The Role of Housing and Community Infrastructure in Successful Aging in Disaster-Vulnerable Areas

Linnel Marie S. Ballesteros[1], Cristina Poleacovschi [2], Ivis García [3], Carl F. Weems [4]

Kaoru Ikuma [5], Chris R. Rehmann [6]

[1] Department of Civil, Construction, and Environmental Engineering, Iowa State University, 394 Town Engineering Building, Ames, IA 50011. Email: linnelsb@iastate.edu

[2] Department of Civil, Construction, and Environmental Engineering, Iowa State University, Town Engineering Building, Ames, IA 50011

[3] Department of Landscape Architecture & Urban Planning, Texas A&M, 3137 TAMU College Station, TX 77840

[4] Department of Human Development and Family Studies, Iowa State University 380 Palmer Suite 2330, Ames, IA 50011

[5] Department of Civil, Construction, and Environmental Engineering, Iowa State University, Town Engineering Building, Ames, IA 50011

[6] Department of Civil, Construction, and Environmental Engineering, Iowa State University, Town Engineering Building, Ames, IA 50011

ABSTRACT

Successful aging is often defined as the low likelihood of disease and disease-related disability, a high probability of high cognitive and physical function capacity, and active engagement with life. However, existing successful aging concepts ignore numerous contextual factors affecting aging populations in disaster-vulnerable areas. Damage to community infrastructure from extraordinary events threatens vulnerable populations, especially older adults, and risk their successful aging. This research aims to address this gap by examining successful aging indicators in disaster-vulnerable areas. Additionally, this research identified the built environment antecedents of successful aging by focusing on the role of recovery of housing and

infrastructure. Towards this goal, this research was conducted in two stages in 6 communities in Puerto Rico from June 2021 to December 2022. First, we conducted 32 ethnographic interviews with older adults (aged 65 and above) and used narrative analysis to interpret their stories of post-disaster recovery as older adults. Second, we conducted 90 surveys with older adults and used Ordinary Least Squares regression analysis to identify successful aging indicators that were impacted in the older adults' housing and infrastructure recovery. Interviews show that as a part of their recovery processes, older adults have been displaced from their homes due to unsafe living conditions, which particularly negatively impacted their sense of control and continuity. On the other hand, there have been beneficial effects as well. For instance, the process of recovery has facilitated the development of strong relationships with family through giving and receiving help from the community. It has also increased adaptability to significant changes, promoted a sense of volunteerism and contribution, and improved self-efficacy by facing and overcoming challenges. Furthermore, analysis from surveys of older adults shows that housing recovery is positively and significantly associated with their sense of connection. Similarly, infrastructure recovery is significantly and positively related to their sense of compensation, challenge, and control.

Keywords: successful aging 1; housing 2; infrastructure 3; post-disaster recovery 4; aging environment

1. Introduction

Older adults experience multiple age-related vulnerabilities, such as higher rates of diseases, limited mobility, and aging alone (Abel & Deitz, 2014). Due to these vulnerabilities, older adults encounter challenges threatening their successful aging, particularly after being exposed to disasters (AARP, 2022). Successful aging generally involves a low likelihood of

disease and disease-related disability, high cognitive and physical function capacity, and active engagement with life (Nakagawa et al., 2020; Rowe and Kahn, 1997). Nonetheless, the current definitions of successful aging are based on the viewpoints of dissimilar, more resilient, and varied demographic groups of older adults, and thus, might not precisely depict the encounters of disadvantaged older adults in communities with inadequate housing and infrastructure.

Successful aging is influenced by factors such as financial well-being, a sense of purpose, access to adequate nutrition, quality healthcare, social services, and meaningful social connections (Cheng & Yan, 2021; Kendig et al., 2014). After disasters, older adults in disaster-vulnerable areas experience additional vulnerabilities related to housing (Merdjanoff et al., 2019), transportation (Annear, Keeling, and Wilkinson, 2014), and healthcare (Bell et al., 2022).

Puerto Rico's older adults, affected by Hurricane Maria, are a prime example of a community struggling with housing and infrastructure constraints in their recovery process are the older adults in Puerto Rico after experiencing Hurricane Maria. Puerto Rico possesses a higher-than-average elderly population, with 21% of its population being 65 years old or older, significantly surpassing the U.S. national average of 16% (Census, 2021). For example, public transportation in Puerto Rico has not been fully restored (Ecola et al., 2020), which decreased the ability of older adults in low-income communities to reach medical resources, including medical treatments and care (personal communication, June 14, 2021) .

This is only one example that outlines how housing and infrastructure recovery likely affected the definition of successful aging for older adults, highlighting the multitude of influencing factors that are unique to their needs. This makes it important to conceptualize their definition of successful aging inductively by identifying essential indicators of successful aging. Thus, first, we ask, *"What indicators of successful aging are critical to older adults in a post-*

disaster environment?" To answer this question, interviews in this study uses a comprehensive framework based on six indicators: continuity, compensation, control, connection, contribution, and challenge (Scharlach, 2017).

Given that housing is fundamental for health and well-being, older adults need to be able to have continuity, consistency, and predictability related to their housing situation—that is, being able to stay at home, including the neighborhood surroundings, without being threatened by displacement after a disaster (Wahl and Weisman, 2003; García and Rúa, 2017). Stable housing allows one to secure material belongings, sustaining long-lasting interests and activities attached to memory, history, and self-identity (Ouwehand, de Ridder, and Bensing, 2007; Lawton, 1982; Rowles and Watkins, 2003).

Similarly, infrastructure, such as public transportation, which is important for older adults to access health care and other services, can be significantly affected during a disaster (Annear, Keeling, and Wilkinson 2014). Infrastructure refers to the fundamental physical and organizational systems that are essential for a community to operate. It plays a vital role in supporting vulnerable populations, particularly the elderly. During hurricanes, roads will be flooded, blocked, or damaged, making it difficult for older adults to access medical care and other critical emergency resources (Contreras and Niles, 2022). Power outages can cause heat waves, and impact access to medical equipment, such as dialysis machines and oxygen delivery systems, resulting in higher mortality rates among older adults (Andrade et al., 2021). Older adults may also have difficulty maintaining contact with family, friends, and other support networks due to disruptions of communication systems. (Kapucu, 2006).

Older adults are known for their community resilience and social capital during disaster recovery. In their recovery processes, they are known to contribute to building relationships by

sharing resources and experiences (Howard et al., 2015). In a similar sense, older adults who have more connections in the community are more likely to be prepared in disasters (Kim and Zakour, 2017). Although the present literature acknowledges the active involvement of older adults in recovery processes, there is a lack of information on how recovery influences successful aging. Hence, there needs a deeper understanding on how housing and infrastructure recovery aspects influence the six successful aging indicators and we ask, "*What are the roles of post-disaster housing and community infrastructure recovery on successful aging?*" To answer this question, this study conducted a set of surveys and interviews with older adults in Puerto Rico who have experienced Hurricane Maria and to gather stories of post-disaster housing and infrastructure recovery.

2. Literature Review

Successful Aging

Researchers have attempted to define successful aging in various ways. MacArthur (1997) first proposed the concept of successful aging, characterized by the capacity to remain in good health and well-being in old age (Domènech-Abella et al., 2018). Spirituality, psychosocial support, nutrition, and emotional health emerged as themes in further studies and models (Iwamasa and Iwasaki, 2011; Ng et al., 2009; Crowther et al., 2002). Studies explored and suggested expanded versions of the MacArthur successful aging model because they believed that the concept of successful aging should encompass more than just physical health—they suggested that successful aging should also include psychological, social, and spiritual well-being. To address these shortcomings, the Process Model of Constructive Aging outlines the importance of the developmental processes of older adults; this model is a useful reference for designing aging-friendly environments and enabling older adults to live fully throughout their

lives (Scharlach, 2017). This model presents six processes explaining older adults' behaviors as they experience aging within their built environments: continuity, compensation, control, connection, contribution, and challenge.

First, *continuity* refers to the ability to preserve a sense of identity by continuing familiar activities that are meaningful to them. Continuity is a strategy to achieve successful aging because it enables older adults to maintain everyday activities, which helps them adapt to the increasing number of changes as they age (Wahl et al., 2012; Atchley, 1989; Lawton, 1983). Second, *compensation* refers to the ability to adapt to age-related changes and challenges. This is particularly important as older adults are prone to health changes, like losing the ability to walk and memory loss. Third, *control* refers to the ability to execute actions required to produce a specific task, giving a person a sense of achievement of performance goals. In other words, the control gives older adults a sense of self-efficacy, which is likely to diminish as their age-related diseases impede their ability to attain specific goals (Schulz et al., 1994). Fourth, *connection* refers to meaningful human interactions that provide older adults with a sense of companionship. Connection is critical to older adults because their social network may have diminished through loss and limited mobility (Cornwell et al., 2008). Fifth, *contribution* refers to contributing or providing service to meaningful causes. Contribution is important to older adults because it gives them a sense of self-perceived purpose and increases their well-being (Tang et al., 2010; Morrow-Howell et al., 2003). Sixth, *challenge* refers to the ability to challenge themselves. It is beneficial for them to have the ability to see every impediment as an opportunity to become better. Environmental conditions requiring small-scale efforts benefit older adults by contributing to improved mobility, muscle mass, and exercise in their physical and cognitive functioning (Brawley et al., 2003).

This model is appropriate for determining factors of successful aging because it represents a multidimensional approach, representing successful aging on personal and contextual approaches, giving regard to the built environments' contributing factors to successful aging and not just the mental or physical health needs (Sharlach, 2017).

Post-disaster housing and infrastructure recovery

Post-disaster housing recovery in this study refers to the level of recovery of residential buildings in the aftermath of disasters. Any damage and failure to recover threatens people's well-being, such as quality of life, physical health, and social relationships (Engel et al., 2016; Fleming et al., 2016; Leung et al., 2019; Sarmiento et al., 2010; Wahl, 2009). Housing is critical to older adults because their physical abilities vary and are often limited (Iamtrakul & Chayphong, 2021). Since housing features change due to hazards, it will significantly affect their well-being (Gell et al., 2020). For example, a house exposed to physical hazards such as slippery floors and obstructed hallways increases the safety hazards of already vulnerable occupants (Iamtrakul & Chayphong, 2021).

Another important component that will affect successful aging includes post-disaster infrastructure recovery. Post-disaster infrastructure recovery refers to level of recovery of the infrastructure in a community that becomes vulnerable in any crisis due to the impacts that an interruption of service would have on citizens. ~~disaster infrastructure vulnerability refers to the infrastructure in a community that becomes vulnerable in any crisis due to the impacts that an interruption of service would have on citizens~~ Generally, infrastructure is essential for older adults. Many older adults need more alternative options for transportation, such as public transit or rides with the family, due to their physical and cognitive limitations (Jeste et al., 2016). Recent literature established that accessible, inclusive public spaces support the older adult

166 population (Mouratidis, 2021; Finlay et al., 2021; Saelens & Papadopoulos, 2008; Kerr et al.,
167 2012). Parks, fitness amenities, and walkable spaces improve health by motivating physical
168 activities such as exercise and walking (Finlay et al., 2021; Saelens & Papadopoulos, 2008; Kerr
169 et al., 2012). Aside from physical public spaces, safe drinking water and proper sanitation, which
170 are identified to be inadequately accessible to older adults and people with disabilities, can also
171 impact an older adult's quality of life because unsafe and improper sanitation are the sources of
172 many diseases that affect older adults' well-being (Wrisdale et al., 2017). While previous
173 literature documented that housing and infrastructure affect successful aging, they have been
174 studied less in the context of post-disaster recovery in Puerto Rico. As these forms of
175 infrastructure become vulnerable after disasters, their level of recovery will likely have distinct
176 and unique effects on successful aging indicators. This study addresses this gap by evaluating the
177 relationship between post-disaster housing and infrastructure recovery on successful aging
178 indicators of older adults in Puerto Rico after hurricane Maria.

179 **3. Methods**

180 *Study design*

181 The study consisted of mixed methods because it finds equal importance of qualitative
182 and quantitative data to answer the two research questions. The first research question focuses on
183 building indicators of successful aging and is answered using interview data. The second
184 research question evaluating the role of post-disaster housing and infrastructure recovery on
185 successful aging is answered using interview and survey data.

186 *Qualitative study data collection*

187 The qualitative study included 32 interviews collected in June 2021 from older adults in
188 Puerto Rico. The interviews were done in four municipalities, namely, Loiza, San German,

Humacao, Caguas, and Yabucoa, to encompass several contexts of disaster vulnerability, such as flooding, storm surges, and landslides. The five municipalities were also chosen because of their varied geographical locations in Puerto Rico. Loiza is a riverside and coastal area, Humacao is a coastal area, and Yabucoa, San German, and Caguas are mountainous areas. To qualify for this study, the participants must be 65 or older and have resided in Puerto Rico when Hurricanes Irma and Maria happened. With an exemption from the Institutional Review Board (IRB), the interview protocol was designed to have open-ended questions to gather more participants' information. The participant names and exact locations were not recorded to protect confidentiality.

The interviews included questions like, “What is successful aging to you?”, “How has the disaster affected your aging experience?” and “How has your life changed after the disaster?” The interviews, including observations, lasted for about one hour. Local research assistants translated the interview questions from English to Spanish and accompanied the first author to administer the interview. The local research assistants periodically translated the participants’ responses to the first author so the first author could assess what follow-up questions should be asked. The interview stopped when the responses reached data saturation such that the responses no longer differed greatly from the previous interviews (Guest & Johnson, 2006). The interviews were audio-recorded for accurate documentation of the participant’s responses. After the interviews were completed, a professional transcriber was hired to translate Spanish to English and transcribe the audio files. The professional transcriber signed a contract that stipulated confidentiality and privacy of the participants shall be maintained. Other identifiable information recorded on audio was redacted and deidentified during the transcription. Additionally,

participant observation notes have been documented to supplement data that audio recordings cannot capture.

Qualitative study data analysis

We used narrative analysis to analyze the data from the interview transcripts. Narrative analysis is a methodology that uses assumptions based on established theories. We used narrative analysis because it is a suitable method for interpreting the stories into themes of successful aging. Since this study is based on an established theoretical framework, we used deductive coding (Bingham & Witkowsky, 2021; Pearse, 2019), which is a top-down approach based on the initial six sets of macro codes defining successful aging including continuity, compensation, control, connection, contribution, and challenge.

It was then necessary to validate all codes within the relevant literature and undergo several iterations before establishing a final literature-supported code framework (Bringer et al. 2006). In biweekly meetings with the research team, the initial and subsequent coding frameworks were presented until consensus was reached on a finalized framework. Using this coding framework, two coders analyzed the interview transcripts independently using NVivo version 15 to analyze the interview transcripts. The first author and an undergraduate student did the coding. The undergraduate student was in their 4th year in the civil, construction, and environmental engineering department when they performed inter-coder reliability. The student is familiar with the project to code three random transcripts and compare the coding results to the actual coding result conducted by the first author to ensure consistency in the responses to the multiple codes. The coders held a virtual meeting to identify and discuss any necessary changes to be made to a random selection of interviews.

Quantitative study data collection.

The data analyzed in the quantitative study were collected in 2022 from participants in Puerto Rico. Data were collected using 90 door-to-door surveys from households of Comerío. This municipality was chosen because Comerío has a median age of 41, which is higher than the median age of the mainland U.S., 38, and represents the median age of Puerto Rico (Bureau of U.S. Census, 2022). To qualify for this study, the participants must be 65 or older and have resided in Puerto Rico when Hurricanes Irma and Maria happened. With the dominance of Hurricane Maria being recalled by participants in the qualitative study, we focused our survey questions on Hurricane Maria. Surveys included 26 questions and were completed in an average of 45-65 minutes. Surveys were originally written in English, then translated into Spanish by a research assistant from Puerto Rico and administered in Spanish. Two research assistants from Iowa State University and hired local research assistants from the University of Puerto Rico distributed and administered the surveys. Each survey was conducted in person, with the research assistant asking each question and, if requested, providing clarifying information.

The survey asked participants for demographic information, successful aging indicators, and post-disaster housing and infrastructure damage and recovery measures. Indicators of successful aging include statements, such as a response to the statement, "When things don't go as well as they used to, I keep trying other methods until I can achieve the same results I used to." In the questionnaire, participants are asked to provide responses on a Likert scale of 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree. The post-disaster housing and infrastructure recovery measures ask questions, such as, "Did you experience damage or loss of the following parts in your home after Hurricane Maria?" Then, if they answered yes, they were asked, "Have you recovered or restored the following parts in your home after Hurricane Maria?" The questionnaire asks participants to respond to choices between

yes and no. An itemized list of questions and their corresponding response choices are found in Appendix A.

Quantitative study data analysis. "~~I am able to continue participating~~

This study uses OLS regression analysis to explore the relationship between community infrastructure recovery and successful aging. We assigned connection, compensation, contribution, continuity, challenge, and control as successful aging indicators. Then, we assigned housing recovery and infrastructure recovery as the two community infrastructure recovery indicators. The models for the analysis warranted control for age, gender, education, income, and the number of children living with the participants.

Measures.

Age, income, and children living with them at home are coded as continuous variables (Appendix A). The survey design accommodates a variety of gender, but all the respondents identified themselves as either male or female. Thus, we coded gender as a dichotomous variable, where male = 1 and female = 2. Education was coded as ordinal, where 1 = primary; 2 = secondary; 3 = college/university; 4 = graduate. The dependent variables were compensation, contribution, continuity, challenge, control, and connection (Appendix A). Each variable was computed as the sum of all its corresponding indicators or scales. The sum of their responses in each of the indicators were then treated as continuous variables in the regression model. Internal consistency (Cronbach's alpha) was calculated for each of these scales. Estimates were as shown in the table below:

Table 1. Reliability statistics of 6 successful aging variables

Variables	Cronbach's alpha	No. of Items	N
Connection	0.63	4	75
Compensation	0.66	4	87
Contribution	0.89	6	89
Continuity	0.69	3	87
Challenge	0.90	3	89

Control	0.71	3	87

The independent variables were post-disaster housing recovery and infrastructure recovery. Post-disaster housing recovery was computed as the sum of all its corresponding indicators or scales. Post-disaster housing recovery, has 15 indicators. One of the housing recovery indicators is a follow-up to the previous question, “Did you experience damage or loss of the following parts in your home after Hurricane Maria?” The main question is, "If "Yes," how soon did it get restored or become usable again?" Then, the responses were dichotomized such that 0 = never restored, and 1 = restored at some point. The sum of their responses in the 15 indicators was then treated as continuous variables in the regression model. The same procedures were done for the infrastructure recovery variable.

Quantitative data analysis.

We used the scales identified as reliable as successful aging indicators. We used a series of OLS (Ordinary Least Squares regression) to describe the relationship between the independent quantitative variables, housing recovery and infrastructure recovery.

4. Results

Descriptive statistics

Table 2 shows the descriptive statistics of all variables, and it is important to note that the average monthly household income of the sample population is only $1,487.11, below the national poverty level of $2,312.50 (ASPE, 2022). Therefore, the sample population possesses noticeably low-income households. The results in these descriptions underscore the economic disparities in the demographics and must be held constant throughout the subsequent analyses. It is also noticeable that the mean scores of compensation, continuity, challenge, and control appear to be high, while the mean scores for connection and contribution are low.

Correlations

Table 3 shows the correlations evaluating the relationships of housing and community infrastructure recovery, and the six successful aging indicators, namely, connection, compensation, contribution, continuity, challenge, and control. There is a significant correlation between contribution and infrastructure recovery, $r(87) = -.23$, $p<0.05$.

Table 2. Descriptive statistics of variables

	N						
Variables	Valid	Missing	Mean	Median	Std. Deviation	Minimum	Maximum
Age	89	8	73.09	72.00	6.660	65	92
Gender	89	8	1.62	2.00	.489	1	2
Education	89	8	2.10	2.00	1.001	1	4
Income	81	16	1487.11	1100.00	1479.525	300	8000
Children	89	8	.43	.00	.620	0	2
Connection	89	8	10.97	10.00	5.254	4	23
Compensation	89	8	13.67	14.00	4.507	0	20
Contribution	89	8	11.65	11.00	6.483	0	27
Continuity	89	8	8.84	9.00	3.652	0	15
Control	89	8	13.11	14.00	2.656	0	15
Housing recovery	87	10	14.31	12.00	13.187	0	55
Infrastructure recovery	87	10	12.34	13.00	5.546	0	29

Correlations

	Age	Gender	Education	Income	Children	Connection	Compensation	Contribution	Continuity	Challenge	Control	Housing recovery	Infrastructure recovery
Age	1												
Gender	0.025	1											
Education	-0.319**	0.057	1										
Income	-0.097	0.086	0.244*	1									
Children	0.236*	0.019	-0.162	0.097	1								
Connection	0.291**	0.137	-0.358**	-0.149	0.165	1							
Compensation	-0.094	0.036	0.209*	-0.203	-0.190	-0.191	1						
Contribution	0.070	0.331**	0.226*	-0.118	-0.175	-0.117	0.423**	1					
Continuity	-0.165	-0.174	0.216*	-0.274*	-0.091	-0.381**	0.464**	0.318**	1				
Challenge	-.360**	-0.061	0.358**	-0.182	-0.167	-0.302**	0.473**	0.181	0.508**	1			
Control	-0.120	-0.028	0.141	-0.612**	-0.202	-0.248*	0.440**	0.332**	0.559**	.533**	1		
Housing recovery	0.179	-0.020	-0.283**	0.072	0.155	0.022	-0.197	-0.179	-0.108	-.143	-.151	1	
Infrastructure recovery	-0.041	-0.121	-0.257*	-0.133	0.188	-0.128	0.002	-0.234*	0.042	.116	-.031	.169	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Investigating the relationship between successful aging indicators and housing and infrastructure analysis through OLS Regression Analysis

Table 4 shows the regression analyses evaluating the antecedents of the six successful aging indicators, namely, connection, compensation, contribution, continuity, challenge, and control. For every successful aging indicator, two models, namely, housing recovery and infrastructure recovery are analyzed as its explanatory variables. The first and second models show that connection has a significant positive association with housing recovery, but not with infrastructure recovery. The third and fourth models show that compensation does not have a significant association with housing recovery, but has a significant positive association with infrastructure recovery. The fifth and sixth models show that contribution does not have a significant association with housing recovery and infrastructure recovery. The seventh and eighth models show that continuity does not have a significant association with housing recovery and infrastructure recovery. The ninth and tenth models show that challenge does not have a significant association with housing recovery but has a significant positive association with infrastructure recovery. The eleventh and twelfth models show that control does not have a significant association with housing recovery but has a significant positive association with infrastructure recovery.

Table 4. Regression analysis showing the relationship between successful aging indicators as dependent variables and housing and infrastructure recovery as independent variables.

	Models	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DV		Connection		Compensation		Contribution		Continuity		Challenge		Control	
CV	Age	0.150	0.160	-0.08	-0.05	0.120	0.120	-0.08	-0.07	-0.16*	-0.12	-0.05	-0.02
		(0.09)	(0.10)	(0.09)	(0.08)	(0.11)	(0.12)	(0.07)	(0.07)	(0.07)	(0.06)	(0.04)	(0.03)
	Gender	2.210	2.450	-0.22	-0.17	3.48**	3.64**	-1.41	-1.47	-0.50	-0.42	-0.34	-0.30
		(1.05)	(1.11)	(1.01)	(0.96)	(1.31)	(1.33)	(0.79)	(0.79)	(0.78)	(0.71)	(0.44)	(0.40)
	Education	-0.84	-1.34	1.24*	1.58	2.21**	1.83*	0.630	0.850	1.44***	1.730	0.480	0.680
		(0.57)	(0.61)	(0.55)	(0.53)	(0.72)	(0.74)	(0.43)	(0.44)	(0.43)	(0.39)	(0.24)	(0.22)
	Income	0.000	0.000	-0.00*	-0.01	-0.00	-0.00	-0.00**	-0.00**	-0.00**	0.000	-0.00***	-0.00***
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	Children living with them at home	0.500	0.520	-0.58	-0.65	-1.60	-1.69	-0.13	0.090	0.230	0.140	-0.26	-0.31
		(0.84)	(0.90)	(0.82)	(0.77)	(1.06)	(0.38)	(0.12)	(0.64)	(0.63)	(0.58)	(0.36)	(0.32)
IV	Housing recovery	0.50**		0.070		0.340		-0.13		0.140		0.050	
		(0.16)		(0.15)		(0.20)		(0.12)		(0.12)		(0.07)	
	Infrastructure recovery	-4.22	-0.19		0.79**		-0.17		0.210		0.82***		0.48***
		(7.14)	(0.32)		(0.27)		(0.38)		(0.23)		(0.20)		(0.113)
	Constant	-4.22	-0.40	18.57**	11.49	-7.33	-4.29	17.29	14.81*	19.54***	12.44	17.64***	13.36***
		(7.14)	(8.12)	(6.90)	(7.00)	(8.97)	(9.78)	(5.41)	(5.80)	(5.35)	(5.24)	(3.01)	(2.90)
Parameters	R^2	0.522	0.464	0.400	0.490	0.494	0.464	0.444	0.438	0.523	0.626	0.673	0.746
	Adjusted R^2	0.304	0.216	0.160	0.240	0.244	0.215	0.197	0.192	0.273	0.392	0.453	0.557
	Model p-value	0.001	0.005	0.040	0.002	0.002	0.005	0.011	0.013	0.001	-0.001	0.001	0.001
	n	80	80	80	80	80	80	80	80	80	80	80	80

329 **p<0.05, **p<0.01,***p<0.001 Standard error values are in parentheses.*

Qualitative Data Results

Successful aging indicators observed in a post-disaster environment were described by older adults in ways that attached to their recovery experiences from Hurricane Maria.

Connection. The association between connection and housing recovery was observed during field work by the first author—those who returned to their homes after renovation maintained close relationship with relatives, such as inviting them to feast on Sundays. For instance, one interviewee had recently had their home rebuilt after it was damaged by flooding, and at the end of the interview the participant's children arrived, carrying food for lunch. Similarly, another participant, still suffering from injuries sustained while repairing her roof after the hurricane, bakes cakes and puddings for her granddaughter who frequently visits. The interviews reveal the importance of connection in the older adults' successful aging process. Participants also mention that their connections benefit them in terms of getting assistance. As explained by one participant about how they felt after the hurricane:

> "Because I have lost very little and I have talked to some people who help me put the windows, something like that. And I feel good because there are people that when they are sick, they don't help them. I feel good, although the help I get from my family is little, but I feel good. I have good friends."

When disaster struck, the need for family members to come together and support one another became more critical. Participant observation showed that older adults relied on their home spaces, such as their patios and dining rooms to maintain meaningful relationships with their children and grandchildren. Visits from family members brought with them supplies, food, and care needed to get through difficult times, which ultimately strengthened familial bonds of the older adults.

Compensation. The association between compensation and infrastructure recovery has been exemplified in the accounts of older adults whose loss of electricity has disrupted most of their daily routines. Despite the disruption, one participant, for example, who uses a wheelchair, has lowered their kitchen sink, and devised tools that require electricity to aid them in their daily tasks. Damage in their kitchen and losing electricity were the

They explained, "Of course, for me, this is like a blessing from God, an experience, because now I bought my machines to.. if you want to, take a look at this room, come on in... I bought new machines and put electric power on them. It is a generator."

They decided to purchase a generator set to ensure that they have electricity for those times that there is a power outage. Their ability to compensate for the things they lacked provided them with a sense of efficacy. Other accounts of positive impacts on compensation are of participants who were able to access physical and mental health assistance after the hurricane. Public health infrastructure appears to have been critical in the older adults' recovery.

Contribution. The association between contribution and housing recovery is observed in the interviews. A participant told us that when their daughter's house had a broken wall, and the daughter's husband did not want to fix it, said, "We will fix it ourselves, and so, we took a wheelbarrow and we started pouring concrete. All the concrete that had spilled, we poured it into the wheelbarrow and we started to turn and we made the wall, that is, it was the wall that had cracked. My daughter and I made the wall. The participant was able to help their daughter in fixing their house, which made them feel that they were being useful in their daughter's life. Similarly, association between contribution and infrastructure damage is exemplified by participants' accounts. Another participant mentioned that they have a water well on their property. When they lost access to water after the hurricane, they used the water from the well

and they were able to share their water from the well to their neighbors. This made them feel that they were being helpful in their community.

Continuity. In a post-disaster environment, continuity has been impacted when the loss of electricity compelled the participants to vacate their homes and live with their adult children. Their daily routines have been disrupted because they were not in their own home spaces. "I felt that I would have to live with my daughter when I did not have my own house," said a participant. “I would disturb her husband and my grandchildren if I did not have my own house. Regardless of whether you have your own room or not, it is yours, and you are free to do whatever you wish. You get up when you want, you go to bed when you want, and you do not disturb anybody.”

Furthermore, older adults often experience a loss of continuity due to the damaged infrastructure that have not fully recovered. The inaccessibility of public transportation after Hurricane Maria had a profound effect on their sense of continuity. Hurricane Maria heightened the lack of access to transportation, affecting their ability to continue providing necessities for themselves. A participant said:

> Some people have cars, but most don't, I feel it is difficult. I think about all those who need it. Especially those who go to work… Because there are no jobs here. You have to go somewhere else. And as I said, food is something basic for me, something very important and I want to have my belongings, I do not need fancy things, just my necessities … [I want to feel] that I can feed myself well and sometimes you can't find anything [good] in this town. Two little stores, one there and one here, neither has anything. Very, very little.

Challenge. The interviews show that some participants often challenge themselves to be able to perform tasks independently. Some participants focused on what they had while they lost services from various infrastructures. For example, a participant explained, "Because… it's not that it's better, but at least it taught me to live with little, to not depend so much on electricity and cell phones. For me, it was a very nice experience. It had been a long time since I saw the moon and stars. At night, I would go out there to see them. And the calm, the harmony among neighbors, the care."

Additionally, the hurricane caused power transmission lines to be severely damaged, and even after 84 days, nine municipalities still did not have a connection to the grid (Kwasinski et al., 2019). Some of the older adults invested in solar energy and generator sets to power their houses. Some participants decided to purchase solar panels after they experienced being without power for a long time. They invested in photovoltaic energy technology in anticipation of being able to continue to provide necessities for themselves during disasters. One participant explained, "There was no major damage but when the hurricane hit, I still didn't have the solar panels. Now…after the hurricane, I went five months without electricity. From September until February. In February 2018, the power came on. Then I decided, and in April 2018 I installed the solar panels."

This participant also mentioned that he has influenced his children to put the same technology in their homes.

Control The loss of electricity after the hurricane bound the older adults to live with their adult children. Additionally, most of these decisions were made by their children, which reflects their loss of autonomy. An example is this conversation with the participant:

Interviewer 2 (in English): If it's okay for me to ask, what made you nervous?

Interviewer 1 (in Spanish): What is it that worries you or makes you nervous?

Interviewee (In Spanish): I am in my son's house, and that house is his.

Interviewer (In Spanish): And would you like to get out of there because you have yours and you feel that you are imposing yourself?

Interviewee (In English): Yes.

The participants whom we interviewed said that when electricity was restored, they were able to resume their daily activities in their own homes, where they are their own spaces. They were able to go back to the comforts that they used to have, being able to act on their own, thus, giving them back their sense of independence and autonomy.

5. Discussion

The overlapping effects of recovering from housing and infrastructure damage in a person are explained by human's natural behavior in a disaster environment. For example, the results show that recovering from a housing damage is a significant predictor of increase in a person's sense of contribution. This result is not surprising, as disasters are known to be predictors of positive connectedness in society (Montesanti et al., 2021; Walsh, 2007). After losing parts of or their entire house, the people see that they share the same challenge with their community. They begin to have feelings of belongingness and compassion for each other, which likely provides them with a sense of connection. They feel more generous as they share their resources in rebuilding their homes, which likely provides them with a sense of contribution. Learning about who they can count on in traumatic situations fosters healing and posttraumatic growth (Walsh, 2007). Similarly, results show that reovering from damage to infrastructure positively impacts their ability to challenge themselves by overcoming any physical impediment they experienced due to the absence of electricity. When older adults experience difficulties or

misfortunes, they can control their situation by pursuing positive attitudes toward it. Overcoming challenges is an adaptive strategy that older adults continually use (Scharlach, 2017). One positive psychological characteristic of overcoming challenges is environmental mastery, effectively managing one's life and the surrounding world (Ryff and Keyes, 1995). The theme that emerged remarkably in this study's interviews was the older adults' recovery strategies using positive responses to the loss of services from the damaged infrastructures, such as appreciating the advantages of not having technology or purchasing photovoltaic technology to compensate for their lost access to electricity. This behavior aligns with the existing study done by Windle and Woods (2004) using a model demonstrating that "environmental mastery is the key to experiencing life satisfaction even in the face of adversity" (p. 595).

6. Limitations

The limitation of this study includes the low number of interviews and surveys and some participants who gave limited responses because the first part of the data collection happened during the COVID-19 pandemic. Our research subjects are older adults who are vulnerable to COVID-19. Therefore, some prospective participants decided not to participate in protecting themselves from a possible infection of COVID-19. Another limitation of the survey is that it was only conducted in one community as a result of limited connections.

7. Conclusions

The increase in the older adult population and the lack of a working-age population due to migration to the U.S. Mainland causes older adults to age alone. Extraordinary events like hurricanes, earthquakes, and the COVID-19 pandemic threaten successful aging of older adults. Following the Process Model of Constructive Aging, this study inductively established six indicators of successful aging: continuity, compensation, control, connection, contribution, and

challenge (Scharlach, 2017). The study also investigated the role of housing and infrastructure recovery on the six interrelated aging processes. Since most indicators of successful aging diverge quantitatively and qualitatively, contextual understanding of the successful aging processes is essential. Neither qualitative nor quantitative data alone can explain successful aging processes. Nonetheless, the results of this research emphasizes the importance of housing and infrastructure recovery and has important policy implications for engineers, researchers, stakeholders, and policymakers who intend and continue to provide equitable resilience in vulnerable communities by building local capacities, such as training local builders and homeowners to increase housing resilience (Ahmed & McDonnell, 2020), proper asset management in the transportation systems (Ecola et al., 2020; Meyer et al., 2010), and providing adaptive protection scheme to improve electric power grid networks' reliability (Dindar et al., 2022).

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APPENDIX A
Variable Keys

Dependent variables	Description	Scale
Compensation	Average of all compensation factors	continuous variable
Contribution	Average of all contribution factors	continuous variable
Continuity	Average of all continuity factors	continuous variable
Challenge	Average of all challenge factors	continuous variable
Control	Average of all control factors	continuous variable
Connection	Average of all connection factors	continuous variable
Independent variables		
housingdamage	Sum of housing elements damaged	continuous variable
housingrestore	Sum of housing elements restored	continuous variable
infradamage	Sum of infra elements damaged	continuous variable
infrarestore	Sum of infra elements restored	continuous variable
Control variables	*Question*	
Age	What is your age?	Continuous variable
Gender	What is your gender?	1 = male; 2 = female
Education	What is your highest level of education completed?	1 = primary; 2 = secondary; 3 = 27ccess27/university; 4 = graduate
Income	If you don't mind sharing, what is your monthlt household income? (This means the total income within your household combined)	continuous variable
Children living with them at home	How many of your children are living with you?	Continuous variable

VARIABLE DETAILS

Variable	*Question*	Measure
Compensation factors		
Compensation_1	*When things don't go as well as they used to, I accept it.*	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Compensation_2	When things don't go as well as they used to, I keep trying other ways until I can achieve the same result I used to.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Compensation_3	When something in my life isn't working as well as it used to, I ask others for help or advice.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Compensation_4	When something in my life isn't working as well as it used to, I decide what to do about it myself, without involving other people.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Compensation_5	In particularly difficult life situations, I try to get help from doctors, counselors or other experts.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Compensation_6	In particularly difficult life situations, I try to manage by myself.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Contribution factors		
Contribution_1	I often get a chance to do voluntary or charity work.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Contribution_3	I often get a chance to care for a sick person with a certain vulnerability	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Contribution_5	I often get a chance to provide help to family, friends, or neighbors.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Continuity factors		
Continuity_1	The area where I live offers sufficient activities for me to pursue my interests.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Continuity_2	I can choose to be as active as I please.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree

Continuity_3	I am able to continue participating in activities I had during pre-retirement.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Challenge factors		
Challenge_1	I am able to get up from a stooping, crouching, or kneeling position by yourself.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Challenge_2	I am able to get up and down a flight of stairs by yourself.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Challenge_3	I am able to stand up after sitting on a chair by yourself.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Control factors		
Control_1	I do what I think is best for me in my life.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Control_2	I lead my life the way other people want me to rather than the way I want to lead it.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Control_3	I know when I need to do things for myself.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Control_4	Other people act for me when I do not want them to.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Control_5	There are certain situations in which other people are better equipped to assist me than I am..	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Control_6	I can choose to do things for myself.	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Connection factors		
Connect_3	Circle the number that best describes how satisfied you are at this time_*Relationships with parents, siblings & other relatives-communicating, visiting, helping*	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree

Connect_5	Circle the number that best describes how satisfied you are at this time_*Close relationships with your spouse or significant other*	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree
Connect_6	Circle the number that best describes how satisfied you are at this time_*Close friends*	1 = strongly disagree; 2 = disagree; 3 = neither disagree nor agree; 4 = agree; 5 = strongly agree

Variable	*Question*	Measure
housing damage	*Did you experience damage or loss of the following parts in your home after Hurricane Maria?*	
Mbrdamage	master's bedroom damage	0 = no; 1 = yes
brdamage	bedroom damage	0 = no; 1 = yes
livingdamage	living room damage	0 = no; 1 = yes
kitchdamage	kitchen damage	0 = no; 1 = yes
diningdamage	dining room damage	0 = no; 1 = yes
bathdamage	bathroom damage	0 = no; 1 = yes
porchdamage	porch damage	0 = no; 1 = yes
floordamage	floor damage	0 = no; 1 = yes
sepdamage	septic tank damage	0 = no; 1 = yes
roofdamage	roof damage	0 = no; 1 = yes
walldamage	wall damage	0 = no; 1 = yes
coldamage	column damage	0 = no; 1 = yes
beamdamage	beam damage	0 = no; 1 = yes
gardamage	garage damage	0 = no; 1 = yes
walkdamage	walkway damage	0 = no; 1 = yes
infradamage	*Did you experience damage or loss of the services/utilities after Hurricane Maria?*	
Electdamage	damage/loss of electrical services	0 = no; 1 = yes
teledamage	damage/loss of telephone services	0 = no; 1 = yes
mobiledamage	damage/loss of mobile phone services	0 = no; 1 = yes

waterdamage	damage/loss of piped water services	0 = no; 1 = yes

Variable	*Question*	Measure
housing recovery	*If "Yes", how soon did it get restored or become usable again?*	5 = never; 1 = (1) Within a week; (2) Within a month; (3) If longer than a month, approximately how many months?; (4) If longer than 12 months, approximately how many years?
Mbrestore	master's bedroom restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Brecovery	bedroom restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Livrecovery	living room restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Kitchrecovery	kitchen restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Dinrecovery	dining room restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Bathrecovery	bathroom restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Porchrecovery	porch restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Floorecovery	floor restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Seprecovery	septic tank restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Roofrecovery	roof restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12
netdamage	damage/loss of internet	0 = no; 1 = yes
tvdamage	damage/loss of T.V. reception	0 = no; 1 = yes
radiodamage	damage/loss of AM/FM radio reception	0 = no; 1 = yes
roadamage	damage/loss 31ccess to drive on the road	0 = no; 1 = yes
pubtransdamage	damage/loss of access to public transportation	0 = no; 1 = yes

		months, approximately how many years?
Wallrecovery	wall restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Colrecovery	column restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Beamrecovery	beam restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Garecovery	garage restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Walkrecovery	walkway restored	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?

Variable	*Question*	Measure
Infrarecovery	*If "Yes", how soon did it get restored or become usable again?*	
Electrecovery	restored of electrical services	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Telerecovery	restored telephone services	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Mobilerecovery	restored of mobile phone services	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Waterrecovery	restored of piped water services	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Netrecovery	restored of internet	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Tvrecovery	restored of T.V. reception	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Radiorecovery	restored of AM/FM radio reception	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Roarecovery	restored access to drive on the road	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?
Pubtransrecovery	restored access to public transportation	0 = never; 1 = (1) Within a week; (2) Within a month; (3a) If longer than a month, approximately how many months?; (3b) If longer than 12 months, approximately how many years?

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The Role of Housing and Community Infrastructure in Successful Aging in Disaster-Vulnerable Areas

Linnel Marie S. Ballesteros[1], Cristina Poleacovschi [2], Ivis García [3], Carl F. Weems [4]

Kaoru Ikuma [5], Chris R. Rehmann [6]

[1] Department of Civil, Construction, and Environmental Engineering, Iowa State University, 394 Town Engineering Building, Ames, IA 50011. Email: linnelsb@iastate.edu

[2] Department of Civil, Construction, and Environmental Engineering, Iowa State University, Town Engineering Building, Ames, IA 50011

[3] Department of Landscape Architecture & Urban Planning, Texas A&M, 3137 TAMU College Station, TX 77840

[4] Department of Human Development and Family Studies, Iowa State University 380 Palmer Suite 2330, Ames, IA 50011

[5] Department of Civil, Construction, and Environmental Engineering, Iowa State University, Town Engineering Building, Ames, IA 50011

[6] Department of Civil, Construction, and Environmental Engineering, Iowa State University, Town Engineering Building, Ames, IA 50011