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How Technology-Based Businesses are Reducing Their Vulnerability During the Natural Disasters?

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ABSTRACT

This article investigates how technological businesses can resiliently exploit opportunities through their business capacity to reduce their vulnerability. We analyzed qualitative data derived from the real experiences of 19 technological firms that were involved in epidemic crises such as COVID-19. Using a qualitative approach, this article introduces a new framework comprising three fields: vulnerability, resilience, and opportunity. This paper first examines what factors lead to the vulnerability of businesses in epidemic crises such as COVID-19. Four levels of vulnerability (Individual, business, national, and international) were identified. Then, by focusing on the business resilience capacity and creating a link with the three perspectives of opportunity (allocative, discovery, and creative), it proposes strategies to reduce vulnerability. To reduce vulnerability, technological businesses are moving along a continuum from optimal resource allocation to opportunity creation based on their business capacities. In this spectrum, enablers and inhibitors are the factors that mediate the speed of their movement toward resilience and stability. This research links three perspectives of opportunity with business resilience during the epidemic crises and shows that technological businesses can reduce their vulnerability through absorptive capacity, adaptive capacity, and transformative capacity, and exploit opportunities accordingly. Since vulnerability assessment is a critical element in the field of disaster risk reduction and sustainability, this study contributes to the literature on sustainability and disasters.

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1. Introduction

Due to increased uncertainties and disruptions in recent years, researchers have been interested in the businesses' ability to improve in response to disturbances to meet consumer demand, confirm target performance, and continue operations in sensitive environments (Azadegan et al., 2020; Dubey et al., 2019; Hosseini et al., 2019). Business owners struggle with extreme levels of vulnerability during crises and some even experience unprecedented failures (Branzei & Fathallah, 2021). Businesses are always faced with disturbances caused by business characteristics or society-level characteristics. When these disruptions are combined with other disasters, the level of vulnerability increases in a complex, non-linear, and systemic manner. Vulnerability is recognized as a potential factor in the failure of small businesses or an obstacle to their recovery from crises (Helgeson et al., 2022). One of these crises that exposed businesses to extreme vulnerability was the COVID-19 pandemic. The high impact of the COVID-19 crisis on businesses has highlighted the need for an in-depth analysis of factors affecting corporate resilience, which can provide useful insights -both for businesses and governments- on how to reduce the adverse effects of crises and provide economic recovery. A better understanding of the elements that make businesses more resilient to pandemic shocks can help identify vulnerable businesses and create targeted plans for more effective crisis responses (Aristei & Gallo, 2024). However, there are still research gaps surrounding the integration of resilience literature with crisis management theories, particularly regarding COVID-19 pandemic crisis, with a focus on SMEs. While the literature on SMEs and resilience is still sparse, it is important to consider the role of entrepreneurs in shaping resilience when examining SMEs. Conflicting results about the integration of these issues have been revealed by researchers. Some researchers have considered the lack of resources and insufficient planning as a factor for high vulnerability and low resilience while others have pointed out the difference in business capabilities. This dichotomy emphasizes the need for a more accurate understanding of how small and medium businesses respond to crises and the factors that can increase resilience and reduce vulnerability (Delladio et al., 2023). Vulnerability is the dark side of resilience that remains largely unspoken (Branzei & Fathallah, 2021). Small and medium-sized businesses are more vulnerable to natural disasters than larger businesses; however, there are not many attempts to systematically assess their vulnerability (Lo et al., 2021). The effects of disasters and accidents are more specific for technology businesses compared to other businesses; because technology is a vast field and tech businesses are not similarly affected (Siri et al., 2020). Contrary to the increasing importance and interest in technological businesses and technological entrepreneurship, its research-based knowledge is still limited (Bailetti, 2012) and the emergence of technological entrepreneurship has caused the important aspects of this knowledge to be placed in an aura of ambiguity and darkness (Peng & Zhang, 2008). The epidemic crisis significantly damages the technology industry, affects the availability of raw materials, disrupts the electronics value chain, and increases the risk of inflation for commodities (Deloitte, 2020). Therefore, in this article, we are trying to study the reduction of the vulnerability of such technological businesses in times of epidemic crises.

This paper integrates the concepts of resilience and opportunity to reduce the vulnerability of technological businesses. To identify business vulnerability factors, we combined the concepts of global changes and vulnerability presented by researchers (Smit & Wandel, 2006) with the concepts of business vulnerability presented by Zhang et al. (2009). For how to reduce vulnerability, we have linked the concepts of resilience capacity presented by Béné et al., (2012) with the concepts of three perspectives of opportunities presented by Sarasvathy et al. (2003). Many researchers have pointed out the connection between vulnerability and resilience. The most accepted view holds that resilience and vulnerability are two opposite concepts. In other words, the more resilient a system is, the less vulnerable it is. Vulnerability is a relatively negative term that is used to indicate the degree of harm a system suffers from a destructive event, and resilience is a relatively positive term to describe the ability of a system to resist this harm (Lin et al., 2017). The business resilience against these vulnerabilities can be considered in two approaches. The first approach to resilience is the ability to return from unexpected, stressful, unfavorable situations and resume previous activities. The second approach includes the development of new capabilities and the ability to acquire and exploit new opportunities through entrepreneurial initiatives that support the reconstruction of infrastructure, goods and services, and new investments created under critical and pressured conditions, which will enhance their entrepreneurial and financial performance (Salvato et al., 2020). In other words, it can be summarized that as crises expose businesses

to vulnerability, they present opportunities to entrepreneurs. To reduce this vulnerability, businesses adopt resilient measures. These resilience measures for entrepreneurs are usually based on the opportunities created by crises, thereby facilitating their growth.

Although many researchers have studied the issue of resilience and entrepreneurial opportunities, the efforts of technological entrepreneurs in creating the three capacities of resilience with the approach of three perspectives of opportunities to reduce vulnerability have not been paid attention to. Our research is probably the first to examine the simultaneous occurrence of three perspectives of opportunity and business resilience capacities in the vulnerability domain of technological businesses.

We are looking for, firstly, *what are the dimensions of the vulnerability of such businesses in the conditions of the epidemic crisis*, and secondly, *how can these vulnerabilities be reduced through resilience and opportunity perspective?* To answer the questions of this research, a qualitative approach, semi-structured interviews, and strongly collected empirical data were used. These are described in the methodology. Then, in the findings section, the results of the interviews are presented, and finally, in the conclusion section, a framework for integrating the concepts of resilience and opportunity is proposed.

Our research makes some significant theoretical and practical contributions. First, by combining two streams of literature (entrepreneurship, resilience), this study fosters our understanding of the relationship between resilience capacities and exploitation of opportunities in times of crisis and how to achieve resilience during a destructive event. What helps businesses in times of crisis is to use the opportunities created by crises (Kusa et al., 2022). Entrepreneurs can benefit from imbalances created by crises and environmental changes (Karamti & Abd-Mouleh, 2022; Wang et al., 2017). Therefore, this research enriches the entrepreneurship literature by highlighting three perspectives of entrepreneurial opportunity during the crisis, which is the second theoretical contribution of this research. Third, Vulnerability research generally seeks to find opportunities to reduce risk through understanding the underlying causes of vulnerability and helps gain insights to identify opportunities for intervention to increase resilience (Miller et al., 2010). On the one hand, since vulnerability assessment is a vital element of disaster risk reduction and sustainability context (Zhou et al., 2015), this study contributes to the literature related to sustainability and disasters. Finally, conducting this study, we can contribute to the literature related to technological businesses. We discover that technological businesses can reduce their vulnerability through the business resilience capacities of absorption, adaptation, and transformation.

Our practical contribution in this research is as follows. A better understanding of vulnerability factors leads to more effective decision making for the development of countermeasures (Ekanayake et al., 2020a). We can assist in decreasing the susceptibility of businesses to future incidents and events, reduce shutdowns, and boost their sustainability by learning from businesses impacted by crises and disasters (Sydnor et al., 2017). This study helps to explain why some technological businesses respond better to uncertainty and what factors are effective in strengthening resilience. Furthermore, this research indicates that even in very uncertain conditions, entrepreneurs can develop strategies for better recovery and survival, as well as providing managers and small business owners with specific solutions to recover from the crisis.

The paper is structured as follows. The next section presents the literature review. Then, in the methodology section, the method, data gathering and data analysis are described. After that, the findings, discussion and proposed framework are presented. The paper ends with Implications, limitations and future scope of research, and conclusion.

2. Literature Review

2.1. Technological Businesses as the Output of Technological Entrepreneurship

Technological entrepreneurship is the link between the technical world and the business world (Levi-Jakšić & Jakšić, 2012). Researchers have provided different definitions of technological entrepreneurship. Spencer et al. (2008) define technological entrepreneurship as the commercialization of continuous innovations and emphasize on the development of independent and new businesses based on the commercialization of faulty technologies. Bailetti (2012) views technological entrepreneurship as investing in projects in which specialized people and heterogeneous capitals, which are intricately related to scientific and technological knowledge developments, are used to

create value and acquire it for a company. Technological entrepreneurship refers to the potential of technological opportunities to successfully establish successful businesses (Petti & Zhang, 2013).

The three main clusters discussed in technological entrepreneurship include the following: 1- the formation of new technology businesses (focusing on approaches to external factors of formation, interdependence between the formation of businesses and technological changes, and consequences); 2- small technology businesses (focusing on revenue generation/cost reduction approaches; operations/transformation in small companies); 3- large technology businesses (organizational entrepreneurship) (Bailetti, 2012).

Our focus in this research is on small technology businesses, and how they can generate more revenue, reduce costs, or transform their business through their operations to become more resilient and less vulnerable during the COVID-19 pandemic crisis. Technology businesses have high levels of research and development and innovation rates; they require substantial relevant knowledge in their innovation processes, often seeking it beyond their borders (Flor et al., 2018). Many would agree that technological businesses stand out in their emphasis on technological activities. The distinguishing features are as follows: the employment of engineers, scientists and academics in higher numbers; investing, at least, 3% of their earnings in research and development activities; the development of complex products; maintaining a fast growth rate and global market for products; achieving a high level of relative research and development investment; having a significant number of research and development personnel; emphasis on applied research vs. development; management's commitment to research and development; the number of new products and their innovation; having products with a short life cycle; technology-based customers; management attitude towards change; management's attitude towards risk; flat organizational structure (Grinstein & Goldman, 2006); engagement in the knowledge-intensive or high-tech sector; having the most advanced technical proposals as a competitive advantage of the company; high value of the company's product or service relative to shipping costs and other logistics costs; membership in ecosystems that facilitate a flow of technological know-how, experienced individuals, and local venture capitalists; engineers who serve as customers and collaborate with companies from other industries (Tanev, 2012); pursuing new business opportunities based on their technology capabilities (Lee et al., 2009).

2.2. Business Vulnerability

The concept of vulnerability is rooted in geographical and natural hazards research; however, over time, this concept has been included in the literature related to agriculture, environment, public health, poverty and development, secure livelihood and famine, sustainability, climate change, and adaptability (Zarafshani et al., 2016). The concept of vulnerability has moved over time from the physical dimensions of vulnerability to incorporate its socio-economic dimensions. Vulnerability research has relied on two schools of thought, the "Human Ecologist School" and the "Structural Perspective." In the human ecologist school, humans act purposefully to reduce potential negative effects. In this view, it emphasizes the level of adaptability and argues that vulnerability occurs due to incorrect adaptive activities by humans. The structural perspective emphasizes the proneness to hazards and believes that natural disasters are caused by the socio-economic characteristics as well as political system of a society (Kim et al., 2021). Vulnerability is an exogenous variable that determines risk and indicates the capacity of the system as well as its readiness to face the risk or anticipated consequences. Risk is a function of hazard and vulnerability, so risk cannot be equated with vulnerability (Ekanayake et al., 2020b). Based on this, the definitions of vulnerability refer to three key components of exposure to shock, sensitivity to shock, and adaptive measures to reduce the effects of shock. According to the definitions, the lower the exposure and sensitivity of a system to shock and the greater the adaptive capacity, the less the vulnerability of the system (Kamalipoor, Akbari, Hejazi, & Nazarian, 2022).

Business vulnerability is the weakness and inability of the business, both quantitatively and qualitatively, to withstand uncertainty (Yan & Zhou, 2010). Small businesses are vulnerable in many ways. Long-term shutdowns, decrease in customers, absence of employees, and reduction and interruption of access to services and suppliers are among the factors that increase the sensitivity of businesses and make them more vulnerable (Lo, Liu, Cheung, & Lo, 2019). Svensson (2002) argues that business vulnerability is a condition in which the company's goals are negatively affected by

disruptions. Vulnerability levels vary across business sectors and are related to the shock to which they are exposed as well as the characteristics of each sector (Skouloudis et al., 2020). Miklian and Hoelscher (2022) define the nature of business vulnerability based on the nature of the business, the nature of the shock, and the nature of the response. Some studies have stated that vulnerability has both positive and negative aspects. The positive side of vulnerability is that businesses improve their adaptive capacity to reduce vulnerability, thereby contributing to their sustainability and growth (Gallopín, 2006).

2.3. Technological Entrepreneurship from the Perspective of Three Views of Entrepreneurial Opportunity

In a crisis, businesses face declining profits, losing their customers and even key employees, so they must seize opportunities (Liguori & Pittz, 2020). Researchers have different definitions of opportunity. Shane (2012) considers opportunities as states in which it is probable to profitably recombine resources.

Some researchers examine opportunities from the perspective of discovery (Kirzner, 1979; Baron, 2006; Fiet, 2007; Murphy, 2011). Some researchers have considered opportunities from the perspective of creation (Schumpeter, 1934), while have adopted a mixed approach to opportunities (Alvarez & Barney, 2007). Sarasvathy et al. (2003) defined entrepreneurial opportunities in three perspectives: allocative, discovery, and creative. We have adopted the approach of Sarasvathy et al. (2003). The allocative approach focuses on the whole system, not on the individual or the organization. In this approach, all economic agents have an equal chance of discovering an existing opportunity. This approach is related to the optimal use of scarce resources. In this approach, opportunity is any possibility of better use of resources. An opportunity arises in two cases. The first case is a short-term imbalance, which leads to short-term profits. The second mode occurs in research and development processes.

The intellectual roots of the opportunity discovery approach are evident in Kirzner's works (Forsgren, 2016). Kirzner (1973) presents his theory from the perspective of demand and market. Kirzner believes that the source of opportunity lies in the environment outside of the entrepreneur or the company that engages in entrepreneurial activities (de Jong & Marsili, 2014). In Kirzner's view, the existence of opportunities requires only a difference in people's access to existing information, and there is no need to create new information (de Jong & Marsili, 2014). Opportunities exist in the market for alert people (or informed people who have the required knowledge) to identify them (Companys & McMullen, 2007; Kirzner, 1973). The opportunity discovery view assumes that opportunities arise as a result of market defects or as a result of changes in technology, consumer preferences, or other characteristics of the industry or market (Shane, 2003). Therefore, Kirzner believes that the market is not always in equilibrium and considers the entrepreneur responsible for bringing the market to equilibrium (Chiles et al., 2007).

The creative approach is rooted in Schumpeter's works (Toma et al., 2014). Schumpeter (1943) believes that changes in technology, political forces, laws, macroeconomic factors, and social trends create new information that entrepreneurs can use to combine resources in a new way and create more valuable combinations from them (De Jong & Marsili, 2010). The creative approach focuses on disequilibrium, new information, radical innovation, and rarity (de Jong & Marsili, 2014). In the creative approach, opportunities arise endogenously as a result of the entrepreneur's actions and reactions and the implementation of his exploration methods to create new services and products (Alvarez & Barney, 2007; Sarasvathy et al., 2003). According to Wood and Mckinley (2010), from the perspective of creation, opportunities to produce new services and products are not necessarily rooted in markets or industries that already exist. In Schumpeter's view, innovative entrepreneurs disturb the equilibrium in the market to create an imbalance (Chiles et al., 2007). Being innovative in the view of creation means providing new products, processes, organization methods, or raw materials for the market, and it is not just about being new for the individual or the organization (Schumpeter, 1934). Sarasvathy et al. (2003) state that there is no clear supply and demand in the opportunity creation approach, and opportunities are created by establishing new markets. Therefore, the conditions for decision-making in this theory are characterized by uncertainty.

Petti (2009) includes all three types of opportunities in his definition of technological entrepreneurship and states that technological entrepreneurs intend to create and earn economic value by identifying (identifying, discovering, and creating) and exploiting technology-based solutions.

Petti and Zhang (2011) also define technological entrepreneurship as the inclusion of all activities related to the identification of potential entrepreneurial opportunities arising from the development of technology and the exploitation of these opportunities through the successful commercialization of innovative products. As can be seen, the core feature of the concept of technological entrepreneurship is the concept of technological entrepreneurial opportunities. In this research, relying on the definitions of opportunity provided by Sarasvathy et al. (2003) and other researchers (Petti, 2009; Petti & Zhang, 2011) in connection with technological entrepreneurship, we seek to use resilience capacities to identify these three types of opportunities in technology businesses.

2.4. Three Business Resilience Capacities

Resilience is the ability of a system to adapt to shocks and stresses. What defines a system as resilient depends on the goals that the system has set and must achieve (Bunch et al., 2020). According to Williams et al. (2017), resilience is the process by which an agent develops the required abilities and uses that ability to interact with the environment to positively improve their performance before and during the crisis and adjust and maintain their performance after the crisis. Business resilience is the capacity of a business to reply successfully to natural and human disasters to maintain or improve its business (Hadjielias et al., 2022). To measure resilience, absorptive, adaptive, and transformative capacities should be considered in relation to shocks and stresses such as epidemics and natural disasters (Bunch et al., 2020; Blanchet et al., 2017; Béné et al., 2015).

Absorptive capacity is often referred to as the ability to take deliberate precautions and handle shocks and stress. The system with absorptive ability returns to its initial state following the shock. The ability to absorb involves preparing for, foreseeing, surviving, and recovering from known shocks and immediate difficulties. To avoid or reduce the damaging effects of shocks on the system, absorptive capacity seeks stability (Jeans et al., 2017). According to Hillmann and Guenther (2020), resilient companies promote change and assist their business in becoming more capable by being able to quickly recover from setbacks.

Adaptive capacity is the ability to make intentional incremental adjustments in advance of or in response to change to increase future flexibility. Making the necessary adjustments allows you to better handle or adapt to a changing circumstance. The ability to accept change inevitable is a crucial component of adaptive capability. The ability to gradually change through a process of ongoing adjustment, learning, and creativity is known as adaptive capacity (Jeans et al., 2017). IPCC (2001) states that adaptive capacity refers to a system's power to adjust to changes to mitigate potential harm, seize opportunities, or deal with their impacts (Béné et al., 2012).

Transformative capacity is the ability to invest in good governance, infrastructure, formal and informal social protection mechanisms, the provision of basic services, and policies/regulations that establish the prerequisites for systemic change to create an enabling environment (Béné et al., 2015). The ability to create a fundamentally new system such that the current system becomes unsustainable due to ecological, economic, or social factors is known as transformative capacity (Walker et al., 2004). Béné et al. (2012) suggests that transformation is necessary when the required change is so significant that it impairs the system's ability to adapt. The adjustments in this situation are no longer incremental. Instead, they have a transformative effect and alter the system's fundamental composition and operation. The nature of the system is often altered as a result of these transformational changes, adding new state variables. Technology advancements, institutional changes, alterations in behavior, and cultural shifts that challenge the status quo may all be part of these developments.

3. Methodology

3.1. Method and Data Gathering

We utilized a qualitative research approach and executed semi-structured interviews with technology business owners to identify vulnerability factors during epidemic crises, such as COVID-19, and to recognize how these vulnerabilities could be mitigated. Since the Covid-19 crisis has been unprecedented and the research studies conducted so far have explored other crises and non-

technological businesses, we have used Qualitative approach to reveal new aspects of resilience and vulnerability. Qualitative approaches rely on the study of non-quantitative aspects of phenomena, subjective objectives, narrative data, thematic analysis, and inductive and subjective inferences (Teddlie & Tashakkori, 2009), providing wealthy points of interest that are not simple to perceive when utilizing quantitative information (Javadian et al., 2020). The qualitative data made it possible to describe organizational experiences about different elements of damage, rehabilitation, and re-establishment. It also revealed specific points of vulnerability within the company in terms of capital, labor, logistical, and market impacts (Skouloudis et al., 2020). We employed purposeful sampling (Patton, 1990). To obtain the desired information, we selected samples that presented the most conducive conditions for providing the required information, were willing to participate in an interview, and were accessible to us.

The samples were selected through scientific and research towns, industrial towns, innovation districts, and utilizing snowball sampling. In terms of geographical area, these samples were located in Iran and were actively engaged in the field of medicine (medical equipment, pharmaceuticals, cosmetics, and industrial and medical products). It is worth noting that in the sample selection process, four criteria were considered for selecting technologist jobs, which include: 1) the product or the production process is technological; 2) the company has passed the commercialization stage; 3) emphasis on research and development and technological innovations; 4) employees with high levels of knowledge and expertise. On the other hand, all these businesses have gone through a similar crisis. Since all these samples had experienced the crisis of the COVID-19 pandemic, we conducted our questions and interviews around this crisis. Table 1 presents the characteristics of the samples. We interviewed 19 technological businesses in depth, trying to conduct these interviews with high precision and reveal the hidden aspects of the subject. We particularly asked interviewees to share the changes they made in the crisis, counting the challenges they confronted and how they reacted to those challenges. To persuade interviewees to share data, we guaranteed that interviewees were totally free to skip a question if they were not interested to respond to. The researcher continuously adjusted the meeting arrangements based on new insights that emerged during the conversations. The interview continued until theoretical saturation was reached. Each meeting lasted about one to two hours. This was achieved in the twelfth sample, but to confirm the sufficiency of the data, the interview was continued until the 19th sample. To make sure that the sessions run effectively and we get the desired information, we used open-ended and power questions, non-leading and non-dual questions. The interview guide is represented in Table 2. We obtained the required data through semi-structured interviews. We also used data from secondary sources to extend the credibility of our research (Van Burg et al., 2020).

As for the verification of the research proposal, the Institutional Review Board (IRB) consisting of four external and two internal reviewers verified the research proposal and research protocol. The faculty board also investigated the research proposal. To approve the two stages of the committee, the work progress report was approved before setting the interview protocol and after the interview. Additionally, the voluntary consent of the participant in a study is now an indispensable part of human research. The process needs to include the three key components: information, understanding, and voluntary agreement, to be ethically appropriate. Therefore, all respondents participated in this study voluntarily, and at any stage of the research, they could refuse to continue the process. Furthermore, data was gathered using semi-structured interviews carried out by an investigator and was recorded word-for-word. The use of open-ended questions within this format provided both the participant and the interviewer with the opportunity to thoroughly delve into the participant's views, experiences, and convictions. To improve the internal validity, data gathering occurred in two phases, allowing for a progressive approach to collecting and analyzing data. A team with diverse expertise conducted content analysis by methodically scrutinizing the interview transcripts multiple times to discern recurring themes and patterns in the participants' responses. To further strengthen the internal validity, the analysis was performed by individuals from various professional backgrounds.

Table 1. Characteristics of the Samples

Case Overview	Owner	Firm Age	Firm Type	Interview Duration	
Firm 1	Male (p1)	12 years	Individual Firm	51 min.	Medical Equipment
Firm 2	Female (p2)	8 years	Family Firm	49 min.	Medical Equipment
Firm 3	Male (p3)	15 years	Individual Firm	55 min.	Medical, pharmaceutical, cosmetic and sanitary equipment
Firm 4	Male (p4)	24 years	Family Firm	88 min.	Medical Equipment
Firm 5	Female (p5)	10 years	Family Firm	65 min.	Medical Equipment
Firm 6	Male (p6)	23 years	Individual Firm	58 min.	Medical Equipment
Firm 7	Male (p7)	18 years	Individual Firm	120 min.	Pharmaceutical, cosmetic, and sanitary equipment
Firm 8	Female (p8)	11 years	Individual Firm	68 min.	Medical Equipment
Firm 9	Male (p9)	10 years	Individual Firm	73 min.	Medical Equipment
Firm 10	Female (p10)	30 years	Family Firm	56 min.	Medical Equipment
Firm 11	Male (p11)	9 years	Individual Firm	50 min.	Pharmaceutical, cosmetic, and sanitary equipment
Firm 12	Male (p12)	7 years	Individual Firm	48 min.	Medical Equipment
Firm 13	Male (p13)	9 years	Individual Firm	83 min.	Medical Equipment
Firm 14	Male (p14)	10 years	Family Firm	81 min.	Medical Equipment
Firm 15	Male (p15)	15 years	Family Firm	68 min.	Medical equipment and endoscopic instruments
Firm 16	Male (p16)	28 years	Family Firm	54 min.	Industrial & Medical Manufacturing
Firm 17	Male (p17)	40 years	Individual Firm	71 min.	Medical Equipment
Firm 18	Male (p18)	7 years	Individual Firm	48 min.	Medical Equipment
Firm 19	Male (p19)	11 years	Family Firm	66 min.	Medical Equipment

Table 2. Interview Guide

Interview guide: General characteristics of the business and the interviewee			
Employee number:	Business age:	Activity:	Company name:
Manager age:	Manager gender:	Financial situation before COVID-19:	Number of branches:
<ul style="list-style-type: none"> ✓ During the COVID-19 crisis, what made your business vulnerable? What else?^{*1} ✓ During the COVID-19 crisis, what external factors made your business vulnerable? ✓ What options and solutions did you use to address these problems?^{*2} ✓ To change the unfavorable conditions of your business during the COVID-19 crisis, what actions could you have taken that you did not pursue? ✓ What obstacles did you face while doing or following these solutions? ✓ In your opinion, what features of your business have fostered the scope of the vulnerability of your business? ✓ During the COVID-19 crisis, what features of your business have reduced the vulnerability of your business? ✓ What abilities/beliefs did you have that helped you reduce vulnerabilities? ✓ What things helped you in this way? (Resources, people, facilities, etc.) ✓ Please explain the culture of the company before and after COVID-19. ✓ Before COVID-19, what other crises have you experienced? How did the experience of those crises affect the management of the COVID-19 crisis? ✓ Was COVID-19 an opportunity or a threat for you? Please explain what this opportunity/threat was. 			
*1. In these questions, the interviewer should first listen to the interviewee completely, then ask "what else" to allow the interviewee to think again so that other insights are gained. Moreover, the interviewer should try to examine the vulnerability of the business from different aspects of the business (finance, human resources, marketing, etc.)			
*2. The interviewer should ask this question for all the problems mentioned by the interviewee.			

3.2. Data Analysis

First of all, we extracted the first-order categories through interviews using Maxqda software. Then, we obtained second-order themes by identifying common patterns in the data. In the present study, to maintain reliability, the interviews were completely recorded, and the complete transcripts were created from the recorded audio files to provide raw data for coding. In this research, we used three types of coding to identify the final dimensions. In the first step, we used open coding. In this type of coding, to summarize a large amount of information, concepts in interviews and documents are classified based on their association with similar topics. After identifying these concepts, axial coding was used. The purpose of axial coding is to establish relationships between the generated categories (in the open coding stage). Finally, we employed selective coding. This type of coding systematically relates the central category to other categories, presenting these relationships in a narrative framework and identifying categories that require further enhancement and development.

4. Findings and Discussion

The analysis of the conducted interviews revealed factors effective in reducing the vulnerability of technological businesses in the epidemic crises. Our interviews revealed four outcomes, including internal business vulnerability, external business vulnerability (inhibiting factors), resilience action, and vulnerability reduction enabler's factors. An example of codebooks along with some quotes from interviewees are presented in Table 3.

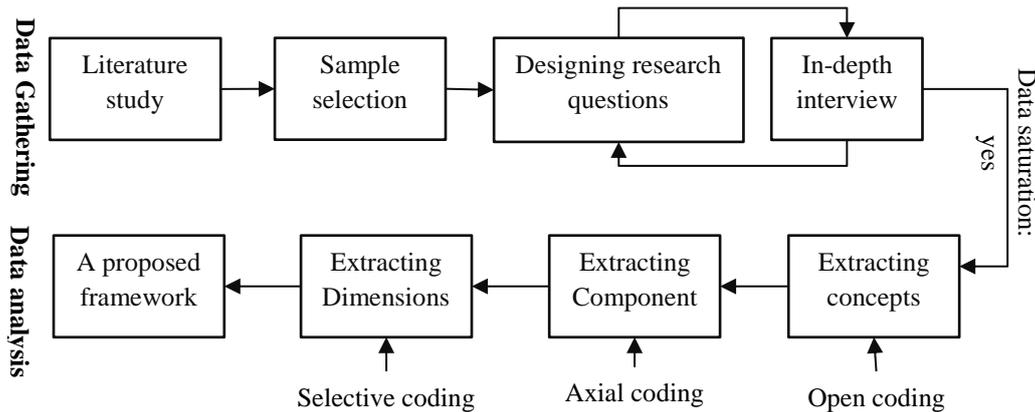


Fig. 1. Data Collection and Analysis Process

Table 3. Example of Codebooks

1 st -order categories	2 nd -order Themes	Overarching Dimensions
Internal Vulnerability		
Increase in employee leave costs due to being infected with crisis; Increase in workplace health costs; Increased shipping costs; Increase in the cost of production.	Cost challenges	Financial vulnerability
<i>P1: "In the conditions of crisis, some of the company's expenses increased and some new expenses were also created. For example, we had to add health expenses to our other expenses. Transportation costs and the cost of raw materials had increased compared to before the crisis"</i>		
Failure to estimate the reasonable price of the product due to material price fluctuations; Fluctuating prices; Improperly ordered pricing from the government, Unfair pricing of government customers; Delay in the supply of raw materials.	Insecure pricing	Marketing vulnerability
<i>P8: "Due to fluctuations in the prices of raw materials and currency exchange rates, we were unable to price our products effectively. This issue rendered the products economically unviable."</i>		
Lack of access to diverse suppliers; Lack of economic justification of working with limited suppliers; Non-cooperation of many foreign suppliers; Taking time to find the right supplier; High dependence on international suppliers; Closure of domestic suppliers	Supplier dependency	Supply chain vulnerability
<i>P18: "One of our challenges and mistakes was that we always bought our raw materials from a small number of suppliers. Some of our suppliers had either limited their activities or could not supply the materials we needed in crisis. We had to look for new suppliers, but it took time for us. At the same time, it was not easy to connect with new suppliers because they had not cooperated with us before and we could hardly convince them to pay for raw materials in the long term."</i>		
External Vulnerability: Inhibitors		
Complicated and cumbersome laws; Export and import barriers; Distribution barriers; Inadequacy of bank loans with business conditions (difficulty in obtaining loans, insufficient amount of loans, increase in demand due to crisis); Tariff and quota barriers; Unreasonable and unfair mandated price; Lack of stability in laws and policies related to health protocols.	Poor quality of laws and policies	Government ineffectiveness
<i>P5: "The government was not prepared for crisis. Government financial aid was not enough at all. On the other hand, the demand for government aid increased during the crisis. The government had to reduce the amount of grants to lend to more businesses. These amounts did not solve the problems of the business owners. Additionally, the government frequently intervenes in pricing and other matters, leading to a situation where the final price of the product does not align with the mandated price."</i>		
Lack of global raw materials: Closure and reduction of activity of global manufacturing companies; Increasing global demand and decreasing supply of raw materials; Sanctions; War between Ukraine and Russia.	Global supply chain disruptions	international vulnerability
<i>P6: "The production of many global companies decreased due to health restrictions or closures. This caused the demand for electronic parts to increase and the supply to decrease. This disrupted our production and also the price of electronic components increased significantly."</i>		

Table 3.

Technological business vulnerability reduction codebook		
Avoiding unnecessary and late innovations; Delaying investment on unnecessary projects; Stopping or postponing collaborative projects that do not conform to critical conditions and late returns.	Optimizing investment	<i>Lean financing</i>
P11: "Before the COVID-19 pandemic, we were in the process of developing new products. However, we halted this development during the pandemic because the production of these products required a significant amount of time and would not yield profits in the short term. Given the decrease in cash flow we were experiencing, it was unwise to invest in new products that would take longer to become profitable and did not align with the critical conditions we were facing."		
Non-dependence on resources; Obtaining multiple and alternative resources; Using national resources; Supplying materials through intermediary countries; Sourcing materials from low-level countries; Buying from the company agency in a neighboring country; Decentralization and lack of dependence on suppliers; Finding new suppliers; Providing materials from different suppliers sporadically and periodically; Decentralization and lack of dependence on distribution channels; Using marketers/sales forces and representatives in different locations; Using an alternative/multi-modal transportation.	Decentralization	<i>Resilient supply chain</i>
P17: "The resources and raw materials we need are supplied from other countries. This has always disturbed us. As much as possible, we procure the resources and materials that we can from within the country so that the price is lower and our work process does not face slowness."		
Sensitivity to environmental and market changes; Providing market-enabled products with rapid production capability; Supply of various products suitable for critical conditions (diversity in the production of masks, diversity in the production of disinfectants - corona treatment products, oxygen supply device, disinfection device, vaccine for COVID-19, Covid-19 diagnostic kit).	Adaptive products	<i>Adaptive marketing</i>
"One of our company's core values is to address a fundamental need within society. When COVID-19 emerged in our country, there was a significant shortage of masks, and everyone was looking to import them. We recognized this gap in the market, as our country did not have any mask production machines. In less than three months, we acquired the necessary knowledge to create the device and successfully brought it to market. We became the first company to manufacture masks domestically."		
Enabler's factors		
Emphasizing learning; Acquiring new knowledge; Having a roadmap for new products and processes; Emphasizing innovation; Paying attention to research and development activities; Using new technologies; Observing technological opportunities; Allocating funds for innovation; Trial and error; Engaging with employees; Hiring expert and technical people	Technological innovation capability	<i>Business capabilities</i>
P4: "By seeking help from our skillful technical and specialist employees, we were able to quickly produce products related to critical conditions. As you can see, we have several production parts and we are equipped with the necessary machines; even if there is no machine, we either make it ourselves or buy it quickly."		
Business size; Business age; Number of business locations; Previous sales; Ownership structure; Business structure		<i>Corporate contextual factors</i>
P10: "We have a long history, which has significantly contributed to our credibility among colleagues and customers. As a result, they have supported us during critical situations. Our suppliers have collaborated with us through long-term agreements, and our customers have been understanding regarding delays in product supply. This extensive experience has not only strengthened our relationships but has also enhanced our operational expertise."		

4.1. Internal Vulnerability of Technological Businesses

According to the coding hierarchy, we found that vulnerability factors appeared on both internal and external levels. Therefore, the first output include the factors that lead to the internal vulnerability of technological businesses. One of the challenges of a crisis is financial vulnerability (Mogaji, 2020). This was also identified in our research. Other researchers also paid attention to financial vulnerability in crisis conditions (Midões & Seré, 2022; Blanco et al., 2021; Lo et al., 2021; Mogaji, 2020; Imran et al., 2017; Zhang et al., 2009). Financial vulnerability refers to the plight of individuals or businesses that feel exposed to financial insecurity due to their inability to manage financial challenges effectively. Imran et al. (2017) also concluded that financial risks are one of the main challenges of SMEs. They argued that these financial risks arise from a wide range of sources. They cited increased labor costs, late payment of debts, price fluctuations, and negative cash flow.

Crises have changed both the context of marketing and the way businesses approach their strategic marketing efforts (He & Harris, 2020). In our research, we identified this disruption under marketing vulnerability. Hoekstra and Leeflang (2020) suggest in their research that changing consumer behavior in crisis leads to disruptions in marketing policies. According to them, the purposes, products,

channels, and target customers are affected by the crisis, so businesses should review them again in crisis conditions. Crises created high uncertainty in upstream suppliers, downstream consumers, and markets. It makes many companies unable to make decisions effectively (Wang et al., 2021). According to Fortune (2020), the COVID-19 crisis led to supply chain disruptions for 94% of Fortune 1000 companies. Our findings also revealed supply chain disruptions as one of the vulnerable dimensions for technological businesses in the crisis.

Our findings indicated that technological businesses faced many challenges in the field of human resources during the epidemic crises, and these challenges made them vulnerable. Researchers have also studied the disruptions caused by employees and human resources during the crisis. Sydnor et al. (2017) have pointed out that one of the consequences of the crisis is the loss of employees. Since employees are serious about the achievement of the business, if they are absent or lost, the company suffers great losses. Khan and Sayem (2013) have suggested that companies that lose their human resources need more time to recover. Kamalipoor et al. (2023) have also noted that the loss of key employees, especially those with specialized knowledge, greatly affects business responsiveness and subsequent recovery.

Many researchers have shown that the adoption of digital technologies in response to crisis is highly important and leads to the improvement of the performance of SMEs (Guo et al., 2020). However, Jnr and Petersen (2021) noted that human resources are one of the primary obstacles to digitalization, primarily due to a lack of digital strategies and an absence of a sense of urgency. Our interviews further revealed that businesses that had not achieved digital maturity faced significant challenges, which made them more vulnerable in the competitive landscape.

Managerial vulnerability was another type of vulnerability revealed in our findings. The reliability of the manager is important in a crisis, fraught with uncertainty. It emphasizes the importance of the capacity to anticipate and identify potential risks and issues that could hinder the company from achieving its objectives. This includes making necessary changes to the management system to prevent interruptions and ensuring a swift return to normal operations in the event of a disruption (Azizi et al., 2021). Giones et al. (2020) introduce business planning as one of the actions of entrepreneurs in conditions of uncertainty and crisis. They state that, since a disaster is an unpredictable event with high uncertainty, official plans are not appropriate. They recommend that informal planning is required to facilitate management decisions and to increase the frequency of re-evaluation of planning and adjustments to reach a more stable environment.

Since the physical and mental health of employees is the basic foundation for effective performance, improving service quality and employee motivation, maintaining survival, well-being and effective management of human resources in the current crisis is one of the goals of every business (Azizi et al., 2021). We called this dimension of vulnerability the personal vulnerability. In our research, this dimension was visible to both employees and managers. Many researches have addressed the unfavorable impacts of crises and disasters on employees and managers. The mental, emotional, and physical safety of employees has been affected by crises. Furthermore, crises have affected the performance of employees, the transferability of employees, workload, and work-life balance, among other factors (Dirani et al., 2020).

4.2. External Vulnerability of the Business: Inhibitors

The second output is external vulnerability. The dimensions of government inefficiency and international vulnerabilities are identified at this level. Since business owners cannot control vulnerabilities that originate externally, we define these types of vulnerabilities as vulnerability reduction inhibitors that affect the vulnerability reduction process. In times of crisis, the role of the government is highly important for the survival of businesses. Government actions and coordination enable companies to grow with limited resources. However, in our research, government support has not been suitable for technological businesses, slowing down the business vulnerability reduction process. Disruptions caused by additional distances, restrictions, and international logistics expose the supply chain to vulnerability through increased time and cost, thereby increasing the probability of supply chain failure (Ekanayake et al., 2020a). The disaster has exposed the fragility and vulnerability of international supply chains (Fonseca & Azevedo, 2020). It has also painfully revealed how dependent we are on foreign markets, both in terms of demand and supply (Hoekstra & Leeflang,

2020). In the interviews we conducted, business owners complained about disruptions in the international supply chain.

4.3. Identification of Vulnerability Reduction Strategies

The third output includes the responses that technological businesses adopt to reduce vulnerability during a crisis. Business owners exhibit different reactions according to their capabilities. In the following, we examined the findings related to the vulnerability reduction of technological businesses.

One of the strategies we found in our research through interviews was lean financing. Lean thinking is based on how manufacturing, service, and government organizations can increase production and innovation through the elimination of waste, reduced equipment, shorter time, and minimized human effort, while gaining the necessary flexibility to face new competitive challenges (Shetty et al., 2010). Businesses must not only implement lean principles in production processes but also consider them in all functional areas. Unfortunately, limited studies have addressed the role of financial performance in lean companies (Nielsen & Kristensen, 2020; Marodin et al., 2018). For a company to perform well, it must adapt itself to the conditions of compliance with lean manufacturing. This includes aligning the role of finance functions with a lean approach (Nielsen & Kristensen, 2020).

Crises with long-term effects have led to changes in people's shopping habits and expectations. This has resulted in a shift in the importance of marketing mix criteria for consumers (Altay et al., 2022). Businesses have been pushed to build entrepreneurial agility to establish flexibility for hypermobility due to the changes brought about by crises in the marketing environment and landscape (He & Harris, 2020). Businesses can adapt their marketing policy in times of crisis (Hoekstra & Leeftang, 2020). In our research, this issue was revealed under the title of adaptive marketing.

In the interviews we conducted, the resilience of the supply chain also emerged. We identified some codes that indicated a resilient supply chain from the interviews. These include adjustability, decentralization, mobilization, intelligence, adaptability, and value sharing. Paying attention to supply chain resilience helps companies deal with supply chain vulnerability and its effects (Ozdemir et al., 2022). This factor has also been noticed by many researchers. They describe it as the dynamic capability to respond rapidly to unforeseen events and the ability to improve quickly while maintaining the continuity of operations (Wang et al., 2021). Fonseca and Azevedo (2020) argued that to create resilient supply chains, attention should be paid to factors such as engagement with critical suppliers, alternative suppliers, improved redundancy, multi-level sourcing, and digitalization.

In terms of vulnerability reduction during the COVID-19 pandemic and technological changes, digitalization and digital transformation were also identified by the interviewees in our research. Following the spread of COVID-19 and due to communication limitations, digitalization has become more important. This disease has acted as a catalyst to move towards digitalization and has changed many business strategies (Altay et al., 2022). Digital tools (e.g. social media) help businesses sustain and respond to business challenges faster through knowledge sharing and communication (Tajpour et al., 2023). Digitalization enables businesses to understand environmental changes with greater speed and diversity at lower cost by reconfiguring their resources to respond to crises (Guo et al., 2020). The term "digitalization" refers to the process of promoting organizational change through the use of digital technologies such as information, computing, communication, and communication technologies (Guo et al., 2020; Vial, 2019). Digital transformation and emerging technologies, including mobile phones, cloud storage, data analysis systems, are being utilized to develop new business models and improve business performance. Due to the development of such transformation, organizations and companies in all industries are rapidly becoming digital and transitioning to a new form of organization (Arabiun et al., 2024).

Another strategy that helps reduce the vulnerability of businesses, which was also found in our interviews, is *adaptive strategic planning*. In a crisis and increasing uncertainty, managers must carefully analyze the resulting impact on their industry and consider new business strategies to adapt to new standards and control risk (Orîndaru et al., 2021). Strategic planning deals with managing the complexity and dynamics of the environment and is recognized as an important element in business performance. Businesses facing a rapidly changing environment require adaptive strategic planning. Adaptive strategic planning involves a business that engages in formal planning that is adaptable to environmental changes (Sumiati, 2020).

Our findings revealed the important role of leadership. According to the conducted interviews, we suggested resilient leadership in critical situations. Businesses can achieve economic sustainability in times of crisis by exercising leadership to respond (Faulks et al., 2021). The limitations and fears of systems and people can be alleviated through effective leadership. Crises enable leaders to take action that provides a competitive advantage to their businesses (Dirani et al., 2020).

4.4. Identification of Enabler's Factors

During the interviews, we found that some businesses were able to adapt to the situations of the crisis more easily than others and were more successful in implementing strategies to reduce vulnerability. This was due to two reasons that we found out through the interviews.

The first reason was the *corporate contextual factors*. The *size and the age of the company* were among these contextual factors. Larger or older companies were able to cope with the crisis better than other companies. This finding was consistent with the results found by other researchers (Lo, Liu, & Cheung, 2019; Nazari Nooghabi et al., 2020; Marshall et al., 2015). Companies with a larger workforce were better able to compensate for the absence of other employees infected with the crisis. Such partnerships and collaborations between employees in larger companies lead to both an idea and a solution in a more fruitful way. On the other hand, older companies were in a better situation than other companies due to their established position in the market and the number of customers they had. Another factor was the *number of business locations*. The travel and communication restrictions for companies with multiple locations and branches had eased. Companies with *good sales* before the crisis experienced less financial vulnerability. These businesses were also better able to finance the production of new products or the implementation of a new process. Furthermore, we found out through the review of businesses that *the ownership structure of the company* and the *organizational structure* can also act as enabling factors. Family companies worked together sympathetically in critical situations. On the other hand, we noticed that companies with flat organizational structures, enjoy cordial relations and high participation among employees and managers, act more agile and more committed in times of crisis.

The second reason that enabled businesses to reduce vulnerability was *business capabilities*. Businesses with *entrepreneurial capabilities* considered the crisis as an opportunity. Businesses whose managers had a challenging spirit and believed that they could take over the market through innovation in critical conditions were more successful. In their conversations, some managers compared themselves to global companies and believed that they could act like them. These managers did not think only about making a profit but believed that their service and product should meet the basic needs of society. They also saw their resource limitations as an opportunity for growth.

Another capability revealed during the interview with the participants was *technological production capability*. Businesses that had appropriate technological equipment and production infrastructure were able to quickly produce products suitable for the crisis. For example, one of these companies was able to produce a mask production machine using technological equipment. Another company quickly developed an oxygen capsule device for hospitals.

On the other hand, businesses that had a long history and were able to use the power of the communication network well in the face of challenges were more successful. This *networking capability* helped them make better decisions. Some businesses also experienced less vulnerability due to the *competitive advantage capability* they already had. These businesses were the only producers in the country; therefore, customers had no alternative options for purchasing products. Some businesses enjoyed a strong market position and a positive brand image. The products of some companies were fully compliant with the conditions created by the crisis, so a golden opportunity was provided to offer more of their products in the market.

4.5. A Proposed Framework for Vulnerability Reduction

We illustrated our findings in the proposed framework (Fig 2). Our findings indicate that businesses become vulnerable in the face of epidemic crises. This vulnerability occurs at four levels (A). The first and second levels of business vulnerability (manager's personal vulnerability and internal business vulnerability) are under the control of business owners, and they can take direct actions to reduce these vulnerabilities. These two levels are shown in circular space (A1). To distinguish the manager's

vulnerability from the vulnerabilities occurring in the business aspects, we have depicted it using a darker color in the circular space. These dimensions are the result of coding in Section 4.

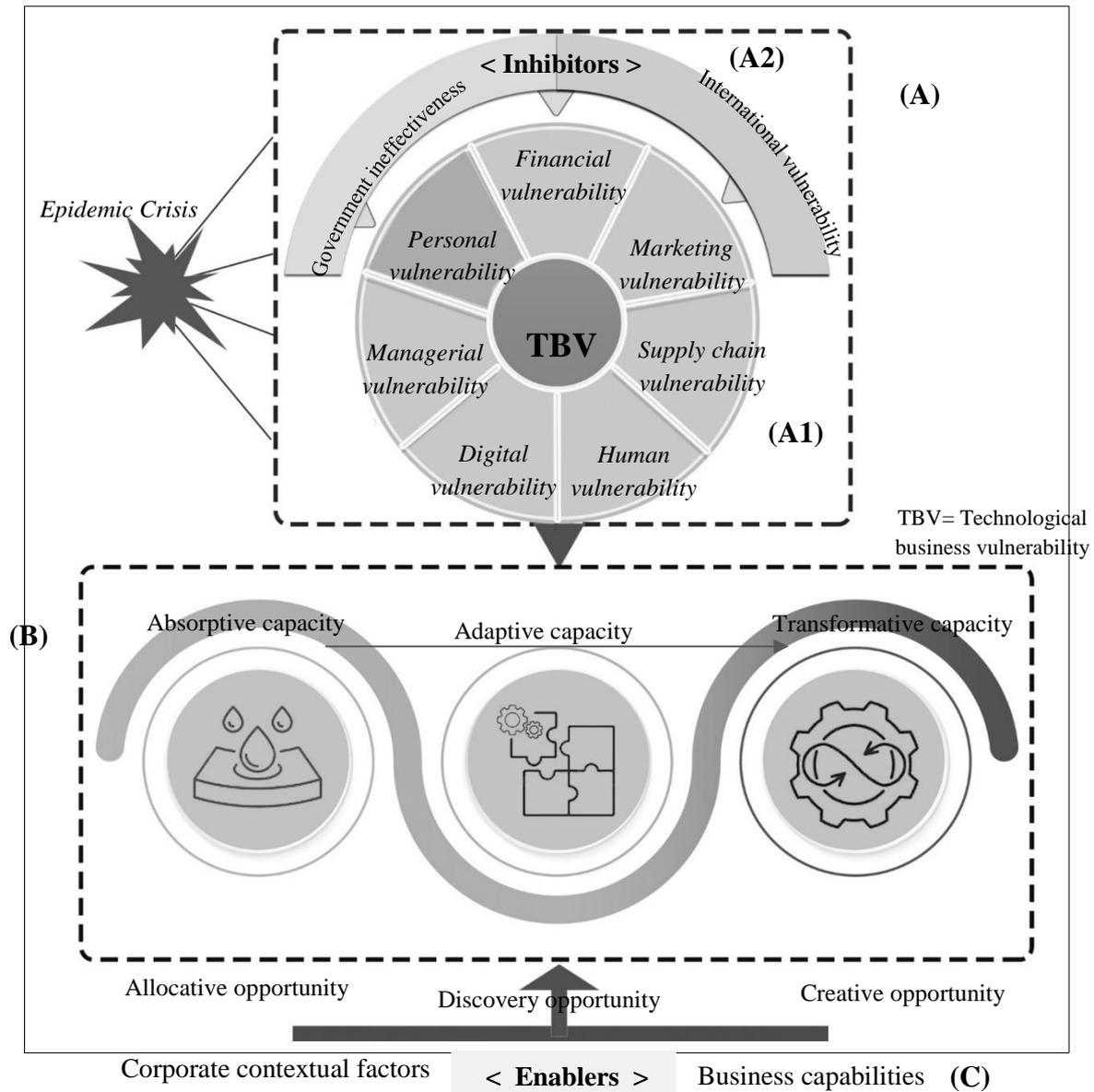


Fig. 2. Proposed Framework

The third and fourth levels of vulnerability (national and international) are related to the external vulnerabilities of the business, which are beyond the control of the business owners, but affect the internal vulnerabilities of the business (A2).

Faced with these vulnerabilities, businesses adopt strategies to become resilient. These businesses operate along a spectrum based on their business resilience capabilities. Based on our findings from the interviews and literature review, we established a link between three perspectives of opportunity (allocative, discovery, creative) and three business resilience capacities (absorptive capacity, adaptive capacity, and transformative capacity) (B). In this research, we found actions suitable for each resilience strategy. These actions are the result of coding in Section 4. Of course, it should be noted that some of these actions do not necessarily fit in one strategy. For simplicity, we have illustrated these actions for resilience strategies separately in Fig 3.

We found that businesses, in the face of crisis, focus primarily on optimizing resources and maintaining their balance. They use their existing resources and capacities to achieve stability. This

business approach is consistent with the perspective of allocative opportunity and resilience through absorptive capacity.

When the effects of risks and crises on businesses are greater than in the past, the stability of businesses no longer helps to keep businesses alive. They seek to take advantage of opportunities created by threats. So they adapt to this situation. They take advantage of the opportunities ahead by making changes to their products and processes. This approach is in line with the vision of discovering opportunity and resilience through adaptive capacity.

As crises become more frequent, prolonged, and severe, minor changes or small innovations are insufficient. These businesses adopted various responses to such crises. If their businesses could be transformed, they would shift towards disruptive technologies, advanced technologies, and new products. Otherwise, they would change their business. This approach is in line with the vision of creative opportunities and resilience through transformative capacity.

Enablers are specified in box (C). These enablers, placed in two categories (Business capabilities and corporate contextual factors), play an important role in choosing resilience strategies and reducing vulnerability. For example, the higher the technological capabilities, the faster businesses can transition towards adaptive and transformational strategies; conversely, the lower these capabilities, the more businesses remain in a state of status quo and stability.

Business Vulnerability Reduction(BVR)				
Allocative view	<p><u>Lean financing</u></p> <ul style="list-style-type: none"> Optimizing costs Optimizing internal processes Optimizing investment 	<p><u>Adaptive Marketing</u></p> <ul style="list-style-type: none"> Current product management 	<p><u>Resilient supply chain</u></p> <ul style="list-style-type: none"> Adjustable Decentralization Mobilization 	<p><u>Resilient leadership</u></p> <ul style="list-style-type: none"> Visionary Employee-oriented Hopeful behavior Motivating and inspiring
Absorptive capacity				
Discovery view	<ul style="list-style-type: none"> Productive financing Viable income stream 	<ul style="list-style-type: none"> Leverage resources Adaptive products Orientation to marketing technology tools Value creation Customer orientation 	<ul style="list-style-type: none"> Intelligent Adaptability Value sharing 	<ul style="list-style-type: none"> Creating a resilient mindset Attention to learning Opportunity recognition Adaptability approach
Adaptive Capacity	<p><u>Adaptive strategic planning</u></p> <ul style="list-style-type: none"> Environmental and business monitoring Participation Futures orientation Promptness Responsiveness Flexibility plan 		<p><u>Digitalization</u></p> <ul style="list-style-type: none"> Digital infrastructure Digital operational/organizational process Digital culture Digital opportunities Digital competence of employees 	
Creative view		<ul style="list-style-type: none"> Adaptive innovative products 	<p><u>Digital transformation</u> Developing products based on digital technology</p>	
Transformative capacity				

Fig. 3. Business Vulnerability Reduction Based on Resilience Capacity and Entrepreneurial Opportunities

5. Implications

We argued that during the normal conditions, technological businesses face complexities. In times of crisis, these complexities will intensify significantly. In other words, it is necessary to make special efforts in different dimensions to ensure the continuation of operations, reduce vulnerability, and

increase resilience. The findings of our research offer a pathway for business owners to pursue the achievement of these objectives. This research has implications for business managers, marketers, and policymakers as follows.

The findings of this research can help managers of technological businesses to face crises, reduce their impacts, and take adaptive and innovative measures. Owners and managers of technological businesses can use our findings to identify the vulnerability factors within their businesses at the personal level, the business's perspective level, and the external level. They can also benefit from the results obtained in the dimensions of finance, planning, marketing, supply chain, leadership, and operations to improve their probability of success in resilience and increase the adaptability of their business. This study also reminds managers and business owners that, by developing networking, technology production, entrepreneurial, and competitive advantage capabilities, they can increase their chances for sustainability and reduce vulnerability during epidemic crises. Managers should pay attention to personal vulnerability caused by negative feelings and beliefs of middle managers and employees regarding environmental challenges and threats because it negatively affects their ability to be resilient and adapt. Managers with a resilient leadership approach can reduce and eliminate the challenges surrounding human resources. To reduce financial vulnerability, managers should take heed of costs, cash flow, and investment and pay attention to the lean financing approach. The results of this study assist managers in improving the digital resilience of their businesses by creating a digital identity and using digital technologies in their operational processes and products.

This study also has implications for marketers. Marketers can take advantage of upcoming opportunities by reviewing current and active products in the market. This research helps marketers to adopt an adaptive approach to their marketing activities. In general, by identifying vulnerable points and relying on business resilience capacities (absorption, adaptation, and transformation), this study helps managers and marketers to take measures based on elimination, reduction, adaptation, or transformation, allowing businesses, individuals, and networks to experience less vulnerability.

Development and growth have always been the most important pivot of policies and programs of distinctive nations. Two critical ways to seek it are providing optimal conditions for entrepreneurship and developing technologies (Isenberg, 2011). Our proposed framework serves as a valuable guide for policymakers in identifying the vulnerable points of businesses, enabling them to make informed decisions regarding appropriate coping and adaptation strategies to address adverse environmental and economic changes affecting technological businesses, as well as targeted programs aimed at eliminating and reducing vulnerability factors. These programs help to reduce vulnerability at the economic and social levels of society. Unfortunately, our findings indicated that government actions and decisions are inhibiting and insufficient for technological businesses, rather than being supportive and empowering. This study assists policymakers and decision-makers in correcting their actions that have negative impacts and enhancing the environment for business development. It is essential for government financial support for technological businesses to differ from that provided to other non-tech businesses. Government institutions should pay attention to strengthening their infrastructures as well as their online and digital platforms. On the other hand, experts and government managers must strengthen their digital mentality and acquire digital knowledge. In times of epidemic crises, it is advisable to disseminate emotional support through public media and news outlets.

6. Limitations and Future Scope of Research

This research has several limitations. First, even though the qualitative research approach is suitable for examining the reduction of vulnerability processes, some limitations still exist, including the inapplicability to all technological businesses during an epidemic crisis such as COVID-19. We gathered data from one country to serve as an example, but it is simply representative of a single region. Given the diversity of ecosystems both within and between nations, we encourage researchers to assess the applicability of our model to various ecosystems. Second, a cross-sectional approach was taken in conducting this study. The inability to examine dynamic changes over time is one drawback of the cross-sectional approach, and the findings of this study may differ from those of a similar study conducted at a later or earlier point in time. Third, in qualitative research methodologies, a small sample size is often a concern. However, we conducted 19 interviews and achieved theoretical saturation. Future studies should examine how business vulnerability can be reduced by gathering

information from a diverse range of stakeholders and employees at various levels of the hierarchy. Based on discussions with business owners, we reached our conclusions. However, in our study, we did not explore the perspectives of employees. We encourage academics to investigate business vulnerability reduction from the standpoint of employees and middle managers who faced challenges during epidemic crises such as COVID-19.

Changes Made: Future researchers can research technological businesses in various industries, which offer intriguing business insights. We advise the researchers to combine quantitative and qualitative approaches and to prioritize the drivers and components identified for analysis. Given that many researchers emphasize the importance of institutional structures in reducing vulnerability (Kamalipoor et al., 2022; Rana & Routray, 2018; Turner et al., 2003), particularly in situations with limited resources and during a crisis, we encourage academics to propose policies that link state policy to the reduction of business vulnerability.

7. Conclusion

The purpose of this study is to develop the capabilities for vulnerability reduction and increasing technological businesses' resilience during the epidemic crisis of COVID-19 by focusing on three resilience capacities (Béné et al., 2012) and three approaches to opportunities (Sarasvathy et al., 2003). This study identifies the vulnerability factors of technological businesses and how to reduce their vulnerability in the epidemic crisis. According to our findings, we offer a multidimensional model of vulnerability reduction that enables technological businesses to achieve greater resilience (See Section 4.5 for findings).

According to the results of this study and other research (Birkmann, 2005; Turner et al., 2003), it can be decided that vulnerability is a multifaceted phenomenon created by the interaction between different factors. In particular, technological business vulnerability is influenced by individual, internal, and external business factors. Technological businesses have been severely impacted by global supply chain disruptions as well as financial, human resources, marketing, and technology challenges. Our analysis revealed that the degree of vulnerability of technological businesses vary according to their capabilities, background characteristics, and their actions during natural disasters. They confront the crisis by using absorptive capacity, adapt themselves by employing adaptive capacity, or implement fundamental changes and transformations in their business. We contribute to the limited literature on the vulnerability of technological businesses, the three capacities of resilience, and the three perspectives of opportunity during epidemic crises. The results of our research are consistent with Galkina et al. (2023), and Delladio et al. (2023). By examining international companies operating under the adverse conditions of a global pandemic, Galkina et al. (2023) revealed that companies develop different dynamic states of their business models throughout the resilience process. Changes in dynamic states are due to the achievement of certain resilience capabilities. Moreover, by examining 80 Italian entrepreneurs who were facing unprecedented disruptions such as the COVID-19 pandemic, Delladio et al. (2023) found that they adopt various resilient measures according to the level of uncertainty and business context. They prepare themselves against the crisis by using new products and new markets, or they control the situation by relying on existing resources. This research provides a general framework for the process of technological business vulnerability reduction. Hence, we greatly contribute to the understanding of dispersed factors of business vulnerability to increase resilience during epidemic crises. Our study provides evidence that vulnerability reduction occurs in different dimensions and that different dimensions play unique and critical roles. This conclusion can have significant implications for future studies on (i) crisis, vulnerability, and business resilience, (ii) entrepreneurial opportunities, and (iii) managers, business owners, and policymakers.

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