories: (1) no recovery, where the enterprise has not resumed operations; (2) initial recovery, indicating that the enterprise has recovered to between 0 and 1/3 of its normal operational capacity; (3) mid-term recovery, signifying recovery to between 1/3 and 2/3 of normal capacity; and (4) full recovery, representing a recovery level above 2/3 of the enterprise's normal operational capacity.

Methodology:

- Survey of 750 businesses. The survey asked questions about business ownership, customer distribution, number of employees, raw material or supply shortages, cash flow shortages, employee panic and shortages, and order cancellations.
- This study examines the business recovery process using a combination of survival analysis and a multistate model. The analysis involves two main parts: one that looks at the factors affecting recovery time and another that models the different stages of recovery and the likelihood of transitioning between them. By using this approach, the study can understand how various factors influence the recovery process and the chances of businesses moving from one stage of recovery to another.

Validation: None described.

Significance: This study contributes to the understanding of business recovery by providing insights into the dynamic recovery process of enterprises during a pandemic. It highlights the different determinants affecting recovery across various industries and stages of recovery. The use of a multistate model offers a nuanced view of recovery, capturing the progression through different recovery states and the factors influencing these transitions.

4. Findings and Impacts

The annotated bibliography presented here is a valuable resource for researchers and practitioners seeking to understand business recovery after disasters. By compiling a diverse range of studies on this topic, this bibliography provides a comprehensive overview of the complex factors that have been found to influence business recovery under different disaster recovery situations and the various methodologies employed to measure it. Overall, the collective findings of these studies underscore the multifaceted nature of business recovery, revealing that a deep understanding of the interplay between various influencing factors is essential for effective recovery strategies. Many studies suggest that factors such as access to financial resources, business characteristics, and owner demographics play a crucial role in determining business recovery outcomes. Others highlight the importance of considering the built environment, lifeline services, and production inputs in understanding business recovery. Some studies also emphasize the need for effective government support and disaster risk reduction measures. These findings demonstrate the importance of emphasizing context-specific approaches to business recovery, taking into account the distinct needs and challenges faced by different businesses. Furthermore, there is not agreement as to what construct defines “business recovery” and the covariates that may help indicate recovery. Like much of the disaster resilience and recovery measurement work, there are extreme limitations on the extent to which baselines a priori are available to measure ex post performance.

The following table summarizes the characteristics of the studies covered in this bibliography. The summary statistics reveal a diverse range of disaster types, with earthquakes being the most frequently studied (35.9 %). The majority of studies focused on small businesses/SMEs (51.3 %) and considered the built environment in their analysis (74.4 %). The most common recovery measurement was operational status (38.5 %). Surveys were the primary methodology used (64.1 %) and often provided data in the same studies to inform statistical modeling (51.3 %). However, validation methods were not consistently reported across studies, with 64.1 % of studies not reporting any validation efforts.

Table 1. Summary Statistics for Annotated Bibliography Entries.

Category	Characteristic	(Frequency) Percent
Disaster Type	Earthquake	(14) 35.9 %
	Flood	(7) 17.9 %
	Hurricane/Typhoon	(8) 20.5 %
	Pandemic	(4) 10.3 %
	Tsunami	(2) 5.1 %
	Multiple/Complex Events	(2) 5.1 %
	Volcanic Eruption	(1) 2.6%
	Wildfire	(1) 2.6 %
Business Type	Small Businesses/SMEs	(20) 51.3 %
	Various Sectors/Industries	(10) 25.6 %
	Manufacturing	(6) 15.4 %
	Retail/Wholesale	(4) 10.3 %
	Service-Related	(4) 10.3 %
	Agriculture/Farming	(2) 5.1 %
	Construction	(2) 5.1 %

	Other	(5) 12.8 %
Built Environment	Yes	(29) 74.4 %
	No	(10) 25.6 %
Timeframe Measured	Less than 1 year	(13) 33.3 %
	(1 to 2) years	(9) 23.1 %
	(2 to 5) years	(10) 25.6 %
	More than 5 years	(7) 17.9 %
Recovery Measurement	Operational Status	(15) 38.5 %
	Revenue/Financial Metrics	(10) 25.6 %
	Production Capacity	(6) 15.4 %
	Time to Recovery	(5) 12.8 %
	Other	(13) 33.3 %
Methodology	Survey	(25) 64.1 %
	Interviews	(10) 25.6 %
	Statistical Modeling	(20) 51.3 %
	Field Observations	(6) 15.4 %
	Other	(8) 20.5 %
Validation	None	(25) 64.1 %
	Cross-validation	(9) 23.1 %
	Pilot Study	(3) 7.7 %
	Expert Review	(2) 5.1 %

A common thread throughout the research is the need for empirical validation of models and methods, as has been pointed out in previous resilience and recovery research [12–14]. Many of the studies reviewed here employed sophisticated analytical approaches, but few explicitly described validation efforts for their survey instruments or modeling approaches. This lack of validation is a significant limitation, as it can lead to uncertainty about the accuracy of measurement leading to study findings. For instance, several studies used a methodology in which recovery outcomes, measured through surveys, were applied to develop models or frameworks intended to predict recovery. While some studies incorporated validation methods, such as cross-validation – splitting the survey data to both inform and test the model – the usefulness of such validation depends on the extent to which the original recovery outcome itself has been validated. Thus, it is important to validate not only the models developed, but also the measurement methods—in this case, surveys.

Additionally, as discussed earlier, measuring business recovery after a disaster is a complex task because of the wide range of circumstances that can influence it. Since recovery, like resilience, is a latent concept [12] shaped by many mediating factors dependent on each disaster's context, approaches to measuring it have varied significantly from one disaster to another, with many studies developing their own unique instruments. This variation makes it difficult to validate methods across different measurement efforts, as the quasi-experimental nature of most recovery research lacks the control of true experimental designs. It also limits the potential for meta-analyses and comparative studies that could advance measurement science more broadly.

This annotated bibliography can be used as a comparative resource for researchers and practitioners seeking to identify and select measurement strategies best suited to their specific

objectives and circumstances. By presenting the methodologies and findings of various studies alongside their contexts, this bibliography serves as a starting point for future work aimed at improving and refining the methods used to measure business recovery.

The bibliography can be used in several ways:

- **Comparative Analysis**: Researchers can compare the methodologies and findings of different studies to identify best practices and areas for further research.
- **Methodology Selection**: Practitioners can use the bibliography to select the most appropriate methodologies for their specific needs and contexts.
- **Contextual Understanding**: The bibliography provides a nuanced understanding of the complex factors influencing business recovery, allowing users to contextualize their own research or practice.

The findings from this annotated bibliography underscore the complexity of business recovery after disasters and highlight the need for continued research to improve our understanding of this multifaceted issue. Future research efforts should prioritize the development of more robust and validated methods for measuring business recovery, as well as the creation of methodologies that can capture the nuances of different disaster contexts. Additionally, validating existing methods through empirical testing and comparison will be crucial for establishing a reliable foundation for research and practice. As a next step, the summaries and contextual information from the studies reviewed here will be compiled into a searchable database, providing a valuable resource for researchers and practitioners seeking to identify relevant studies, compare methodologies, and access key findings. By advancing recovery measurement methodology, promoting the use of validated approaches, and making existing research more accessible, researchers can help to inform the development of more effective strategies for supporting businesses and promoting community resilience in the face of disasters.

5. Conclusion and Future Research

In conclusion, the annotated bibliography underscores the need for empirical validation of models and methods used to measure business recovery after disasters. While the studies reviewed here have made significant contributions to our understanding of business recovery, the lack of validation efforts in many of these studies is a notable limitation.

By using this bibliography as a resource, researchers and practitioners can gain a deeper understanding of the complex factors influencing business recovery and identify and improve upon effective methodologies for measuring it. Future research should prioritize empirical validation to ensure that models and methods are robust and generalizable.

Ultimately, the development of validated models and methods will inform the creation of more effective strategies for supporting businesses and promoting community resilience in the face of disasters. As the frequency and severity of disasters continue to increase, the importance of rigorous validation cannot be overstated.

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