Cost-Effective Business Resilience Decision Making

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COST-EFFECTIVE BUSINESS RESILIENCE DECISION MAKING[†]

Noah Dormady[‡]
John Glenn College of Public Affairs
The Ohio State University
Columbus, Ohio, US

Adam Rose
Price School of Public Policy
University of Southern California
Los Angeles, California, US

Chris Snider
The Snider Group
Whitby, Ontario, Canada

Alfredo Roa-Henriquez
College of Business
North Dakota State University
Fargo, North Dakota, US

Summary:
Practitioners, scholars and students engaged in the analysis or evaluation of natural hazard impacts, particularly those involved in quantifying economic disruptions, should understand basic analytical principles and best practices. Economic analysis of disasters is particularly challenging, and there are best practices that can be employed to address many of these measurement and quantification challenges, including survey-based empirical data collection and analysis techniques.

Once these challenges are considered, and an evaluation has been performed, another more difficult challenge occurs—how that information can be used to effectively and cost-effectively improve hazard resilience. This involves how businesses, organizations and communities can then use those analyses and data to improve operations, improve resilience, and restore functionality at the lowest cost.

The choices a business makes in the aftermath of a disaster can play a key role in its ability to continue operating, as well as in its pace of recovery. Those operational decisions are critically important and must be informed by a complex set of factors beyond property damage alone. It is important that decisionmakers develop a set of evaluation criteria for quantifying business resilience, with an explicit focus on cost-effectiveness. This is important because, due to the wide-ranging nature of disaster impacts, many disrupted businesses pursue resilience actions for which costs exceed avoided losses. In other words, they spend more money to avoid losses than the value of those losses. Recent natural disaster data collection and analysis efforts from Hurricane Harvey and other major disasters reveal that many businesses respond to disasters in cost-effective ways, while others spend inefficiently on resilience actions, or tactics.

It is important that society learns from the experiences of businesses affected by prior disasters, so that businesses, organizations and communities can more effectively and cost-effectively respond to future disasters, prepare for hazards, and accelerate recovery when disasters strike. It is also important that these objective, data-driven decisions, which aim to avoid economic losses and hasten recovery, consider the role of insurance. Insurance policies, practices and incentives can vary, and they can fundamentally alter the behavior of firms in responding to natural disasters.

As such, cost-effective business resilience decision making is multi-faceted. It involves operational decisions in the presence of post-disaster constraints that impact the firm's ability to produce its goods and its services. It involves cost and investment considerations, dynamic decision making, and it involves external opportunities and limitations associated with contractual, legal and regulatory, and insurance-related considerations.

Keywords: *Economic Resilience; Disasters; Hazards; Enterprise Resilience; Cost-Benefit Analysis; Business Continuity; Hurricane Harvey; Decision Science; Insurance.*

Introduction to Business Resilience Decision Making

Natural hazards and catastrophic events impact businesses in many complicated ways. The evaluation of these impacts is more extensive than a focus on property damage alone, which is often exclusive or predominant. This narrow focus has important implications for business continuity and recovery. A more holistic perspective that includes consideration of business interruption (BI), which is oftentimes uninsured, incompletely insured, or difficult to insure, would result in a fundamentally more robust resilience planning process. This chapter shows, on the basis of data from the past experiences of firms in Texas impacted by Hurricane Harvey, that BI can be orders of magnitude more costly than property damage, and it is more conceptually challenging to quantify, evaluate and ultimately avoid.

A more complete decision-making process will also include considerations for BI, or put simply, how each business' operations are disrupted. This requires a focus on how the firm uses its inputs (e.g., capital, labor, infrastructure, materials) to produce its goods, products or services. To aide in this conceptualization, the chapter draws upon economic production theory (e.g., Rasmussen, 2013; Varian, 1992), which provides a scientific foundation for evaluating a firm's change in behavior to respond to disruptions, limitations and input constraints (Rose, 2009). Essentially, production theory explains how individual businesses combine inputs as efficiently as possible to produce goods and services. Dormady et al. (2019a; 2022a) provide a detailed exposition, along with citations for several relevant additional readings on the topic. The presentation here is meant to be accessible and non-technical for a broad readership.

How a business responds to a major disruption needs to be based on fundamental aspects of the disaster. Of critical importance is an evaluation of the intersection between the use of production inputs and the sources of disruption. In other words, decisions must also consider how a business is uniquely impacted by different types of disruptions. These can include infrastructure disruptions that limit access to electricity, water or natural gas. These can include transportation disruptions that impose constraints on accessing materials, or that keep employees from accessing worksites. These can also include supply-chain disruptions that limit access to key material inputs. And, importantly, these can and often do include complex situations in which a firm can experience multiple interruption types simultaneously.

Effective business continuity and recovery decision making must account for both of these considerations—how a firm uniquely uses its inputs and how those inputs are disrupted, impacted, and limited by the exigent conditions of a catastrophic event. Consequently, cost-effective resilience strategies vary for different types of businesses, different types of disasters, and other contextual conditions. What works for one business may not work for another, because of those unique circumstances. Best practice decision making is informed by historical practice, learning from the past experiences of other similar types of firms that experienced similar disruptions. In other words, falling back on past best practices derived during normal operations, or falling back on best practices derived during prior disasters where disruption characteristics or conditions were different, may make it more challenging to identify and implement cost-effective avoided losses for the case at hand. Moreover, without the use of objective resilience metrics that prioritize tactics by costs and benefits, or by focusing only on property damage, decision makers may be unaware of inefficiencies in their resilience strategies.

Therefore, the practical importance of this chapter is that it provides a way to conceptualize business resilience decision making in terms of prioritizing costs and benefits of specific resilience actions, or tactics.[i] Rather than ad-hoc changes to production or operations, or providing one-size-fits-all checklists or best practice guidance to firms as is currently done in a variety of contexts, our aim is to provide an accessible way of considering various approaches to business continuity and recovery in terms of practical and empirical metrics that quantify costs and benefits of concrete resilience tactics, with an explicit focus on: a) the unique considerations associated with the sources of disruption, b) how the firm uses its technological inputs, c) opportunities, challenges and limitations from insurance instruments, d) unique considerations associated with repair and reconstruction investments, and e) other key considerations.

The purpose of this chapter therefore is to provide a synthesis of the literature on economic resilience to disasters with an explicit focus on decision making. This includes key decision-making considerations and also inputs to the decision-making process that should be considered. This chapter similarly aims to analyze the relationship between property damage and BI. It emphasizes the importance of disruptions to infrastructure and supply-chains, and it also emphasizes the importance of insurance and how insurance policies and provisions can be complimentary with both resilience and mitigation. It aims not only to provide a summary of recent research in this domain, but, also, keeping in mind that business owners and operators will be reading this work, to help inform their own resilience and business continuity decisions with the latest research. This provides a pragmatic approach for students engaging themselves in the process of learning this literature. Students can learn by placing themselves into the pragmatic decision-making process of the business.

The Societal Importance of Cost-Effective Business Resilience

Economic consequences of natural and human-induced hazards are the subject of a large and increasing volume of academic research. The reader is encouraged to see Dormady et al. (2022b); Botzen et al. (2019), and the National Research Council (2022) for summaries of recent academic work in this field. The volume of this work has been steadily increasing both in the United States and in other developed, and developing nations for the past 25 years, and longer (see e.g., Hosseini et al. (2016) for a comprehensive summary of approaches and methods in resilience, including economic resilience as well as engineering concepts).

The prominence of the research field is a reflection of the societal importance of the subject matter itself (Stevenson et al., 2016). That is, natural disasters are consequential, not simply because of the direct physical damage or loss of life that they cause, but also because of their economic consequences. Those economic consequences include but are not limited to business interruption (BI), and other associated societal disruptions. These impact businesses directly, and they also impact society writ large, with associated impacts on economic welfare (Hallegatte, 2014). When a bridge is destroyed in a disaster, for example, the economic consequence of impaired commerce and reduced business activity can far exceed the value of the property damage to the bridge itself. These economic disruptions ripple throughout supply chains, compounding the economic disruption even further. In economic terms, there are both *direct* and *indirect* economic consequences.[ii]

Consider a few statistical reference points. In terms of frequency, natural disasters are more common than one might expect. According to Bondonio & Greenbaum (2018), who conducted an analysis of federal disaster assistance at the county level in the US between 1989 and 1999, on average each year, about one-third of US counties experience a disaster and request federal assistance (annual average of 29.7%). Put another way, on the whole and not accounting for hazard-prone regions, the likelihood that a given county in the US will be affected by a catastrophic hazard and require federal assistance is about one in three. Additionally, according to the National Oceanic and Atmospheric Association (NOAA), the US has experienced 371 disasters exceeding $1 billion (in inflation-adjusted 2023 dollars) since 1980 (see National Centers for Environmental Information (2023); Smith & Matthews (2015)). According to the same source, there were 60 of these events in the last three years, alone, and they estimate that the total direct costs of US disasters since 1980 is just over $2.6 trillion. Moreover, the most recent Intergovernmental Panel on Climate Change report (IPCC, 2023) projects that such disasters will be on the rise in the future.

Similarly, it is estimated that since 2017 the US has experienced an annual average of 15 natural hazard events exceeding $1Bn USD (McKinsey & Company, 2023). This represents an increase of approximately 33% from the prior decade and more than a 50% increase prior to 2007. Since 1991, the cost of catastrophic natural disasters has steadily increased (McKinsey & Company, 2023). And, Munich RE's NatCatSERVICE estimates that in 2023 global disasters cost insurers $95Bn USD (Artemis, 2023).

Importantly, those cost estimates are only direct costs in terms of property damage, and do not fully include direct and indirect BI (including supply-chain effects). How much larger is business interruption than property damage? The answer to that question depends on a variety of factors, most of which are challenging to estimate and/or validate for a variety of empirical reasons (Botzen et al., 2019). Research in this domain is making considerable progress, but estimates can vary considerably in the absence of common empirical approaches.[iii]

Dormady et al. (2022a) conducted a detailed set of business surveys on a sample of firms affected by Superstorm Sandy and Hurricane Harvey and found that on average, the dollar value of BI was approximately 900% larger than property damage for businesses. While this estimate is likely to be challenging to generalize to other regional economies or disaster types, it is important to note because it demonstrates the relative magnitude of BI to property damage. Other examples where BI significantly exceeded property damage are the September 11 World Trade Center attacks (Rose et al., 2009) and Hurricane Katrina (Rose & Oladosu, 2008). There are also many cases where property damage does not exist or is relatively small in comparison to BI, such as electric power outages (Rose et al., 2007) and COVID (Walmsley et al., 2023).

So, while the exact historical average of the magnitude of BI to property damage is not clear and is still evolving, one conclusion is highly salient—BI is not trivial and should not be neglected in business resilience planning and in business continuity decision making. This should also provide insights into the relative magnitude of losses that are not insurable. And, it should reinforce the importance of conceptualizing resilience decision making in terms of prioritizing post-disruption actions by cost-effectiveness.

The Business Interruption versus Property Damage Paradox

This fact illuminates a key paradox that frustrates natural hazards economists and other technical experts in this field. Both government and business oftentimes focus the bulk of their resilience planning expenditures and efforts, and their insurance expenditures, on addressing property damage.[iv] Not only is property damage often considerably smaller in dollar terms than BI, but BI is generally less adequately insured. A 2007 study found that only 32% of firms with annual revenues less than $1 million carry BI insurance (see NAIC (2007); see also Smith & Matthews (2015)). Moreover, once the disaster has occurred, there is virtually nothing that can be done to reduce property damage—the damage has already occurred. This then begs the question, why are policymakers, government agencies and individual businesses focused so heavily on addressing property damage? And, why is so little attention given to addressing BI?

This is the case in part because property damage is more straightforward to evaluate and is easier to quantify, and therefore to insure. Addressing BI, however, requires a clear conceptualization of how to quantify business continuity and recovery, and it requires objective metrics that can evaluate the worthwhileness of explicit resilience actions, or tactics, in terms of their cost-effectiveness. It requires an empirically derived method or approach that can inform a business' resilience strategy based upon the learned experiences of other business like their own, that are of similar size and type, and economic sector. It requires empirics that are informed by cost and effectiveness data derived from past business experiences with similar disruption types and input constraints.

This paradox has roots in the history of insurance, dating as far back as September 2, 1666, with the Great Fire of London (Hodgson, 1984). It was this event in history that is credited with the development and evolution of modern-day insurance. The focus since has been on the physical property damage aspect of coverage, with the belief that preventing fire damage will inevitably reduce or prevent business interruption revenue from that physical location. BI insurance evolved more within the traditional maritime marine industry. Insurance was provided based on the value of goods sold that were being transported and the payment for the coverage was a percentage of the goods value once it reached the destination safely. It has not generally been until recent history and globalization in the 1980's that BI coverage has emerged as being more of a threat to a business than the loss of a property.

Of importance however is the fact that BI insurance coverage is generally activated by an insurable physical damage loss, thus still making the business focus of loss prevention based on physical damage protection. This approach has results in the practice of placing caps on BI coverage indemnity periods (typically 12 months) as well as unique deductibles of both time and value. Coverage limits are generally derived from a company's annual balance sheet and in the event of a loss, forensic accounting is deployed by insurance carriers (as needed) to calculate the current trajectory of revenue and an appropriate valuation of lost revenue, up to the indemnity period and subtracting the deductible. Insurance may not cover lost market share and will not extend past the indemnity period unless additional extended indemnity coverage is requested as part of the initial policy.

Given both the operational and insurance-related connections between BI and property damage, there should be, at the very least, a focus on identifying a balance between decisions that focus on property damage and decisions that focus on reducing BI with the balance being dependent on cost-effectiveness considerations. That balance begins by first understanding the conceptual difference between two important concepts, *resilience* versus *mitigation*. These two concepts are more thoroughly explained in Dormady et al. (2022b) and Rose (2007). This focus is also important because the very definitions of resilience that are most often relied upon for decision making, particularly in the public sector, provide considerable overlap in key concept terminology. See definitions by the National Research Council (2022) and the National Institute of Standards and Technology (NIST, 2020). These more common definitions tend to conflate actions taken before a disaster to reduce property damage and actions taken after a disaster to cope or maintain function. However, there is a perfectly good term for actions taken before a disaster—*mitigation*. Mitigation includes activities such as strengthening building structures, retrofitting facilities to improve their probability of failure, etc.[v]

Blurring the definitional lines between business activities that contribute to resilience from those that contribute to reducing property damage, which is mitigation and is distinct from resilience, does a disservice to businesses that require clear concepts to inform cost-benefit decision making that can help them prioritize actions when it is no longer possible to reduce property damage, and it does a disservice to those communities or customers relying upon those businesses. In other words, this paradox carries consequences for society. If a business cannot identify which set of resilience tactics will result in the greatest avoided losses for the least cost, then that business will be forced to fall back on historical best practices, one-size-fits-all checklists, or other ad-hoc approaches. This lack of conceptual clarity makes it more challenging to find the most cost-effective strategies.

Unlike mitigation, which focuses on reducing property damage, and which cannot be undone once the disaster has hit, resilience focuses on addressing post-disaster losses such as BI that can be orders of magnitude larger than property damage in dollar terms for affected businesses. Resilience begins when the disaster strikes and carries through until the business has recovered or has entered into its new post-disaster normal. This is not to ignore the important pre-disaster work that can be done to preposition resilience actions for the greatest impact and cost-effectiveness ahead of a disaster (NIST, 2020). But, if those pre-disaster actions are intended to reduce property damages when the disaster hits (e.g., deterrence or target-hardening), they are distinctly mitigation. Prepositioning for resilience actions may aid in the implementation of resilience once the disaster strikes. Put another way, mitigation and resilience can work hand in hand.

Defining Resilience as Distinct from Mitigation

In the broadest of brush strokes, resilience can be thought of as efficient recovery. As distinct from mitigation, resilience can be defined as one of two forms. In general, Static Resilience refers to the ability of the system to maintain a high level of functioning when shocked (see, e.g., Holling, 1973). *Static Economic Resilience* is the efficient use of remaining resources at a given point in time (Rose, 2004; 2009; Rose & Dormady, 2021).[vi] It refers to the core economic concept of coping with resource scarcity, which is exacerbated under disaster conditions. Business continuity implemented efficiently is thus synonymous with static economic resilience.

In general, Dynamic Resilience refers to the ability and time-path of the system to recover (see, e.g., Pimm, 1984). *Dynamic Economic Resilience* is the efficient use of resources over time for investment in repair and reconstruction (Rose, 2007; 2009). Investment is a time-related phenomenon—the act of setting aside resources that could potentially be used for current consumption in order to re-establish productivity in the future. Static Economic Resilience does not restore damaged capacity and is thus not likely to lead to full recovery in cases where such damage takes place.[vii] That does not mean that static resilience is trivial, as it can represent the lion's share of avoided economic losses for a business. It simply means that without dynamic resilience, full recovery is not generally possible using static resilience, alone.

The next section presents three resilience metrics that can be used to inform cost-effective business resilience decision making and which can be used to evaluate resilience tactic implementation planning efforts to improve business continuity and recovery.

Key Concepts and Metrics

Before resilience metrics that can be used to inform cost-effective resilience decisions are presented, it is important to define some key concepts. The authors first begin by defining two additional types, or distinctions within the definition of resilience, the concepts of *inherent* versus *adaptive* resilience. In this section they also define two additional core concepts, *avoided losses* and *potential losses*, and they explain how they are distinguished from one another and why they are important to decision making. Following the presentation of these concepts, the authors discuss three important resilience metrics that can be used to support cost-effective business resilience decision making.

Inherent versus Adaptive Resilience

Inherent resilience is already built into the system before the disaster strikes. It is either intrinsic, such as the ability to substitute ordinary inputs or the existence of excess capacity, or pre-positioned, as in the purchase of a portable electricity generator or lining up alternative input suppliers. For the most part, inherent resilience tactics can be triggered immediately (e.g., use of inventories), and, in fact, triggered automatically in some cases (e.g., excess capacity). Moreover, the costs are often incurred in advance of a disaster (e.g., back-up electricity generators, build-up of excess capacity). Some intrinsic tactics may, however, dissipate over time (e.g., the stock of inventories, excess capacity) (see Dormady et al. (2022a); Rose(2007)).

Adaptive resilience is more about unanticipated actions, and even improvisation. Firm-level actions with an adaptive resilience component often improve productivity over time. This can include for example, increased substitution possibilities, relocation opportunities and technological change. Note that some tactics have both inherent and adaptive components. One example is input substitution, which can be undertaken with the pre-disaster options and possibilities embodied in elasticities of substitution, or which can be enhanced after the disaster strikes to make the substitution even easier, thereby imposing less of a potential cost penalty of using alternative input combinations (Dormady et al., 2022a; Rose & Liao, 2005).

Generally, costs associated with implementation of inherent resilience tactics are incurred after the disaster has hit, and the resilience tactic has been implemented to maintain business function. However, for inherent resilience tactics, implementation costs may best be carefully considered in cost-effective business continuity planning as distinct from pre-positioning costs. Pre-positioning costs that are incurred in advance of a disaster should be considered (or weighted) in light of several considerations. Among the most important are the following three: 1) the probability of the disaster or disruption, 2) the application of the tactic to future disasters beyond a single use case (i.e., will pre-positioning be a sunk cost or will it be useful for multiple future disruptions), and 3) the discount rate otherwise known as the firm's internal rate of return. For adaptive resilience tactics, only implementation costs are generally needed, since these tactics are applied with certainty after the disaster strikes (hence no probability or discounting adjustment is needed).

Readers are referred to Cutter (2016), Dormady et al. (2019a; 2022a), and Rose (2009; 2017) for a more detailed conceptual description of inherent versus adaptive resilience. The authors note that these two concepts are important to cost-effective resilience decision making because they can influence both the cost and the effectiveness of the tactic or set of tactics. Generally, and without regard to any specific business, sector or tactic type, research demonstrates (Dormady et al., 2022a) that tactics that can have an adaptive component tend to be more effective and more cost effective, while inherent resilience tactics tend to be less costly to implement.

Avoided Losses and Potential Losses

Business interruption (BI) cannot be understood without first understanding two additional microeconomic concepts. The first of these is *avoided losses*. Avoided losses are, just as the term suggests, the value of losses that are avoided by the implementation of a proactive individual, or set of, post-disaster resilience actions, or tactics. The second of these is *potential losses*. Potential losses are BI losses not necessarily incurred by a firm, but which would otherwise be incurred in the absence of concrete steps (tactics) to mute BI losses and maintain business continuity.

Another way to conceptualize potential losses is as a counterfactual, baseline, or control condition that is consistent with the way in which a business would conceptualize decision making when they are struck by a disaster. Once struck by disaster, a business will be forced to evaluate the likely outcome of a set of tactics to avoid losses, considering the likely outcome in the absence of implementing those tactics. The absence of resilience actions entirely, or the do-nothing outcome is referred to as *maximum potential losses* (for a given disaster), i.e., those BI losses observed by firms not implementing any resilience actions.[viii] These can be thought of as the "do-nothing" losses, or what the firm would observe in the absence of any explicit resilience actions. Dormady et al. (2022a; 2019b) estimate this using survey instruments that query executives or business owners to identify the sales revenue losses that would have been observed had resilience tactics not been implemented.

This highlights the importance of these do-nothing losses as a conceptual reference point because other resilience metrics, described in detail in Hosseini et al. (2016) and distinguished in Dormady et al. (2022b), are compared against the counterfactual condition of the absence of the disaster. The authors note that those metrics, often referred to as "loss triangle" metrics, are less relevant for pragmatic business decision making because the absence of the disaster is functionally outside of the business's control. The implementation of a tactic or set of tactics is on the other hand, within their control and a much more reasonable comparison. Therefore, the metrics presented below compare outcomes between whether or not the tactic is implemented, rather than metrics that make comparisons relative to the absence of something outside of the business' control.

It is also important to note that all economic resilience metrics have a counterfactual condition. That is, they compare outcomes between two different alternative states of nature. Some of these counterfactuals are more tractable than others. Some are based on observed losses, which can be referred to as "loss-triangle metrics," as they relate to common visualization of the time-path of business functionality beginning when the disaster strikes and concluding at recovery (see, e.g., Rose, 2007). Dormady et al. (2022b) discuss most of these metrics in a systematic review. Specifications of this metric are subject to the criticism that they are actually measuring losses, rather than resilience (see, e.g., Bruneau et al. (2003)). Other resilience metrics are based on a counterfactual condition based on the absence of the disaster. These metrics are subject to similar criticisms.

Firm-level Resilience Metrics

It is important that business decisions be guided by pragmatic resilience metrics that inform the most cost-effective steps a business can take when it is disrupted. These metrics should be actionable and help prioritize concrete next steps. And, while resilience metrics that compare to a counterfactual of the absence of a disaster may be helpful for academic applications, they fall short of providing actionable decision-making guidance for real businesses who do not have the option of turning back the clock and making the disaster disappear.

Here, three metrics are presented, and intended to be helpful for resilience and business continuity decision making. They each are based on the three concepts; implementation cost, avoided losses and maximum potential losses. These metrics put the decision maker in the proverbial driver's seat by enabling them to conceptualize each tactic's efficacy in terms of tractable measures like output and sales revenue.

The first of these is the resilience metric (RM). It was originally coined "direct static economic resilience (DSER)" by Rose (2004)[ix] and later adapted in various case studies by Rose and colleagues cited in this chapter and by Dormady et al. (2022a) to empirically measure effectiveness of specific tactics at the micro level. The RM represents the proportion of maximum potential losses that a firm avoided using a tactic. The RM is given by:

$$RM_{i,j} = \frac{AvoidedLoss_{i,j}}{MaximumPotentialLoss_i}$$

where the RM for firm i using tactic j equals the avoided losses associated with the tactic divided by the maximum potential losses faced by the firm.

As an example, an RM of 0.04 indicates that a firm avoided 4% of its maximum potential losses by using a tactic *j*. Moreover, RMs are easy to interpret because they are bound between 0 and 1. The RM is bounded by 0 because both avoided losses and maximum potential losses are strictly positive. It is also bound by 1 on the other end as a firm cannot avoid greater than one hundred percent of the losses that it would have observed in the absence of resilience actions. While the RM can be considered an impact metric, this metric was supplemented by the authors in recent work (see Dormady et al. (2019a; 2022a); Rose (2017)) to include cost considerations. The additional two metrics described below do just that.

The second metric is the benefit-cost ratio (BCR). Because cost-effectiveness is a critical consideration not only to economists but also to individual businesses, the BCR provides an accessible "bang for buck" metric to gauge the relative cost-effectiveness of resilience actions or tactics. This helps decision makers, as well as insurers, prioritize resilience expenditures and investment decisions. The BCR provides a ratio of dollars in to avoided BI losses out. For firm i using tactic j:

$$\text{BCR}_{i,j} = \frac{AvoidedLoss_{i,j}}{Cost_{i,j}}$$

where the BCR equals the avoided losses associated with that tactic (its effectiveness) divided by the cost.

As an example, a BCR of 5.71 indicates that a firm avoided $5.71 in losses for every dollar spent on a given tactic. This metric is most useful for comparison among tactics and for prioritizing which tactics to use. The below metric, the RCE, is useful for determining the extent of implementation for a tactic—i.e., how much it can or should be used. It is also helpful to note that BCRs less than 1 indicate tactics that are not fully capturing their implementation costs. This does not necessarily mean that the tactic should not be implemented, as the tactic may be necessary for other non-economic considerations. It is also important to note that BCRs can be negative or nondefinitive. Negative BCRs occur when the implementation cost of a tactic is negative, or a savings, such as in the case of some conservation efforts. And, nondefinitive BCRs exist when implementation costs are cost-neutral.

The third metric introduced in Dormady et al. (2022a) is the resilience cost-effectiveness metric (RCE). It is given by:

$$RCE_{i,j} = \frac{RM_{i,j}}{Cost_{i,j}}$$

where the RCE for firm i using tactic j is equal to the RM of the tactic divided by its implementation cost. The RCE is interpreted as the proportion of maximum potential losses avoided for every dollar spent on a tactic. Often and depending on conditions such as firm size, it is helpful to rescale RCEs to larger dollar denominations. For example, an RCE of .002 can indicate that a firm avoided 0.20% of its maximum potential losses for every ten thousand dollars spent. This can be scaled as appropriate based on the targeted level of resilience and the size and scope of the firm and tactic. The RCE combines the RM and the BCR together so that cost-effectiveness decisions can be made in light of the desired target of avoided losses. This may support decision making that is based on investment targets, informing the question of how much a firm needs to spend in order to reach a given resilience target (e.g., avoiding 30% of its maximum or do-nothing losses).

Another metric worth noting because it specifically isolates the effectiveness of dynamic resilience comes from Rose (2007). He identifies this effectiveness as the integral sum of the sales revenue obtained (or loss of revenue avoided) through the hastening of recovery through investment and repair minus the sales revenue that would have occurred had the firm not made additional investment. In subsequent research Rose & Dormady (2018) and Xie et al. (2018) point out that dynamic resilience is promoted more by accelerating (jump-starting) the pace of recovery than by shortening its duration (see also Baghersad & Zobel (2022); Zobel (2014)).

Observational Data from Hurricane Harvey

It may be helpful to readers to see examples of these metrics applied to observational data from the past experiences of businesses affected by a major disaster. In this section, the authors provide some helpful tables with some basic summary statistics from data collected from firms affected by Hurricane Harvey in Texas in Autumn 2017 (N = 153 businesses). Some of these results were previously published in Dormady et al. (2022a) for the manufacturing sector along with summary statistics for other sectors. Readers are referred to that publication for a detailed summary of the methodological approach and survey methods used in gathering this data, as well as sample size and other details. While that publication focuses on two major disasters, here the authors focus only on results from Hurricane Harvey and exclude more advanced statistical approaches so that readers can focus on basic principles for decision making.

The sampling approach stratified respondent firms by size and property damage, and thus included firms that observed property damage and BI, and firms that observed only BI without property damage. In total, 58% of firms in the sample had both BI and property damage. Figure 1 provides a graphical map of the location of firms (by business address) and their reported BI as measured by the percent of sales revenue lost over the duration of their respective recovery window. The authors note that business and supply-chain linkages can result in BI at considerable distances from the affected area or inundation area. For example, Hurricane Harvey had considerable economic impacts on businesses located in the Dallas-Fort Worth metro area.

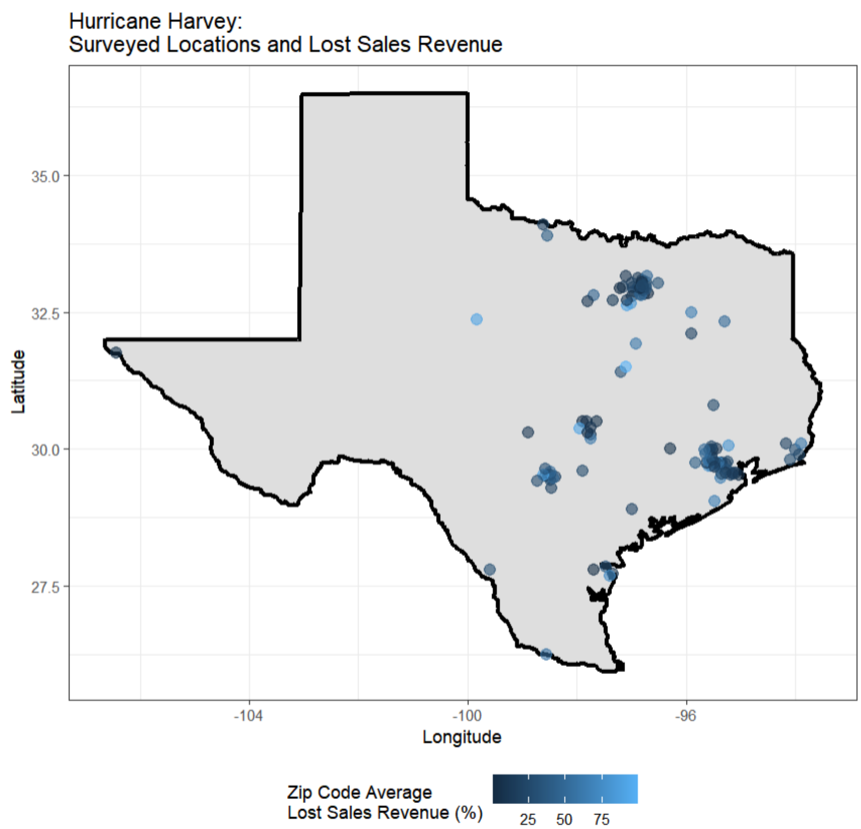

Figure 1. Surveyed Locations and Business Interruption

Business interruption by zip code of business activity for Hurricane Harvey. Gradient shading reflects magnitude of sales revenue losses by respondent firm. Source: Authors.

To illustrate the point made previously about the importance of focusing on BI in addition to property damage, the authors compare the dollar value (in 2018 USD) of reported business property damage and BI. Table 1 provides this by sector for a six-sector aggregation by North American Industrial Classification System (NAICS). It also provides this for all respondent firms in total across all sectors. Values are reported in medians to address relative firm size differences. For example, in the trade sectors, BI was reported to be more than 58 times larger than business property damage. Overall, BI is 129 times larger than property damage. Table 1 also separates out these values for the subsample of firms that experienced both property damage and BI in the right-hand side columns. Overall, among firms observing property damage, BI was about 7.5 times greater than property damage.

Table 1. Property Damage and Business Interruption by Sector from Hurricane Harvey

Sector	Property Damage	Business Interruption	Property Damage (among firms with property damage)	Business Interruption (among firms with property damage)
Agriculture, Mining, Energy, and Construction	$15,000	$500,000	$100,000	$3,187,500
Transportation, Communication, and Utilities	$100	$1,125,000	$87,500	$3,187,500
Manufacturing	$250,000	$1,751,875	$300,000	$5,000,000
Trade	$3,100	$179,875	$85,000	$360,000
Finance, Insurance and Real Estate	$22,500	$65,625	$112,500	$147,500
Service	$500	$256,250	$25,000	$723,750
All Sectors Combined	$2,000	$259,125	$75,000	$568,750

Note: Table provides values at the median for all firms in the sector.

Table 2. Sources and Magnitude of Business Disruption by Sector from Hurricane Harvey (All Firms)

Sector	Agriculture, Mining, Energy, and Construction	Transportation, Communication, and Utilities	Manufactur-ing	Trade	Finance, Insurance and Real Estate	Service	All Sectors Combined
Employees unable to travel to work	10%	10%	11%	10%	10%	10%	10%
Employees moved away	5%	10%	9%	0%	0%	0%	0%
Communication problems	10%	10%	9%	5%	5%	5%	10%
Supply chain problems	10%	10%	11%	10%	8%	0%	10%
Power outages	10%	10%	11%	8%	3%	0%	5%
Natural gas outages	0%	0%	10%	0%	0%	0%	0%
Water outages	5%	0%	9%	0%	0%	0%	0%
Transportation problems	10%	10%	10%	20%	8%	10%	10%
Facility underwater	0%	0%	3%	0%	0%	0%	0%

Note: Table provides values at the median for all firms in the sector.

As mentioned previously, it is important for a business to consider its production function and how it uses its inputs (e.g., labor, materials, capital) to produce its products and how disruptions to those various inputs would impair its ability to maintain function in the aftermath of a disaster. In other words, it is not enough for a business to simply plan for a flood versus a fire, but it should also understand how its factors of production would contribute to disaster losses if they were curtailed. Tables 2 and 3 provide some respective results from Harvey, by sector, for a group of disruption types that generally map to factors of production. Respondents were asked to apportion their BI by input disruption type. Labor and infrastructure and materials flow disruptions of various kinds are included.[x] For labor disruptions, the estimates separate out employees who were permanently lost to the business due to relocation from employees who were temporarily unable to come to work. Both tables provide values at the median of the sample. Table 2 provides values for all firms in the sample, while Table 3 separates out values among the subsample of firms with physical property damage.

Table 3. Sources and Magnitude of Business Disruption by Sector from Hurricane Harvey (among firms with property damage)

Sector	Agriculture, Mining, Energy, and Construction	Transportation, Communication, and Utilities	Manufacturing	Trade	Finance, Insurance and Real Estate	Service	All Sectors Combined
Employees unable to travel to work	10%	10%	11%	10%	15%	10%	10%
Employees moved away	5%	10%	10%	10%	0%	0%	5%
Communication problems	10%	13%	8%	0%	5%	2%	5%
Supply chain problems	10%	10%	11%	10%	3%	10%	10%
Power outages	12%	10%	11%	10%	15%	10%	10%
Natural gas outages	3%	8%	10%	0%	0%	0%	0%
Water outages	8%	10%	10%	0%	0%	0%	0%
Transportation problems	15%	10%	10%	20%	10%	10%	10%
Facility underwater	10%	10%	9%	10%	13%	10%	10%

Note: Table provides values at the median for all firms in the sector.

The results indicate considerable heterogeneity across firm- and disruption- types. This provides some insight into the diversity in factors of production used by businesses. But more importantly for purposes of cost-effective continuity planning, there is no one-size-fits-all planning approach. In other words, all of these firms faced a common disaster (a hurricane) but they experienced considerably mixed impacts across various sources of their losses. For example, while the median firm in the trade sector experienced 20% of their losses resulting from transportation disruptions, the median finance, insurance and real estate sector firm attributed only 8% of their losses to transportation disruptions. The pragmatic conclusion that should be clear is that a business should not plan for addressing disruptions to only a subset of production factors. A disaster can impact a business' production process in peculiar and unanticipated ways, and it may be most prudent to build resilience plans that address all production factors.

Another helpful way to view this data is separately by the three main components of the metrics presented. Recall that those components were Avoided Losses, Maximum Potential Losses, and the Amount Spent on Tactics. Table 4 provides these by sector, and again separates results between all firms, and only firms observing property damage. It shows both median values and average, or mean values. It is also important to note that tactic cost can include tactics with cost-neutral and cost-negative (savings) implementation. Many firms reported both cost saving and cost incurring tactics at the same time.

Table 4. Cost and Effectiveness by Sector, Hurricane Harvey

	All Firms in Total					
	Avoided Losses		Amount Spent on Tactics		Maximum Potential Losses	
Sector	Median	Average	Median	Average	Median	Average
Agriculture, Mining, Energy, and Construction	305,000	408,125	47,500	231,063	640,000	37,853,195
Transportation, Communication, and Utilities	48,750	328,750	1,500	28,633	1,500,000	51,163,437
Manufacturing	225,000	1,102,136	164,900	687,717	997,500	65,833,911
Trade	138,750	219,406	51,650	188,688	331,875	2,766,219
Finance, Insurance & Real Estate	11,500	22,650	10,000	11,260	132,625	19,790,643
Service	86,250	325,808	13,750	186,617	311,250	9,941,413
All sectors combined	102,500	413,500	17,500	244,003	410,000	21,787,489
	Firms with Property Damage					
	Avoided Losses		Amount Spent on Tactics		Maximum Potential Losses	
Sector	Median	Average	Median	Average	Median	Average
Agriculture, Mining, Energy, and Construction	305,000	454,167	47,500	247,667	3,897,500	40,662,501
Transportation, Communication, and Utilities	48,750	328,750	1,500	28,633	4,145,000	17,285,000
Manufacturing	455,000	1,330,250	681,000	838,322	1,220,000	80,048,586
Trade	62,500	226,100	20,000	240,460	293,750	2,131,500
Finance, Insurance & Real Estate	38,750	33,833	7,500	11,433	300,000	26,747,800
Service	135,000	454,302	45,000	245,566	775,000	15,556,175
All Sectors Combined	145,000	547,095	45,000	317,724	750,000	28,057,742

Note: Table 4 includes only cost-incurring tactics in the estimation of avoided losses and tactic implementation costs, and cost-neutral and cost-negative (savings) tactics are not included. All values in 2018 USD.

Across all sectors, the average firm reported avoided losses of approximately $413K. This value is driven upward by the share of large multinational firms in the sample, and the authors believe the median is a more accurate representation for generalizing. The median value is $102K. Restricting the sample to only those firms with property damage, median avoided losses increase from that value by approximately 40%. Across all sectors, maximum potential losses are, at the median, just over $410K, and at the average they are approximately $21.7M. Generally, the greatest avoided losses and maximum potential losses are found in the most capital-intensive sectors such as manufacturing and transportation, communication and utilities.

The amount spent on tactics should be contextualized relative to its respective resilience metrics, which are provided below, because of the presence of cost incurring and cost neutral tactics. In Dormady et al. (2022a) a more detailed deep dive into these cost values for the manufacturing sector is provided, and separated out for cost saving and cost incurring values. As presented in Table 4, the sample and present results are presented as observed by individual firms (i.e., a firm-level analysis) rather than at the tactic level where one could separate out the amount spent on individual tactics. This approach of evaluating the cost of tactics separately should be considered for any individual business continuity planning process, however, here the results are shown at the aggregate business level. Overall, firms spent approximately $17.5K on cost-incurring resilience tactics at the median, and $244K at the average. Among firms with property damage, these values are $45K and $317K. Across the board, the manufacturing sector spent the greatest on the implementation of resilience tactics.

Resilience metrics are presented at the firm-level in Table 5.[xi] It provides metrics at the median of the samples, and the presentation omits the averages for concision.[xii] Across all firms, the median BCR is 5.86. This indicates that the median firm avoided $5.86 in sales revenue losses for every dollar spent on cost-incurring resilience tactics. Among firms with property damage, that value is 3.22. The greatest BCRs were reported among transportation, communications and utilities sector firms. Manufacturing firms with property damage report the lowest median BCRs. However, manufacturing firms observed the most favorable RMs among firms with property damages, avoiding more than 37% of max potential losses at the median. Manufacturing firms with property damage thus implemented less cost-effective tactics than other firms but implemented them to a greater extent and thus avoided a greater proportion of maximum potential losses than other types of firms. Contrariwise, firms in the transportation, communications and utilities sector, while observing the most cost-effective tactics, utilized them considerably less extensively, avoiding only a little greater than 3% of their max potential losses.[xiii] Generally, the other sector with the lowest RMs for cost-incurring tactics was finance, insurance and real estate.

As mentioned previously, the RCE metric reports on the extent of avoided losses per $10K spent implementing cost-incurring tactics. Service sector firms without property damage reflect the highest RCE values, while among firms with property damage, the finance, insurance and real estate sector reflects the highest RCE values. This is driven by that sector's low median maximum potential loss and tactic expenditure values. Compared to manufacturing, the median finance sector firm had less than a quarter of the maximum potential losses and spent 90 times less implementing tactics. On the whole, however, firms avoided approximately 14% of their max potential losses for every $10K spent, and this number is 4% (3.5 times smaller) among firms with property damage.

Table 5. Aggregate Sector Resilience Metrics

Sector	Agriculture, Mining, Energy, and Construction	Transportation, Communication, and Utilities	Manufactur-ing	Trade	Finance, Insurance and Real Estate	Service	All Sectors Combined
All Firms in Total							
BCR (Median Avoided Losses/Median Spent)	6.42	32.50	1.36	2.69	1.15	6.27	5.86
RM (Median Avoided Losses /Median Maximum Potential Losses)	0.4766	0.0325	0.2256	0.4181	0.0867	0.2771	0.2500
RCE (Median Resilience Metric/Median Spent) (Per $10K)	0.1003	0.2167	0.0137	0.0809	0.0867	0.2015	0.1429
Firms with Property Damage							
BCR (Median Avoided Losses/Median Spent)	6.42	32.50	0.67	3.13	5.17	3.00	3.22
RM (Median Avoided Losses /Median Maximum Potential Losses)	.0783	.0118	.3730	.2128	.1292	.1742	.1933
RCE (Median Resilience Metric/Median Spent) (Per $10K)	0.0165	0.0784	0.0055	0.1064	0.1722	0.0387	0.0430

Note: Table 5 includes only cost-incurring tactics in the estimation of metrics using avoided losses and tactic implementation costs, and cost-neutral and cost-negative (savings) tactics are not included. All values in 2018 USD.

Empirically Informed Resilience Decision Making

This section focuses on the practical implementation of empirical resilience metrics. So far, the chapter has introduced some technical concepts and some advanced resilience metrics and demonstrated their measurement in the aggregate among firms impacted by a major disaster. But the practical implementation of this information for an individual business deserves attention. How can an individual business apply these concepts and metrics to their own business continuity and resilience management planning process? What should the set of considerations be when deciding how to plan and process this information? These considerations include characteristics specific to the business, identifying limitations and constraints, and other production and operations considerations such as supply-chain concerns and regulatory considerations.

Using Cost and Effectiveness Data

It is important to note that the information necessary to formulate and build a firm's resilience metrics may be more challenging to obtain for some businesses than others. For large businesses and multinationals with highly complex and interdependent production processes, estimating key metric components such as maximum potential losses may require scenario-based estimation, sensitivity analysis and modeling capabilities.[xiv] They have a decided advantage with risk management departments, resilience officers and/or external consultants with analytic capabilities that small and middle-market firms do not have. However, while they generally have greater technical and analytical complexity, they also have more technical interdependencies and operational complexity, and face greater exposure to hazard risks. For smaller businesses or businesses with less production or operational complexity, these informational challenges may be more easily overcome. At the same time, smaller businesses generally do not have the capability to estimate or model tactic implementation scenarios that large businesses do. Middle market, or mid-sized enterprises, face a unique set of challenges as they are generally more complex but often have some of the same limitations of smaller firms.[xv]

To utilize this approach, a firm needs to identify the three metric components. These are the implementation cost for each tactic, avoided losses from each tactic, and maximum potential losses. The cost of implementing each tactic may require adjustment for factors such as the firms' discount rate, if appropriate. The avoided losses and maximum potential losses, which are conceptually described earlier in the chapter, can be estimated by the identification of three specific levels of output or sales revenue over the time horizon associated with the implementation of each tactic: 1) the output or sales revenue the firm would have made during the same period of time as the duration of the tactic, 2) the output or sales revenue the firm estimates it will make during that time *with* the implementation of a tactic(s), and 3) the output or sales revenue the firm estimates it would make during that time in the *absence* of the implementation of a tactic(s). The difference between 3 and 1 provide the maximum potential losses, while the difference between 3 and 2 provide the avoided losses.

Sales revenue, which is a flow rather than a stock, is generally more conceptually tractable for estimation purposes for businesses, but, for some, output as measured by units of production may be more appropriate. The authors note that the time horizon over which sales revenue is measured as a flow can be a conceptual grey area for decision makers because the timeline of the disaster's disruption and the timeline of the implementation of a tactic(s) can be different. A pragmatic approach is recommended when considering the timeframe involved, and considering that some tactics may take some time to implement or may be limited in implementation due to physical constraints such as the red tagging of the facility, discussed below. As such, the authors encourage thoughtful consideration of issues such as lag effects (e.g., tactic implementation today may not be reflected in sales revenue for several days or longer) when estimating avoided or maximum potential losses. The timeframe suggested in the previous paragraph (i.e., estimation of these flows over the timeframe of the implementation of the tactic) may be appropriate for some and not for others because of these and other related issues. More fundamentally, these decisions should be pragmatically guided by the question of cost-effectiveness, and the temporal dimension, while presenting estimation challenges, should not detract from that overall objective.

There are also some fruitful decision support tools evolving in this space that may help support at least some of these objectives. Some of the authors of this manuscript have a decision support software tool developed in collaboration with the US Department of Homeland Security that uses observational data collected from disaster-affected businesses to produce resilience metrics for users and to aide in future business continuity and resilience planning decisions. The Resilience Calculator (available at https://resiliencecalculator.com/) has two suites or modules. One is retrospective in nature that allows a business that has experienced a disaster to obtain resilience metrics to assess its own resilience. The other is prospective in nature and supports planning by matching businesses with other businesses of similar types and sizes and disruption characteristics and providing expected benefit-cost and other metrics for future scenarios in support of data-drive resilience planning.

Additional Considerations

While resilience metrics help to identify strategic priorities for business continuity and resilience planning, such as the prioritizing of resilience tactics and the evaluation of alternative resilience plans, there are of course several other key considerations that can impact the implementation of cost-effective resilience.

The nature of the firm itself is of course a preeminent consideration. That is, the size of the firm, its sector and production process, and how it uses inputs and how those inputs respond to various types of interruptions. This can also include regional, spatial and local market considerations. While many of these considerations were described earlier in the chapter, the authors highlight the importance of considering how the nature of a business can influence cost and effectiveness. Oftentimes businesses are guided by information provided by other types of firms that may or may not be generalizable to their own enterprise, and this can potentially lead to misguided decisions and inefficient recovery. Resilience checklists and related applications can provide very helpful information and a thorough set of considerations; however, estimating any of the resilience metric components with data or experiences from fundamentally different businesses deserves considerable caution.

Ideally, it would be more beneficial for a decision maker to have access to a tool or set of tools that provide a large sample of cost and effectiveness data for similar businesses that have experienced similar disruptions. Businesses could then learn from the experiences of other businesses as closely matched to their own as possible and learn from them based on what they did that worked and what they did that did not work in terms of cost and effectiveness. The information could be used to assess internal cost and loss estimates, and if different, may help to elucidate cost parameters or considerations omitted from one's internal analyses.

Supply chain considerations are also important, and they are discussed in greater detail in the next section regarding insurance considerations. In the current business environment, competition does not only occur between individual companies alone, but rather between supply chains (see e.g., Christopher (2000)). Depending on the number of layers small- and medium-sized companies (SMEs) find themselves away from the nucleus firm, SMEs can be more exposed and more vulnerable to a variety of risks including natural disasters, geopolitical events, economic fluctuations, and technological disruptions. Ideally, a firm not only needs to consider its own operations and the range of resilience tactics available, but the level of integration, and the required capabilities demanded by its supply chain. These requirements might include specific inventory management policies, supplier redundancy, agile operations and strategic partnerships that allow businesses to share and diversify their risks.

Communication is also an important consideration. In order to improve organizational resilience and deploy effective decision making for recovery, communication is paramount and should exist between all levels of staff at each location, as well as between decision-makers across like/sister facilities. Firms with effective resilience planning oftentimes establish a location- or division-specific resilience committee or department, as well as a corporate resilience committee or department.

Within a location or division (with multiple locations with similar operations), communication from frontline employees through procurement/sales into the management group should be involved in the local communication and committee discussions. Front line employees will be familiar with any type of production concerns or critical components operations. Maintenance would be familiar with the status of equipment and building operations. Procurement and sales would have insights into raw materials and current sales as well as excess capacity related to procurement, sales and logistics. Management would be able to collate the location resilience data and work within the corporate entity to understand spare capacity at their location in a given timeframe. Having a clear picture of the location capacity and communicating it to the broader division/group will allow the entire organization to know where spare capacity exists, in which region, and thus be able to properly plan for alternative production. It also allows for testing of a business continuity or resilience plan and making affordable, cost-effective resilience decisions that will help reduce lost revenue and maintain market share.

Beyond communication, multi-location and multi-facility firms may also observe tactic implementation differences that need to be taken into consideration. The applicability of resilience tactics and their cost effectiveness can differ among various component facilities (e.g., headquarters versus assembly lines versus storage facilities). Rose and Huyck (2016) show how resilience analysis can be applied at a higher level of resolution and how it can improve the accuracy of estimates of BI losses that can be prevented. This can be useful to both insurer and insured evaluating disaster risk, which has the potential to lower BI losses.

Establishing a resilience organizational capability would be similar to an organization's Health & Safety Committee. The focus would revolve around a well selected group of individuals that can meet on a scheduled basis and ensure the proper communication of the state of the location's operations, including, but not limited to, level of production capacity, spare critical parts, availability of key employees, preventative maintenance, preparation for probable natural hazards events (typical for their locations region) and known risk exposures still to be eliminated or reduced.

Through communication and a business resilience committee, the organization can better select the appropriate resilience measures in the event of an unexpected large loss or shifting of operations in preparation for a known impending loss, such as hurricanes, wildfires, and floods.

Two key areas with consideration to resilience communication are the real-time knowledge of spare capacity within a production line, across sister locations with similar production lines, and excess capacity in warehouse storage and logistics. The authors refer to this as the resilience tactic *excess capacity*. If part of the organization's resilience plan includes use of external partners for spare capacity of production or storage, they too can be consulted on a frequent basis. In addition, having knowledge of critical equipment and spare parts is also key for capacity relocation and overall operational resilience.[xvi]

In practice, there can often be information asymmetry in planning for excess capacity. This is because most organizations make assumptions as to spare capacity within their group and from external sources that are frequently incorrect. Due to a lack of communication and knowledge of the staffing/costs to shift production to these possible alternatives, as well as not fully understanding how insurance coverage may or may not provide relief, firms may find themselves in a position where their initial planning is not viable and may not even be feasible at the most critical time(s).

Finally, criticality of equipment (capital) is also a key consideration. For organizations that have critical equipment (production equipment for manufacturing; air handling units for commercial real estate; x-ray/MRI/CAT equipment for health care; etc.), having a clear understanding of where, within or outside the group, the same equipment may either be sourced and brought to the loss location or where production can be shifted to the alternative location is a key component of operational resilience. If an organization procrastinates on planning critical equipment redundancy (including critical spare parts) they will likely face a loss event and use more time sourcing alternatives. Typically, the longer it takes an organization to implement an event loss reduction action, the longer the subsequent recovery time will take with varying exponential degrees. Substitution of critical or spare parts with inferior or alternative parts may create additional operational or cost-effectiveness considerations down the road, as well as doing damage to a business's reputation. Knowing the organization's ability to recover aging equipment allows for future planning and understanding sources that can be used to either shift production, move to an external source or procure new equipment.

Key Considerations for Business Interruption and Contingent Business Interruption Insurance

This section focuses on the decision-making process as it relates to binding insurance coverage for business interruption (BI) and contingent business interruption (CBI). It also touches on the insurance risk perspective of how to assess and manage insurable and non-insurable risk in the process of prospective planning and resilience action planning. It is noted at the outset that, in some nations or contexts, some of the presented terminology that is used here may be different.

Insurance is a key component of any risk transfer to a business' overall resilience. The general process begins with an initial risk assessment to understand the current state of risk exposure, what is tolerable and what is not tolerable. The next step is to reduce or avoid any possible risk exposures in order to reduce the need for risk transfer (insurance) or risk acceptance (willingness to absorb losses). Engaging insurance at this stage allows for the insurer's engineering department to help ensure that mitigation/avoidance measures do not create other uninsurable risks. When looking to transfer risk, there will always be an absorption of loss prior to the insurance being activated (due to a deductible), as well as an absorption of some recovery costs after the indemnity period.

Globally, BI insurance coverage is underwritten in two different underwriting models. The first is the Gross Profits model. This provides coverage at the time of the insurable loss, through the recovery phase and the ramp up of production to pre-loss levels (within the given indemnity period). Second is the Gross Earnings model, which provides coverage at the time of an insurable loss until the recovery has completed (essentially the point just prior to turning on the replaced production) but does not include the ramp up of production to pre-loss levels. See Figure 2. Extra coverage is required to deal with this area of recovery. Gross Earnings is the model used in the United States, Japan and can also be found in some policies within Canada. The remainder of the world, and more commonly used in Canada, is the Gross Profit model. Understanding a firm's BI insurance policy and if it is written in the Gross Profit model or Gross Earnings model is key information when assessing and understanding a business recovery that is insurable.

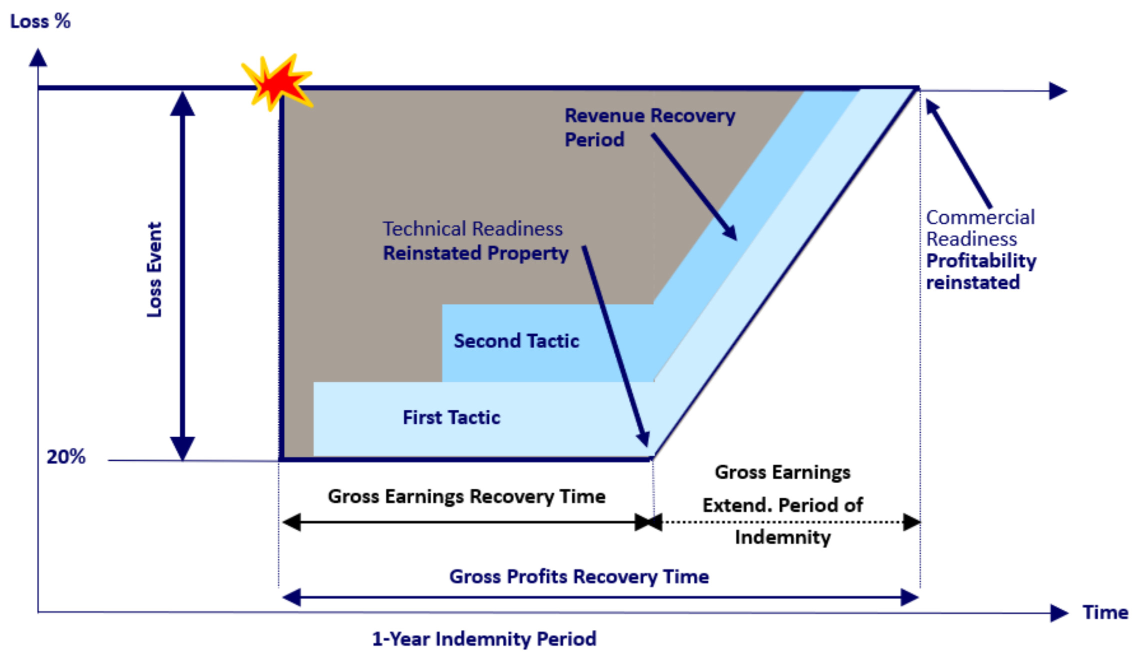

Figure 2. Gross Earnings and Gross Profit Models of BI Underwriting (with tactics).

The insurer's perspective of BI losses maps conceptually to the metrics used by academics in intuitive ways. In Figure 2, the total "bathtub" area of losses (grey rectangle plus blue triangle) represents what the authors refer to as the maximum potential losses. These are losses that are observed in the absence of proactive static resilience tactics. The losses not incurred due to the implementation of those tactics are represented by the rectangular areas for each alternative, where the total area of each tactic's recovery rectangle represents the losses avoided by an individual tactic. (Note that Figure 2 presents only cost-effective tactics, whereas cost ineffective tactics may be illustrated with incomplete recovery or a lower recovery path.) Insurers will first evaluate losses without implementation of tactics (maximum potential losses), under the assumption that tactics are either ineffective or not yet implemented. From there, insurers report the recovery of revenue (losses avoided) based on sound business tactics deemed to be plausible and of reasonable cost. Implicitly, insurers consider BI loss estimates using both the RM and BCR metrics.[xvii]

Of key importance, however, is that BI insurance generally does not reimburse beyond the maximum potential loss and will not reimburse for the expenses associated with implementing resilience tactics if those tactics do not recover dollar for dollar (i.e., BCRs less than 1) and if the tactic cost raises the claim value above maximum potential loss. For example, if an affected business avoids $400K in sales revenue losses using a tactic but spent $500K implementing that tactic (BCR=0.8), the maximum recoverable value is $400K if the BI policy is actuated. This may provide additional incentive for proactive cost-effective resilience planning for insured firms, as they will want to know ahead of time which tactics are most likely to have uninsurable implementation costs.[xviii] Note, however that BI policies will differ from this model in other nations based on gross earnings or gross profit models. Insurers and brokers should be consulted on coverages. Note also that the concept of extra expenses, discussed below, allows for the recovery of additional tactic implementation costs.

Another key component to understanding BI coverage (and CBI coverage) is that it is triggered by an insurable event (Routledge, 2012). If there is not an insurable event, then coverage may not be activated. CBI is coverage for a firm's first-tier suppliers or customers that have been specifically named within their policy.[xix] The best way to describe a loss event not covered by insurance would be a flood to the surrounding area of a firm's production facility. The firm and its supplier do not incur any physical damage losses due to the flood, but the impaired transportation routes cause BI as they impact operations. The insured firm observes lost revenue as it is unable to receive supplies from its contingent supplier or get its product(s) to market, but without the insurable damage event, BI and CBI would most likely not take effect.

This important consideration, taken in context with the BI loss estimates from observational data provided, should highlight the imperative of proactive resilience planning and what the authors have been discussing in this chapter. This is critical because disasters result in considerable BI for a wide swath of firms that do not observe property damage and thus may not be able to insure against those BI losses (e.g., the many firms in the Dallas-Fort Worth area that were impacted by Harvey) because of supply-chain linkages or other market interdependencies. In the absence of proactive resilience tactic implementation, these firms will be unable to recover those BI losses through insurance instruments.

Consideration for Supply Chain vs Value Chain and the Vulnerability Assessment Process

Within a business resilience assessment process, it is important for resilience planning and BI insurance decision making to be informed about losses that are not covered. Some key terminology and concepts from the insurer's perspective include:

- Supply Chain – Generally defined as the procurement, transportation, and storage logistics of the upstream supply of goods or services that are required for a business to produce its product(s) and get them to market. Downstream sales, transportation and logistics may also be considered. The focus is generally on procurement spending by a supplier or volume of supplies by a supplier.

- Value Chain – Generally defined as the complete upstream chain, internal organizational interdependencies chain and downstream chain. The focus is on *revenue generation* throughout the whole chain, from as far upstream to as far downstream as possible.

- Internal Interdependencies – These exist only within an organization's family of locations and do not take into consideration any suppliers or customers outside of the organization's family. The focus is generally on two risk impacting areas:

  1. Identifying the largest internal bottleneck or revenue impacting location. As an example, in retail, BI insurance values are calculated and reported at the store level; however, the largest risk of an interruption is generally at a regional warehouse that supplies multiple retail locations and e-commerce.
  2. How the BI insurance coverage is spread across multiple internal locations. There are two possibilities:
     i. Each location has a separate reported BI value. A loss at one location can have a ripple effect across other interdependent locations. These losses can stack together resulting in a multi-location BI loss, which requires forensic accounting to validate the actual revenue loss from each location.
     ii. A blanket BI policy can be placed over all internal locations with a specific BI limit. Regardless of the number of locations impacted by the loss, the accounting of the revenue lost will be covered under the single blanket policy up to the limits.

- Contingent Business Interruption (CBI) – As just noted , CBI (or CTE = Contingent Time Element) is a coverage for the first-tier supplier and first-tier customer. Generally, these suppliers and customers must be specifically named in the policy and additional dependency/revenue at risk that each may impact. Most commercial insurance carriers will provide varying levels of coverage depending on the risk information provided about the CBI covered supplier/customer. The more risk-engineering information that can be gathered and provided to the insurance carrier and the less risky a loss of the named supplier/customer will have as a revenue loss impact, the more limits the insurance carrier may deploy. It is not uncommon for a carrier to request an insurance risk assessment to be completed at a CBI named supplier in order to determine their potential loss impact to the insured. As noted earlier, both BI and CBI coverage must have an insurable damage loss at the covered location in order to activate the policy. BI and CBI coverage may have a time or dollar value deductible.

Vulnerability assessment is a key phase of insurance planning and business continuity planning. It first begins with an assessment of potential losses across internal locations, suppliers and customers. The full assessment can be broken down into four parts. First, upstream assessment of all named CBI suppliers as well as any additional suppliers at various tiers. Second, insurance-based risk assessment of internal locations occurs with a focus on BI and interdependencies, starting with the largest revenue generation locations. Complete assessments for all locations help to map out interdependencies and to identify excess capacity. Third is downstream, which includes an assessment of all named CBI customers and other key logistical locations outside of the organization. Finally, the last step in the assessment process is deconstruction of the value chain. This begins with finished goods at the customer's location, starting with the largest customer by revenue or the largest single product by revenue. The process then follows the product flow back through the organization and back to the original suppliers. During the assessment, all key components are identified, and the process will continue to follow those components from downstream back to upstream. Generally during this process there are additional key components from suppliers that were not deemed key during the upstream to downstream assessment and would have been missed when applying mitigating and resilience actions to reduce losses.

There can also be situations in which there exist tensions between the insurer and the insured, some of which are strongly influenced by market conditions. Market conditions can be identified as either a "hard market", "soft market" or a "transition market." These markets can impact an insurer's decision to provide specific peril coverage, premium pricing as well as peril coverage limits. During a change in markets the policy negotiation process can become contentious between the involved parties (insurance carriers, brokers, and customers).[xx] Policy limits, the amount of coverage an insurance carrier is willing to provide for a specific peril or policy, may change, and this may require a customer to bring on other carriers to complete the full insurance program. Insurance carriers may decline to provide coverage of specific perils, such a flood insurance or fire damage caused by wildfires and in extreme cases, several insurance carriers may decide to completely exit a market, leaving a customer without a specific coverage.

A "hard market" can best be described as a market in which the insurance carrier tends to have more ability to pick and choose what or who they insure. The market tends to occur after regional or global events (such as a pandemic) and insurance carriers begin to shrink or refocus their book of business to reduce or eliminate more risky customers or industries. During a hard market there is greater emphasis from insurance carriers to have customers plan for the both mitigation, and the implementation of resilience tactics to reduce their own risk and to facilitate greater avoided losses of insured firms. Due to the shrinking market choice for customers during this time, firms tend to need to develop capabilities for the implementation of more effective resilience tactics in order to acquire coverage.

A "soft market" is essentially the opposite of a "hard market." Insurance carriers begin to open their book of business and become more competitive in writing policies. In these conditions the balance of power tends to shift back towards the customer seeking coverage and having more insurance carriers seeking to write their business. There is still an emphasis on firms developing mitigation and resilience tactic capabilities, but the requirements tend to be more relaxed.

A "transition market" is simply the stage between the hard and soft market. A transition market may only be a few months in duration or can last up to a year or two. During these market conditions, developing cost-effective resilience capabilities is important, while also working effectively with a broker that can help leverage current and pending market conditions to acquire favorable policy wording and policy limits.

Summary of Insurance Considerations in Operational Resilience Planning

Overall, insurance coverage for an organization is paramount to continuity planning, as it is a key part of the risk transfer portion of business resilience. Not only is it important to understand the firm's insurance policy and the triggers and/or conditions that will activate the BI coverage, but also to utilize the spectrum of available insurance risk engineering services to bring a risk perspective unique to the industry and apply it to the firm's resilience planning. BI and CBI insurance should be considered complementary to resilience tactics, as cost-effective resilience planning, and mitigation should precede risk transfer to an insurer.[xxi] The authors also emphasize that implementation of mitigation and resilience often has the added benefit of reducing insurance rates.

In the first half of 2023, Munich RE estimated total natural hazard losses at $110Bn USD (see Munich RE, 2023). In the same timeframe the estimated insurable losses were only $43Bn USD, less than 50% of total losses. Reporting by Insurance Business Magazine (July 2023) estimated the insurable losses at $53Bn USD, but also indicated that approximately 77% of those natural catastrophic losses were derived from events within the United States. These data reinforce our previous points that there is a large portion of natural hazard losses that are not covered by insurance. This should serve to reinforce not only the importance of addressing BI, but also the importance of making cost-effective insurance decisions within the context of resilience and business continuity planning.

Insurance risk transfer is a key aspect of resilience planning for an organization. Understanding the organization's insurance policy details, what coverage is provided and under what circumstances will allow any risk management group to better prepare, develop a continuity plan, and formulate a recovery strategy based on metrics, such as is presented in this chapter, that allows for minimal interruption to the production, process or service provided by that organization. Additional considerations for business continuity planning and insurance decision making are provided in the supplementary appendix.

Conclusion

This chapter has presented several important considerations to help businesses improve their resilience to disasters, and that should serve to help other researchers and students understand several key concepts in microeconomic resilience. Economic resilience is intended to promote efficient continuity of business operations and recovery. The emphasis on efficiency is intended to save businesses money in coping with disasters.

Our analytical framework encompasses aspects of mitigation, resilience, and insurance so that businesses can better assess the trade-offs and complementarities among these three approaches to reducing the costs of disasters. However, the chapter focuses on resilience to business interruption, as this strategy is often neglected, despite many cases where BI dollar value exceeds that of property damage.

Our analytical framework is grounded in economic production theory but presented in non-technical language to be accessible to a broad readership. This foundation is the basis for our definition of economic resilience, the specification of resilience tactics, and ways to measure their contribution to resilience.

Obtained data are presented from a survey of businesses in Texas affected by Hurricane Harvey in 2017. It is a prime example of a disaster that caused much more extensive BI losses than property damage for the business community. The data are presented to illustrate the wide variation across sources and magnitude of losses by economic sectoral category. The results indicate a one-size-fit-all approach is not appropriate. Instead, this chapter provides insights and data that can help businesses fine-tune resilience strategies.

The authors also provide an extensive discussion of the role of business interruption and contingent business interruption insurance in coping with disasters in the context of our analytical framework. The primary consideration is that BI compensation requires the implementation of efficient resilient tactics to obtain maximum allowable compensation. An example of the complementarities between strategies is that the implementation of resilience tactics can result in reduction of insurance rates. Several others are discussed.

As to future research, there is a great need for more primary data collection, especially with regard to examining more perils and a finer delineation of economic sectors. More research is needed on trade-offs and complementarities between pre-disaster mitigation, resilient recovery and insurance, including work on comprehensive modeling to optimize the mix of these three strategies.
Future research is also likely to identify obstacles to implementing resilience tactics, and intra-firm tactic differences (e.g., tactic cost and effectiveness differences across firms within the same parent company, across branches, or operational units). This can include inadequate maintenance of excess capacity, such that there may be delays or constraints in bringing operations back online. This may also include a focus on whether resource pooling may conflict with, or be impacted by, anti-trust legislation or regulations as post-disaster firm cooperation may present operational red flags to regulators.

Finally, future research is likely to focus on considerations of equity, including disparities across income groups and firm sizes. This is likely to include considerations of social justice such as racial and ethnic group differences in recovery or in terms of experienced cost-effectiveness. Some of these authors for example are beginning a multi-year study of women- and minority-owned business experiences with disaster recovery. Research like this is likely to focus on differences across various social and economic strata in resilience outcomes of all types, including cost and effectiveness of resilience tactics.

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Appendix. Additional Resilience and Business Continuity Planning Considerations

For ease of exposition, this appendix provides some additional considerations for cost-effective resilience and business continuity planning. It begins with a description of organizational flow, including organizational and logistical management, and the role of market integration in the supply and value chain. It then provides some additional key considerations for cost-effective decision making that deal with balancing value chain risk in the context of incorporating insurance considerations into planning.

Understanding Organizational Flow for Manufacturing – Impact on Business Resilience

Understanding product flow is key to cost-effective resilience decision making. A firm will have an additional incentive to hasten recovery by the time its BI coverage expires, and this incentive is further compounded by the aim of avoiding any loss of additional market share observed during the disruption.

There are two organization flow models that are prevalent in the supply and value chain, and there are two organization flow models that are within a firm's manufacturing location(s). These are horizontal and vertical integration. A horizontal supply/value chain happens when the organization has one or more locations that are completing the same task, but other tasks associated with bringing the product to market are handled externally. A vertical supply/value chain happens when the organization has business control over the supply/value chain with multiple locations each completing a task in the overall formulation of the product from raw material to finished goods and sales. Organizations can have both a horizontal and vertical integration within their production of a product. A good example would be the automotive manufacturer, which typically has both horizontal and vertical integration.

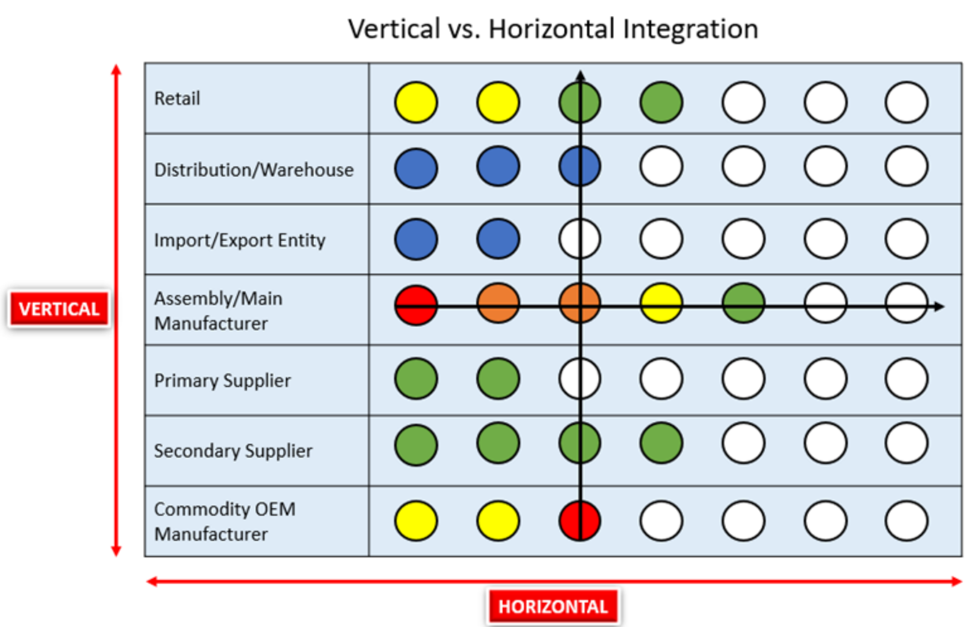

Figure A1. Horizontal and Vertical Integration in Organizational Flow

It is similarly important for a firm to understand the difference between Just-in-Time (JIT) and Just-in-Sequence (JIS) logistics and how these can influence its cost-effective resilience decisions. JIT is a logistic process where the specific supply is received at the location required in a timeframe that is very short and close to use. This helps minimize floor/rack space needed to hold a large volume of supplies. From an insurance business resilience view, a delay to a supply arriving for a JIT process generally means that the whole production line is shut down and cannot be restarted until that one specific supply arrives.

JIS is a logistic process where the specific supply is received at the location in a timeframe and sequence along the production line. JIS process generally also includes the JIT process. An organization must have a good recovery plan as well as flexibility within the production process when deploying a JIS/JIT logistic process.

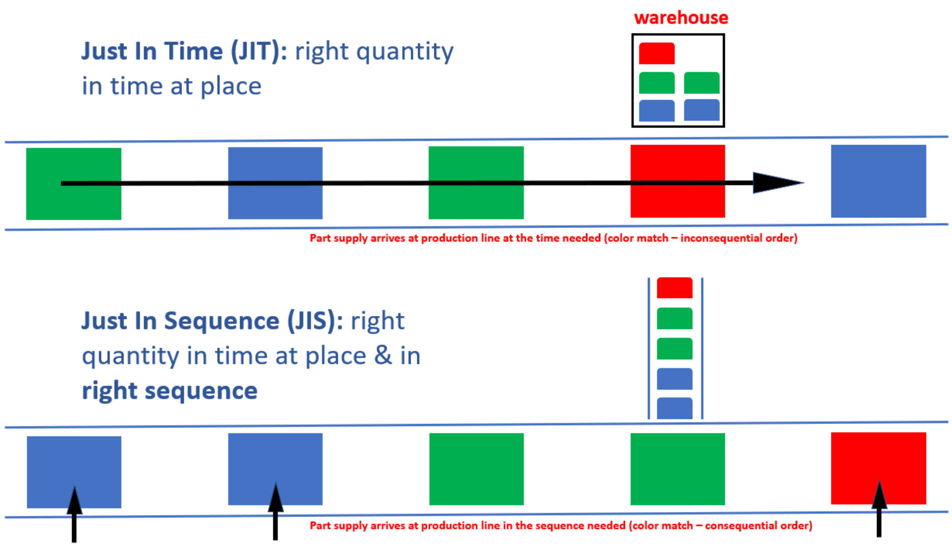

Figure A2. JIT and JIS Logistics

Additional Insurance Considerations for Cost-effective Resilience Planning

Depending on your business operations (manufacturing, storage, assembly, etc.), one of the most important considerations vis-à-vis insurance coverage and resilience decision making is the coverage of Extra Expenses. Extra Expense insurance is generally a separate coverage from BI but can be commonly found in a typical Property/BI policy. Extra Expense coverage is activated by a physical damage insurable loss event and will provide direct cash infusion for expenses over and above typical operating costs. These are the funds that organizations use to immediately acquire an alternative location, increase costs of labor to shift employees from the loss location to an alternative location (transportation, housing, etc.) or, in general, expenses to recover a business not part of the traditional operating expenses. This is key in cost-effective resilience planning as understanding the added costs to invoke recovery plans quickly and knowing the proper Extra Expense coverage in place, can help effectively implement resilience plans.

All aspects of resilience decision making, to be effective, require a level of flexibility in the organizational operations. This will allow many more alternatives to be available as well as managing added costs and expenses, thus being more cost effective. The basic idea of flexibility is to manage the risk of loss to the cost of resilience and to locate the best intersection point where resilience is effective and the cost to implement the resilience decisions is at a level acceptable to the organization (see Figure A3).

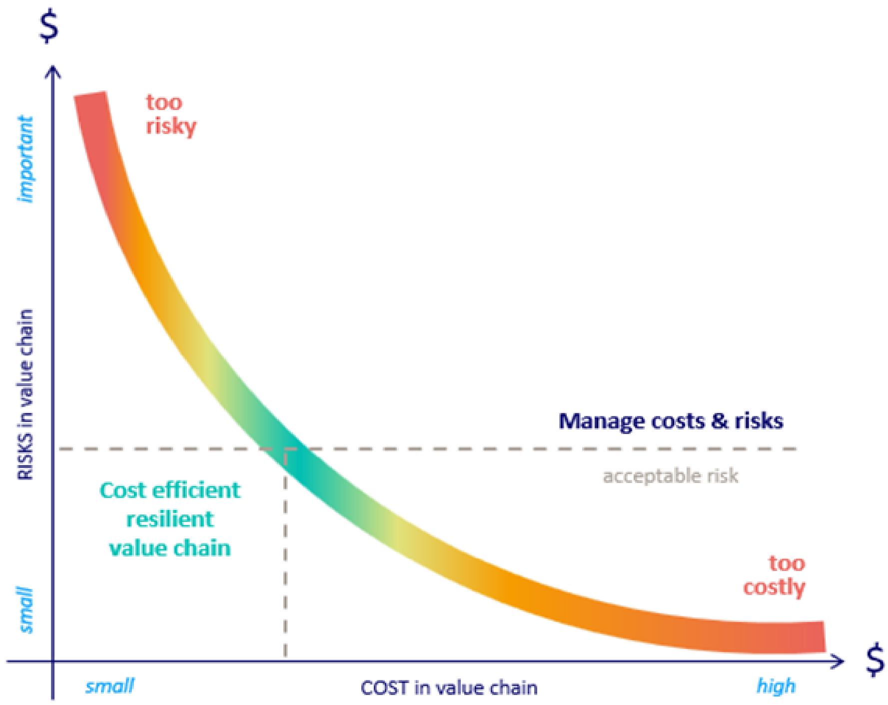

Figure A3. Balanced Value Chain Risk and Cost-Effectiveness

By locating the most effective risk reduction measures at the best cost savings allows for a better understanding of what insurance coverage may be needed as well as the coverage limits. Put another way, insurance coverage decisions should be made once a firm has a solid understanding of its BCR metrics. Other aspects of resilience that can have an impact on insurance coverage and limits are related to the planning of alternatives, utility back-ups (e.g., emergency generator) and excess stock levels, as described below.

Alternatives – May be internal or external alternative locations. Capacity needs to be present as well as managing quality. Alternatives may also include purchasing a like product and repackaging or having a 3rd party manufacturer produce the product. For natural hazard loss events, alternatives are best located in the region, but outside of a typical event boundary. Planning with the alternative locations and understanding what is required to enact the shift of process/production and ensuring that all critical aspects are available and in place is crucial. For medical/pharma, there may be a need to pre-qualify equipment at alternative locations based on FDA requirements. Within North America, there are three main languages spoken/written and, if alternatives exist between Mexico, United States and Canada, there may be a need to provide specific printed boxes (external packaging), labeling or product packaging.

Utilities – With severe weather and natural hazard events, it is typical for utilities in a region to be impacted. This may include electricity, water (process and potable), gas and other fuel (diesel/gasoline). All, depending on the time of year, can be considered critical. The most common resilience tactic for electricity and fuel is to have a fixed generator or portable generator for electricity and ship in fuel from an unaffected location after the event begins. While provisions can be put in place to essentially guarantee these contracts, there can still be difficulty with delivery of fuel or, in the event of a very large regional event (e.g., August 2003 Blackout in Southern Ontario and NE United States), the portable generation units and fuel may be redirected to critical needs such as hospitals, airports and emergency services. Any resilience planning should take into consideration both minor and major events and the different complexities associated with both types. This form of planning will go directly to the ability to recover faster and thus impact the type of insurance coverage available and the rate/cost of that insurance coverage.

Excess Stock – In an effort to reduce costs, several organizations in the manufacturing industry have reduced the quantity of buffer stock available to be distributed into the network. This buffer stock was seen as taking up storage space and logistics costs for recovery of events with interruptions that rarely seemed to occur. Buffer stock allows you to have a specific time of interruption while you can still provide the market with your product. The aim is to maintain a buffer stock to a level that would equate to a typical insured loss (such as a flood) and continue putting products into the marketplace while the organization recovers and can start producing again. A lack of buffer stock can cause revenue loss and market share loss. Buffer stock is a key component of a manufacturing organization that insurance carriers review as part of a strong resilience plan. While still insurable, the lack of a buffer stock may have an impact on the organization's ability to recover quickly and as such would impact a risk engineering quantitative assessment. The quantitative risk engineering data is used by underwriting when determining policy coverage and rates. Unfortunately, several organizations, while realizing the cost saving of reducing buffer stock, did not complement the investment to resilience and protection needed on the other end of the spectrum. As a result, with a reduced buffer stock of goods to deploy to the market, organizations incurred larger impacts to business revenue loss, as well as more difficulty recovering the current production levels and securing market space.

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[‡] Correspondence: 1810 College Rd, Columbus Ohio 43210, USA; email: dormady.1@osu.edu

[i] Business resilience tactics include a range of activities intended to cope with disruptions in disasters. These include activities such as authorizing second shifts to make up for lost production (production recapture), isolating resources that were not impacted by the disruption (resource isolation), relocating business activity (relocation) and several others. These are defined in several published works (see e.g., Rose, 2007). They are integrated into microeconomic theory and mapped to numerous publications and definitions of supply-chain resilience tactics in Dormady et al. (2019a). And they are quantified empirically in Dormady et al. (2022a).

[ii] See Rose (2004) for an elucidation of distinctions between direct and ripple effects and Rose (2009; 2015) and Rose et al. (2017) for comprehensive frameworks to analyze and measure total economic impacts.

[iii] While it is difficult to estimate and validate BI estimates, there are a many innovative empirical estimation approaches being advanced today. Ultimately, analyses based on direct data from businesses is generally preferred, but there are other means of obtaining estimates. This includes BI insurance data.

[iv] The underlying rationale for this statement differs between these two types of entities. For businesses, it is evidenced by the much larger proportion of firms that have property and casualty insurance versus business interruption insurance. For government, it refers to two considerations. First is government statistics on these 2 types of disaster impacts. Property damage is much easier to calculate than BI because it is readily visible and takes place in a shorter period of time. In contrast, BI takes place over a period of time, typically many months, and is not as readily visible. The second aspect deals with government's coverage of property damage versus business interruption. Major government programs, such as FEMA Public Assistance and its Hazard Mitigation Grant Program are almost exclusively limited to repair and reconstruction of assets (see Rose et al., 2019). An exception is the Federal Crop Insurance Program, which essentially covers lost revenue from damaged crops.

[v] For a detailed assessment of mitigation activities, including a cost-benefit analysis of mitigation activities, the reader is encouraged to see Rose et al. (2007) and Multi-Hazard Mitigation Council (2019).

[vi] Methods for estimating these conditions using surveys can be found in Dormady et al., (2022a), at the micro level and input-output modeling in Rose (2007), computable general equilibrium modeling (Xie et al., 2018), or combination of the two (Wei et al., 2021) at the macro level.

[vii] Efficiency is a hallmark of economics, a discipline that has often been referred to as the "science of scarcity." Scarcity of many kinds is commonplace in the aftermath of disasters. How remaining resources are used, plays a critical role in affecting disaster outcomes. Resilience, as commonly defined in several disciplines, refers to rebounding in the aftermath of a shock, but the vast majority of these other definitions do not explicitly include or provide details of this being efficient in terms of resource utilization.

[viii] We acknowledge the difficulty of measuring the maximum potential loss in the context of economic consequence analysis of disasters. For example, it is much easier in the case of total destruction, as in the case of the 2001 World Trade Center Attacks (Rose et al., 2009), than when assets are only partially destroyed (Rose et al., 2017) or when no property damage is observed as in the case of Covid-19 (Walmsley et al., 2023).

[ix] An analogous definition is applied at the macro level. See Rose (2004).

[x] One of the major challenges to businesses struck by a disaster and who have to decrease or suspend production is a lack of working capital. Property and casualty insurance payments can be used for repair and reconstruction, but if insurance does not cover these, funds may be needed to make the first payroll as a business reopens and actual sales of goods produced are not necessarily immediate. See Rose (2017).

[xi] If the reader is interested in seeing tactic-level BCR or RM metrics, see Table 5 in Dormady et al. (2022a).
[xii] Note, the values in Table 5 can be derived directly by using metric component values provided in Table 4.
[xiii] Note that the RM metric as reported here does not fully capture additional share of losses avoided by cost-neutral or cost-saving tactics.
[xiv] The survey data presented in the previous section did not require respondent firms to provide detailed technical modeling results, but rather relied upon C-level executives or similar as respondents providing expert judgment-based estimates. Intra-firm sensitivity analysis was not required but may be applicable and helpful for internal resilience planning processes.
[xv] Firm size differences can play a key role in efficient resilience operations and planning. The reader is encouraged to see Fiksel (2015) for a discussion of tradeoffs associated with firm size in enterprise risk management. The reader is also encouraged to see Moore et al. (2000) for a discussion of risk management strategies specific to middle market firms, but with a focus explicitly on hedging strategies. And, the reader is encouraged to see Dormady et al. (2021) for an experimental analysis of the role of information in resilience decision making among middle market firms.
[xvi] Note that a localized impact from a natural disaster may reduce the extent to which excess capacity can be implemented as a resilience tactic.
[xvii] Many of the resilience tactics mentioned in this chapter are explicitly or implicitly mentioned in BI insurance contracts (see Rose and Huyck, 2016; Johnson and O'Toole, 2005; Lewis and Farrell, 2005; and Northwestern States Portland Cement Co. vs. Hartford Fire Insurance Co., 1966).
[xviii] BI coverage can account for losses observed at a lag or time delay following the disaster or disruption. If a firm's revenues are not lost immediately with the disruption, such as with the use of inventory buffer stock, some tactic implementation costs, often referred to as increased costs of work, can be recoverable within the indemnity period.
[xix] There is a mischaracterization in Rose and Huyck (2016). That paper suggests that "'contingent' BI stems from disruptions to off-site sources, such as the supply chain or infrastructure, on which the firm depends" (at p. 1). However, contingent BI insurance only covers first tier suppliers and customers, and does not cover lost BI to the firm due to infrastructure failures or further upstream and downstream components of the supply-chain beyond the first tier.
[xx] See also Rose and Huyck (2016) for several examples of tensions between insurers and insureds regarding BI claims.
[xxi] The development of an optimal disaster risk reduction strategy can be complicated (Rose, 2017), since mitigation, resilience, and insurance all have unique features. For example, adaptive resilience tactics have a major advantage in that they do not need to be risk-adjusted. There is no need to adjust the benefits by multiplying them by the probability of occurrence. This is also the case with mitigation, because uncertainty is eliminated once the disaster has struck. At the same time, some forms of mitigation do have the advantage of protecting against several threats and prolonged durations (e.g., land-use planning or structural reinforcement of buildings, both of which can protect against earthquakes, hurricanes, terrorist attacks), while a given resilience tactics is applied on a one-shot basis for recovery from each separate disruption. Also, while insurance modifies risk for an individual business, it does not do so for society as a whole, because, at that level, it is not a risk reduction strategy but rather a risk transfer strategy.