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Assessing Organizational Resilience Capacity to Flooding: Index Development and Application to Greek Small and Medium-Sized Enterprises

A. Skouloudis, K. Evangelinos, W. Leal-Filho, P. Vouros, I. Nikolaou, T. Tsalis

Abstract**—**In this study a composite index of factors linked to the resilience capacity of small and medium-sized enterprises (SMEs) to flooding is proposed and tested. A sample of SMEs located in flood-prone areas (n = 391) was administered a structured questionnaire pertaining to cognitive, managerial and contextual factors that affect the ability to prepare, withstand, and recover from flooding events. Through the proposed index, a bottom-up, self-assessment approach is set forth that could assist in standardizing such assessments with an overarching aim of reducing the vulnerability of SMEs to floods. This is achieved by examining critical internal and external parameters affecting SMEs' resilience capacity which is particularly important taking into account the limited resources these enterprises tend to have at their disposal and that they can generate single points of failure in dense supply chain networks.

Keywords**—**Floods, SMEs, organizational resilience capacity, index development, Greece.

I. Introduction

FLOODS have been the most frequently occurring natural disaster. Such extreme weather events account for almost 43% of all recorded natural disasters in the world [1]. SMEs are more vulnerable to face floods compared to larger business entities, so they are disproportionately affected by such environmental perturbations [2]. Financial and other resource constraints, the lack of appropriate skills, knowledge or time, short-term planning and reactive responses along with the fact that they tend to be owner-managed (resulting in command-and-control management approaches) all conduce to limited opportunities to bounce back and (quickly) recover from flooding [3]-[7].

The resilience capacity of business against an extreme weather event (e.g. flooding) can be defined as the rate of recovery and restoration of the entity's performance to pre-disturbance conditions, the amount of disturbance (i.e. the threshold level) a business entity can absorb before losing structural and/or functional parameters that could alter business activity or lead in ceasing operation, as well as the degree to which the firm demonstrates impact resistance (i.e. maintains its function) before performance levels are driven to zero [8]. However, while SMEs' resilience capacity is acknowledged as an essential attribute in effectively overcoming uncertain situations [8]-[10], empirical literature addressing driver and barriers of SMEs' resilience capacity to natural disasters and extreme weather remains thin on the ground and primarily supported by anecdotal evidence or normative assumptions [11]-[14]. While research studies focus on impacts and critical issues linked with flood recovery and other extreme weather events [15]-[21], much work still needs to be done in order to gain a better understanding of measures and/or actions that allow SMEs to successfully resist flood impacts.

Against this background, this paper outlines the development and implementation of a SME flood resilience capacity index (FRCI). This quantitative metric is applied to Greek SMEs from flood-prone areas and essentially pertains to cognitive, behavioral and contextual parameters (factors) that affect a SME's ability to configure effective responses to overcome flood challenges. With the proposed indicator-based assessment, the research team's aim is to provide insights towards analytical frameworks that could assist in standardizing screening tasks with an overarching objective of reducing SMEs' vulnerability to such natural hazards. This is possible by framing key internal as well as external aspects affecting SMEs' capacity to be resilient, which is essential given that they tend to be single points of failure and significant sources of vulnerability losses in supply chain networks.

The rest of this paper is structured as follows. The next section presents the material and methods. Section III presents the findings of the study. The paper concludes with relevant implications and by setting forth future research perspectives.

II. Material and Methods

A sample of 391 SMEs owners-managers from flood-prone areas in Greece was administered a structured questionnaire examining factors that shape organizational responses to flooding. Most enterprises of our sample (74%) provide retail services, 17% are manufacturing firms and 9% are agricultural enterprises. Likewise, most firms are micro and small ones (82%), and had experienced flooding at least once in recent years (74%) with 29% of the respondents denoting that the severity of flood damages to their business premises was far from negligible.

To develop the composite metric, we conducted a thorough literature review on factors describing organizational resilience capacity, with a special focus on SMEs vis-à-vis floods and

A. Skouloudis*, K. Evangelinos, and P. Vouros are with Dep. of Environment, University of the Aegean, Lesvos, Greece (*e-mail: skouloudis@aegean.gr).

W. Leal-Filho is with Research & Transfer Centre "Sustainability and Climate Change Management" (FTZ-NK), Hamburg, Germany.

I. Nikolaou and T. Tsalis are with Dep. of Environmental Engineering, Democritus University of Thrace, Xanthi, Greece.

other weather extremes [11], [22], [23]. The review of prior studies lead us in framing three overarching groups of parameters that influence an enterprise's resilience capacity against flooding: (i) cognitive factors referring to perceptions and attitudes to risk awareness and proactivity as well as the SME owner's knowledge-understanding of climate change impacts and underlying links to extreme weather; (ii) behavioral-managerial factors referring to organizational behavior, planning and learning, managerial culture, technological and financial resources as well as organizational leadership capabilities; contextual factors indicate the pivotal role of critical stakeholders in SMEs' ability to withstand and recover from flooding.

An initial list of items was prepared, utilizing knowledge from existing studies and developing new items-statements with experts' input. This process resulted to an array of items comprising an initial version of the resilience capacity index. This composite metric was pre-tested on a small number of SMEs following convenience sampling. The results of the pilot survey allowed us to re-examine and reduce the number of items, refine the scales and finalize the proposed measurement instrument assessing factors of SMEs' resilience capacity to flooding. The FRCI can be presented as:

$$FRCI = \sum_{i=1}^{n} \sum_{j=1}^{3} A_{ij} \times w_{ij}^{A}$$

where A are the various aspects of cognitive (CG), behavioral (B), and contextual (CN) factors comprising the FRCI; i = 1, 2, … n, indicates each individual resilience capacity factor; j = 1, 2, 3 are the various parameters pertaining to the respective aspect A of cognitive (j = 1 = CG), behavioral (j = 2 = B), and contextual (j = 3 = CN) factors while w_{ij} is the individual weight of each resilience capacity parameter (i.e., each j factor).

In order to define the relative factor weights we opted for an analytic hierarchy process (AHP) pairwise comparisons process, utilizing a web-based AHP tool [24]. To this regard, we gathered the input of an expert panel (comprised of academic researchers, management consultants and auditors of business continuity systems) on the prioritization of factors. The consistency ratio (CR) of expert ratings is 0.3% [25]-[27] while the aggregate expert judgments have satisfactory AHP consensus (75%) in terms of overlap between the individual judgments of the expert group members. The max-min normalization technique was applied to the data collected from the sample SMEs in order to re-scale responses to a distribution value 0-1. The factors' weights (included in the appendix along with a short description) were then combined with the normalized (resilience capacity) factor values in order to derive the FRCI for the sample SMEs:

FRCI = [0.88 * KNOW] + [0.144 * ATT] + [0.118 * LEAD] + [0.108 * CULT] + [0.111 * TECH] + [0.104 * PLAN] + [0.095 * LEARN] + [0.113 * FIN] + [0.071 * RELAT] + [0.078 * INST]

Confidence Intervals for the FRCI Based on Bootstrap Technique

Sample point estimates of the average and median values of composite metrics - such as the FRCI - tend to be reported as highly variable as well as dependent of the specific datasets derived from samples. Hence, confidence intervals of prediction accuracy were extracted. To achieve this, the non-parametric bootstrap technique [28] for constructing confidence intervals for the FRCI was employed. In this way, neither specific assumptions on the distribution of the FRCI are required nor large samples since the specific technique relies on resampling from the initial sample. Various alternative methods for creating the bootstrap confidence intervals for the FRCI were applied: the basic bootstrap (BB), the normal bootstrap (NB), the percentile bootstrap (PB) and the bias-corrected accelerated (BCa) bootstrap [29].

III. Findings

In Table I, a summary of descriptive statistics for the sample SMEs is presented. Mean FRCI is 0.609 with considerably lower scores on aspects pertaining to contextual parameters affecting flood resilience capacity. Grouping the mean scores (%) of the FRCI factors into the three domains, it is evident that flood resilience capacity is primarily driven by cognitive factors, followed by managerial competencies, while contextual factors leave much to be desired (Fig. 1). Moreover, looking closer to the various FRCI factors it is evident that it is knowledge/understanding, organizational learning and planning as well as technological resources that mainly define SMEs' resilience capacity, followed by leadership capabilities, the owner-manager's attitudes to flood risks and perceptions of proactive protective measures. In contrast, the results of this assessment suggest that relational resources and institutional support mechanisms or the internal culture that nurtures the anticipation of flooding have little contribution to SME resilience capacity (Fig. 2).

TABLE I
SUMMARY DESCRIPTIVE STATISTICS FOR FACTORS DESCRIBING SME RESILIENCE CAPACITY AND THE COMPOSITE INDEX

	KNOW	*ATT*	*LEAD*	*CULT*	*TECH*	*PLAN*	*LEARN*	*FIN*	*RELAT*	*INST*	***FRCI***
Min	0.022	0.012	0.015	0.000	0.009	0.000	0.000	0.000	0.000	0.000	***0.286***
Max	0.088	0.107	0.118	0.095	0.111	0.103	0.095	0.108	0.071	0.057	***0.885***
Mean	0.069	0.071	0.074	0.044	0.078	0.072	0.052	0.086	0.037	0.028	***0.609***
Median	0.072	0.065	0.074	0.048	0.083	0.070	0.052	0.081	0.035	0.026	***0.605***
Mode	0.077	0.061	0.096	0.032	0.074	0.070	0.052	0.108	0.041	0.026	***0.599***
StDev	0.015	0.029	0.024	0.021	0.023	0.023	0.034	0.025	0.015	0.012	***0.119***
1st Quartile	0.061	0.053	0.059	0.032	0.065	0.056	0.026	0.081	0.029	0.020	***0.530***
3rd Quartile	0.083	0.081	0.096	0.060	0.092	0.084	0.078	0.108	0.047	0.036	***0.694***

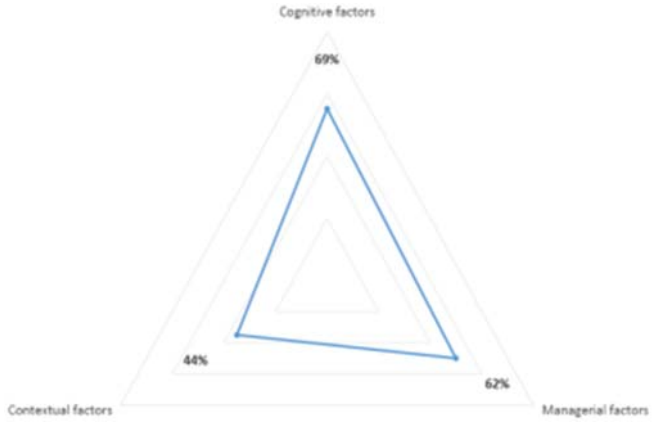

Fig. 1 Mean scores (%) among the three domains of factors describing SME flood resilience capacity

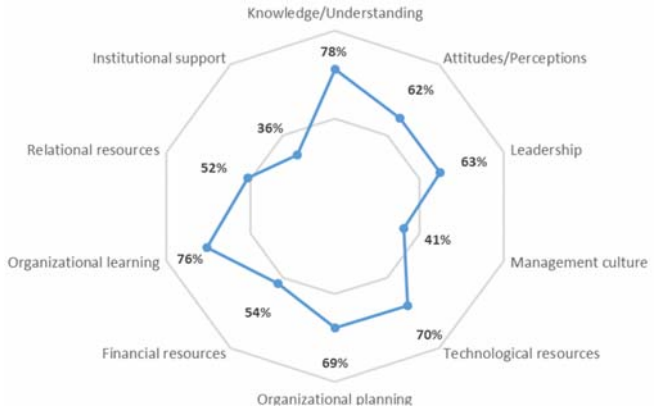

Fig. 2 Mean scores (%) among the ten factors comprising the SME FRCI

The bootstrap subsampling technique was performed using a sample of 10,000 iterations to generate the subsamples. In Fig. 3, based upon the 10,000 bootstrap subsamples, the histogram and normal probability plot for the FRCI is presented. It is evident from the graph that the bootstrap samples follow the normal distribution.

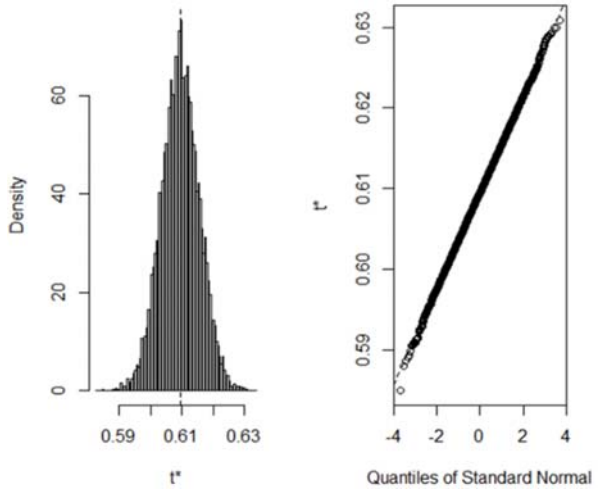

Fig. 3 Histogram & normal probability plots for the Bootstrap sample

Based upon the 10,000 bootstrap subsamples, the 90% and 95% bootstrap confidence intervals were devised in order to reach a reliable estimate of the range of values of the FRCI index in the population of SMEs in Greece. In order to increase the robustness of the results we obtained; the four alternative bootstrap confidence intervals were calculated. Thus, in Tables II and III we present the 90% and 95% Normal, Basic, Percentile and BCa bootstrap confidence intervals for the FRCI, respectively.

TABLE II
90% BOOTSTRAP CI FOR THE FRCI BASED ON 10,000 BOOTSTRAP REPLICATES

Bootstrap CI (90%)	FRCI
Normal	0.5873-0.6056
Basic	0.5873-0.6055
Percentile	0.5874-0.6055
BCa	0.5875-0.6056

TABLE III
95% BOOTSTRAP CI FOR THE FRCI BASED ON 10,000 BOOTSTRAP REPLICATES

Bootstrap CI (95%)	FRCI
Normal	0.5855-0.6074
Basic	0.5854-0.6072
Percentile	0.5857-0.6074
BCa	0.5857-0.6075

The alternative confidence intervals are in high compliance and the population-wide FRCI index has been estimated to range between 0.59 and 0.61 (considering a two-digit precision). This indicates that the FRCI for a domestic SME (as this was calculated from the application of the bootstrap technique) is expected to be found within the above range, with 95% level of confidence.

IV. Discussion - Concluding Remarks

This study seeks to contribute the extant literature in three ways. First, a composite indicator is set forth to investigate determinants of SMEs' flood resilience capacity, allowing for insights on how various internal and external aspects define the organizational ability to tackle flooding. Second, evidence from Greek SMEs are provided, shedding light on contributing factors and possible barriers. Third, an assessment methodology on SME resilience capacity characteristics is formulated and can be replicated to other areas, contributing to the domains of regional studies, business sustainability and continuity research and the theorization of organizational resilience to EWEs.

Studies such as ours add to the field of climate services and the under-researched topic of organizational resilience to extreme weather events and ever-increasing natural disasters. In line with UN's Sustainable Development Goal (SDG) 1 - Target 1.5 (i.e., 'by 2030, build the resilience of (…) those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters') [30], it attempts to quantify business resilience capacity to floods and link such information to SMEs' assistance needs. The latter is of critical importance, given that the previous decade damages

from extreme weather events and natural disasters have reached record-breaking levels (in monetary terms) and the occurrence of such events and disasters is escalating [31], [32], suggesting that SMEs' ability to cope with flooding becomes a sheer necessity.

The SME-FRCI reflects a scanning process of comparing disaster experts' analysis of flood impacts with survey evidence (such as those our study yielded) as input for prioritizing interventions. Thus, it can provide some actionable insights towards the development of customized SME-specific flood preparedness toolkits in order to increase their resilience status (which could also allow them to indicate essential support needs). To this regard, the FRCI can be a meaningful tool for business consultants and networks that support or guide SMEs on continuity planning and management, where prioritization of actions in terms of appropriateness as well as financially viability is important. In a similar vein, as certification services of climate risk assessments is a pressing issue for the private sector, the FRCI's structure and rationale may assist in devising formal certification/auditing processes for individual enterprises (or small business consultants). Lastly, the index presented in this study could inform providers of disaster risk insurance through the refinement of balanced scorecards or updated screening criteria that could assist in specifying premiums of SME-oriented micro-insurance products towards the endorsement of a 'flood-proof' SME sector.

APPENDIX

TABLE IV
RESILIENCE CAPACITY FACTORS, EXPERT WEIGHTS AND EXPLANATORY DEFINITIONS

	Factor	Factor weight	Factor definition/explanation
Cognitive factors	Knowledge/ Understanding (KNOW; 4 items)	0.088	Sufficient knowledge of climate change driving forces, its impacts and the underlying links to extreme weather/flooding (i.e. situation awareness; good knowledge of what climate change is, what causes climate disruptions, understanding of the low probability/high impact risk linked to extreme weather and the relative increase of such events in absolute numbers in recent years).
	Attitudes/ Perceptions (ATT; 7 items)	0.114	SME owners-managers have positive attitude on the importance of proactivity against flooding and demonstrate awareness of flood risk(s) (i.e. acknowledgement that flood protection is not merely the responsibility of the state authorities, that such extreme weather events can happen at any time during the year, that flood protection is not just good-to-have but an essential aspect in business preparedness and continuity).
Managerial factors	Leadership (LEAD; 4 items)	0.118	Leadership (behaviour) in times of adversity implies that (SMEs which are) leaders make sense of the environment in which they find themselves, and after a certain threshold in handling adversity is crossed, they initiate a new phase in the organization's lifecycle involving new routines and/or structural patterns, embracing organizational change and new management techniques compared to other peer enterprises.
	Management culture (CULT; 3 items)	0.108	A management culture with resilient characteristics allows to strengthen an organization's ability to anticipate floods and to understand that adversity can strike at any time, therefore proactively fosters risk awareness and centers on long-term survival as well as the need to involve all employees in resilience-building practices and flexible responses toward adverse conditions.
	Technological resources (TECH; 3 items)	0.111	Technological interventions within the business premises to protect from flooding and reduce the time and cost for recovery (e.g. raised level at which machinery, electrical sockets and products are located/stored, flood-resilient flooring, door guards and air brick covers, small-scale retrofits or special mechanisms to prevent damage to expensive equipment in business premises, etc.).
	Organizational planning (PLAN; 2 items)	0.104	Development of organizational plans to prepare for crises, external shocks and ensure functionality during times of adversity (as in the case of flash floods).
	Organizational learning (LEARN; 1 item)	0.095	The ability of an organization to learn from past events and utilize such experiences to anticipate future adversity.
	Financial resources (FIN; 1 item)	0.113	Financial slack resources that provide security to respond effectively to crises, allow the organization to prepare for & anticipate crises before they occur and enable a quick recovery in times of crises.
Contextual factors	Relational resources (RELAT; 3 items)	0.071	Healthy, positive and strong relationships both within and outside an organization with key stakeholder groups of the enterprise who can provide financial and/or in-kind support in case of emergency (e.g. other local enterprises and community members, business partners, suppliers, customers, friends and relatives, consultants).
	Institutional support (INST; 6 items)	0.078	Local and Central Government authorities and institutions (incl. chambers of commerce, business associations/federations, providers of capital) whose decisions and active support in form of laws, regulation, financial and non-financial assistance allows enterprises to successfully deal with flooding impacts.

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