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Structuring disaster resilience attributes for small and medium enterprises in Padang city – Indonesia

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Abstract. Business resiliency has been highlighted as one of the main domains in disaster management research. As a small business unit characterized by a high vulnerability to disaster disruption, Small and Medium Enterprises (SMEs) becomes those that are impacted most by disaster disruption. This research proposes to structure disaster resilience attributes for SMEs in Padang city by developing methodology applying fuzzy Delphi techniques to identify the relevant disaster resilience attributes, and then Best-worst method to prioritize the final attributes list. Through gathering experts' opinion, we obtained final list consisting of 26 suitable disaster resilience attributes grouped in four resilience dimensions. We revealed that the "management structure", "insured business asset" and "building utility" are ranked the highest. Physical resilience was found to be the most crucial dimension since four of its attributes are placed in the higher rank. This result may reveal that physical infrastructures of SMEs in Padang city are considered as a main concern by the three experts to be developed to be resilient against disaster disruption. This result can be used as the basis for interested parties to prioritize the effort to improve SMEs' capability in avoiding or mitigating future disaster disruption, especially in facing earthquake and tsunami.
Keywords: Disaster resiliency, Small and medium enterprise, Fuzzy Delphi, Best-worst method, Decision making

1. Introduction

The issue of disaster resilience has become the interest of many researchers in many years. In addition to its impact on people and the environment, disaster also have tremendous effects on business continuity in the aftermath of disaster. Business disruptions that are not coped effectively can come at a huge financial impact because of disrupted relation with partner, revenue losses, sales opportunity losses, etc. Getting back to bussiness after disaster is not an easy task, but a complex arrangement on the critical process that consumes considerably amount of resources and time. Resilience is one of the key strength for business to gain back its business function as prior to disaster. In disaster management domain, resilience have been an inclusion to apply as a framework for focusing on the priority of risk identification and reduction, culture of safety development, and strengthening preparedness and response capabilities [1]. Resilience is described as essential resources and characteristics that can help maintain or regain pre-disaster levels of operations function and realize successful adaptation [2].

In literatures, disaster resilience is defined from different point of view. From community prespective, Mayunga [3] mentioned that disaster resilience is the capacity or ability of a community to anticipate, prepare, respond and recover quickly from impacts of disaster. In organisational and business continuity perspective, Mitroff [4] defines resilience as a continuously moving target that enhances performance of business both in normal and disruptive situation. Seville et al. [5] mentioned that resilience as an ability/capacity of organization to survive, and even thrive, in times of crisis and emergencies. A resilient business provides competitive advantage and is used as a measures of business's health [6].

Small and medium enterprises (SMEs) are business units that are highly vulnerable to disaster risk. SMEs are those that are impacted most by disaster disruption. They are less likely to have inadequate capacity to respond and recover back after disasters, as most of them is not or less engaged in disaster risk reduction effort. They usually do not have the ability to absorb risks and the impacts of disasters, since they often operate with a few employees and are unable to spread and transfer their risks [7]. SMEs, especially in developing countries, also do not have the necessary concern and knowledge of their vulnerability to develop and implement business continuity plans [8].

This research attempts to explore disaster preparedness of SMEs in Padang city, West Simatera - Indonesia, by studying its resiliency against disaster risk. Our work is motivated by the impact of the 2009 earthquake hit West Sumatera which damaged thousands of SMEs in Padang City and surrounding district resulting in the closure of businesses. After nine years of such big disaster and since there is an increasing caution of forthcoming megathrust earthquake predicted to occur in this area, it is become increasingly important to examine the current resilience of SMEs to disaster risk. Research on SMEs resilience against disaster disruptionis is quite limited. Most researches in disaster resilience topic focus on proposing a framework of resilience models as well as conducting resilience evaluation on community perspective [9-11]. Although several researches attempt to address such issue in SMEs context, they posess some drawback in terms of measurement scope of evaluation. Furthermore, most of them are conducted in developed countries and those focus on such issues in developing countries are still scarce [12]. This study tries to fill this gap. The purpose of this study is to propose suitable attributes for resilient SMEs in Padang city. This research is the first step toward our advanced studies on evaluation of disaster risk reduction efforts in this city. Structuring disaster resilience attributes is carried out by identifying and prioritizing resilience attributes that could be used as the basis for government and interested parties to prioritize the effort to improve SMEs' capability in avoiding or mitigating future disaster disruption, especially in facing earthquake and tsunami.

In this research, through gathering experts' opinion we propose to adopt a fuzzy Delphi technique to identify the relevant disaster resilience attributes of SMEs. The fuzzy Delphi has been widely used in numerous management science field to achieve a consensus among a group of people where vagueness and uncertainty in the decision-making are often occurs [13]. The best-worst method (BWM), which is know as a novel and efficient pairwise comparison method [14], is then applied to gain the ranking of attributes that could help the stakeholders and policy maker to focus and prioritize the effort designed toward disaster risk reduction.

2. The methodology

2.1. Survey questionaires

We conducted survey research in which rating scales questionaires are used to gather experts opinion by eliticing judgment on the degree of importance of each resilience attributes applied to SMEs context. For this purpose, fuzzy linguistic scales are provided as shown in Table 1. This rating scales questionnaire establishes the relevant disaster resilience attributes from the initial list identified from current literatures.

Table 1. Fuzzy intensity of attributes importance

Linguistic variables	Fuzzy Preference (Triangular Fuzzy Number)
Very low important (VLI)	(0.0, 0.1, 0.3)
Low important (LI)	(0.1, 0.3, 0.5)
Medium important (MI)	(0.3, 0.5, 0.7)
High important (HI)	(0.5, 0.7, 0.9)
Very high important (VHI)	(0.7, 0.9, 1.0)

2.2. Respondents

The number of experts asigned to fill the questionnaire is decided not to be necessarily high. This rules relies on the fact that in group decision making there is no strong correlation between the number of experts and the quality of judgment [13]. Even involving more experts who may have inadquate experiences may results in weak decision accuracy [15]. In this research, we arrage the qualification of experts to: (1) have theoritical and practical experience of working in disaster management field; (2) have at least five years' professional experience in SMEs development domain; (3) have experience in facilitating or organizing projects or activities geared towards disaster relief operation. Based on this qualification, three expert are chosen which includes academician with strong background in disaster management research, Head of Cooperatives and Small and Medium Enterprise office West Sumatera Province, and Disaster -NGO representative.

2.3. Data collection

First, the data of resilience attributes were gathered from literature review of nine research papers. A total of 202 resilience attributes were collected based on the type of disruption (man-made and natural disruption) and the context to where they were measured (community and organization). Redundancy check is then carried out which generates initial draft of 26 disaster resilience attributes of SMEs. These draft were then submitted to the expert for verification. The last step was done through a survey where questionnaires were distributed to the experts personally utilizing fuzzy Delphi techniques and fuzzy BWM. The flow of methodology is shown in Figure 1.

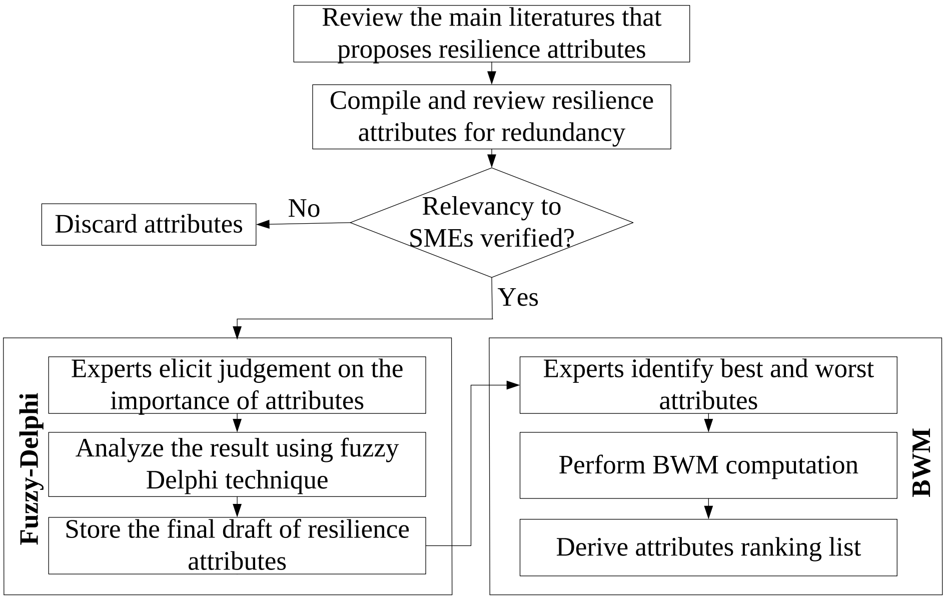

Figure 1. Flowchart of methodology

2.4. Computational procedure

In general, the procedure of structuring disaster resilience attributes of SMEs at Padang city is itemized as follow:

- Review the main literatures which proposes resilience attributes, examine the attributes which relates to disaster disruption and filter them for redundancy.
- Ask the experts to examine the relevancy of attributes to the context of SMEs. The attributes which are not relevant are discarded from the initial draft list.
- Gather data from the experts through rating scales questionnaires for judgement of importance of each disaster resilience attributes using linguistic scale in Table 1. Let $\tilde{b}_i^k = \left(b_{il}^k, b_{im}^k, b_{iu}^k\right)$

denotes the importance in triangular fuzzy number (TFN) of attribute *i* set by expert *k*, then the aggregate TFN, $\tilde{b}_i$, is stated as

$$\tilde{b}_i = (b_{il}, b_{im}, b_{iu}) = \left(\min_k b_{il}^k, (1/K)\sum_{k=1}^{K} b_{im}^k, \max_k b_{iu}^k \right) \quad (1)$$

Table 2. Disaster Resilient Attributes

Dimension	Attributes	Abbrev.
Physical Resilience (PR)	Building utility	PR1
	Housing type	PR2
	Evacuation access	PR3
	Housing age	PR4
	Shelter facilities	PR5
	Transportation facilities	PR6
Organizational Resilience (OR)	Leadership	OR1
	Staff engagement	OR2
	Informed decision making	OR3
	Innovation and creativity	OR4
	Unity of purpose	OR5
	Leveraging of knowledge	OR6
	Management structure	OR7
	Proactive posture	OR8
Social Resilience (SR)	Connectivity awareness	SR1
	Information exchange	SR2
	Community engagement	SR3
	Comprehensive partnership	SR4
	Cooperation with local community	SR5
Economic Resilience (ER)	Dependency on external funds	ER1
	Diversified business	ER2
	Business size	ER3
	Access to market	ER4
	Insured business asset	ER5
	Disaster management budget	ER6
	Access to credit	ER7

- Defuzzify $\tilde{b}_i$ using the center of gravity method as

$$b_i = (b_{il} + b_{im} + b_{iu})/3 \quad (2)$$

- Set a desired value of α [0, 1]. If $b_i \geqslant \alpha$, include the attributes *i* in the attributes final list. Otherwise, discard the attributes.
- Ask the experts to choose the best (e.g. most desirable, most important) and the worst (e.g. least desirable, least important) attributes from a set of decision *n* attributes $\{a_1, a_2, ..., a_n\}$ from the attributes final list.
- Using Saaty scale (1-9 scale), perform pairwise comparison which obtains two vectors named as best-to-others (BTO) and others-to-worst (OTW) vectors. The BTO and OTW vectors are formulated as $A_B = \{a_{B1}, a_{B1}, ..., a_{Bn}\}$ and $A_W = \{a_{1W}, a_{1W}, ..., a_{nW}\}^T$, respectively, where a_{Bj} is the preference of the best attribute a_B over attribute *j* and a_{jW} is the preference of attribute *j* over the worst attribute a_W; $j = 1, 2, ..., n$.
- Compute the optimal weights $(w_1^*, w_2^*, ..., w_n^*)$ using equation (3) below.

$$\text{Min} \quad \varphi \quad (3)$$

s.t.:

$$\left|\omega_B - a_{Bj}\omega_j\right| \le \varphi \quad \text{for all } j$$

$$\left|\omega_j - a_{jW}\omega_W\right| \le \varphi \quad \text{for all } j$$

$$\sum_j \omega_j = 1, \quad \omega_j \ge 0 \quad \text{for all } j$$

3. Result and discussion

There were 202 candidates of resilience attributes generated from literatures. After the two filtration processes as described in the previous section, the number of candidates were reduced to the final list of 26 attributes which is considered suitable as disaster resilience attributes of SMEs in Padang city. The final list is shown in Table 2 where the attributes are grouped into four different resilience dimension i.e., physical, organizational, social, and economic resilience. Using fuzzy intensity scale in Table 1, experts opinion are gathered to determine the the importance of each attributes. After coverting experts opinion into TFN, the TFNs were aggregated using equation (1) to obtain an aggregates $\tilde{b}_i$ (Table 3). The aggregates $\tilde{b}_i$ were then defuzzified using equation (3) in order to obtain the crisp scores b_i. The next step is obtaining the value of α as a thresold value of decision as explained in Section 4.5. For this data, all experts provided the same value i.e., α = 0.4. As stated earlier, if $b_i \geqslant \alpha$, then the final attbutes *i* is included in the final list of disaster resilience attributes. The result shows that all attibutes are accepted (Table 3).

Table 3. Aggregate fuzzy judgment and decision on attributes

Attri-bute	Expert 1				Expert 2				Expert 3				Aggregate $\tilde{b}_i$	crisp b_i	Decision
	Rating	TFN			Rating	TFN			Rating	TFN					
		l	*m*	*u*		*l*	*m*	*u*		*l*	*m*	*u*			
Physical Resilience															
PR1	VHI	0.7	0.9	1.0	VHI	0.7	0.9	1.0	VHI	0.7	0.9	1.0	(0.7, 0.9, 1.0)	0.867	Accepted
PR2	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	MI	0.3	0.5	0.7	(0.1, 0.5, 0.9)	0.500	Accepted
PR3	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	VHI	0.7	0.9	1.0	(0.1, 0.6, 1.0)	0.578	Accepted
PR4	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	MI	0.3	0.5	0.7	(0.1, 0.5, 0.9)	0.500	Accepted
PR5	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	VHI	0.7	0.9	1.0	(0.1, 0.6, 1.0)	0.578	Accepted
PR6	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.1, 0.6, 0.9)	0.522	Accepted
Organizational Resilience															
OR1	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	VHI	0.7	0.9	1.0	(0.1, 0.6, 1.0)	0.578	Accepted
OR2	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.1, 0.6, 0.9)	0.522	Accepted
OR3	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
OR4	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	MI	0.3	0.5	0.7	(0.3, 0.6, 0.9)	0.611	Accepted
OR5	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
OR6	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	MI	0.3	0.5	0.7	(0.3, 0.6, 0.9)	0.611	Accepted
OR7	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	LI	0.1	0.3	0.5	(0.1, 0.4, 0.9)	0.478	Accepted
OR8	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
Social Resilience															
SR1	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	VHI	0.7	0.9	1.0	(0.5, 0.8, 1.0)	0.756	Accepted
SR2	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
SR3	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	MI	0.3	0.5	0.7	(0.3, 0.6, 0.9)	0.611	Accepted
SR4	HI	0.5	0.7	0.9	MI	0.3	0.5	0.7	HI	0.5	0.7	0.9	(0.3, 0.6, 0.9)	0.611	Accepted
SR5	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
Economic Resilience															
ER1	LI	0.1	0.3	0.5	HI	0.5	0.7	0.9	VLI	0.0	0.1	0.3	0.0, 0.4, 0.9)	0.422	Accepted
ER2	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
ER3	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
ER4	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted
ER5	VHI	0.7	0.9	1.0	MI	0.3	0.5	0.7	VHI	0.7	0.9	1.0	(0.3, 0.3, 1.0)	0.689	Accepted
ER6	VHI	0.7	0.9	1.0	HI	0.5	0.7	0.9	VHI	0.7	0.9	1.0	(0.5, 0.8, 1.0)	0.778	Accepted
ER7	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	HI	0.5	0.7	0.9	(0.5, 0.7, 0.9)	0.700	Accepted

Best and worst dimension as well as attributes within each dimension were selected by each expert, and after that all preference rating used for BTO and OTW vectors are determined. Using equation (3), the dimension weights and attibutes weights are calculated, and by averaging these value the mean weights are obtained. The rank of atributes are derived by obatining attributes global weight by which each attributes weight is multiplied with the weight of their correspoding dimension.

Table 4. Global Weight of Disaster Resilient Attributes

Resilience Dimension	Dimensions weight			Ave.	Attrib.	Attributes weight			Ave.	Global weight	Ranking
	Exp.1	Exp.2	Exp.3			Exp.1	Exp.2	Exp.3			
Physical	0,207	0,197	0,495	0,300	PR1	0,139	0,373	0,189	0,234	0,070	3
					PR2	0,149	0,131	0,149	0,143	0,043	11
					PR3	0,141	0,232	0,137	0,170	0,051	7
					PR4	0,434	0,131	0,084	0,217	0,065	5
					PR5	0,089	0,081	0,388	0,186	0,056	6
					PR6	0,048	0,050	0,052	0,050	0,015	23
Organizational	0,587	0,197	0,209	0,331	OR1	0,140	0,086	0,114	0,113	0,037	12
					OR2	0,116	0,114	0,085	0,105	0,035	13
					OR3	0,070	0,029	0,068	0,056	0,018	22
					OR4	0,349	0,171	0,068	0,196	0,065	4
					OR5	0,023	0,114	0,038	0,058	0,019	20
					OR6	0,070	0,086	0,114	0,090	0,030	16
					OR7	0,116	0,257	0,342	0,238	0,079	1
					OR8	0,116	0,143	0,171	0,143	0,047	9
Social	0,079	0,073	0,088	0,080	SR1	0,046	0,506	0,161	0,238	0,019	21
					SR2	0,198	0,071	0,056	0,109	0,009	26
					SR3	0,106	0,190	0,161	0,152	0,012	25
					SR4	0,451	0,095	0,460	0,335	0,027	18
					SR5	0,198	0,138	0,161	0,166	0,013	24
Economic	0,127	0,533	0,208	0,290	ER1	0,113	0,371	0,025	0,170	0,049	8
					ER2	0,042	0,124	0,149	0,105	0,030	15
					ER3	0,042	0,124	0,116	0,094	0,027	17
					ER4	0,127	0,041	0,100	0,089	0,026	19
					ER5	0,338	0,124	0,349	0,270	0,078	2
					ER6	0,169	0,124	0,174	0,156	0,045	10
					ER7	0,169	0,093	0,087	0,116	0,034	14

Table 4 shows that the highest ranked attribute is “management structure”, followed by “insured business asset” and “building utility” at the second and the third ranked, respectively. From the resilience dimension point of view, organizational resilience is placed as the most important dimension due to the highest aggregate score. More in detail from expert judgement, this result comes from the fact that the organizational dimension is considered as the most important and the second most important by expert 1, and the others (expert 2 and 3), respectively. However, it should be noted that, in general, four of physical dimension attibutes are placed the higher rank. This fact may reveal that physical infrastructures of SMEs in Padang city are considered as a main concern by the three experts to be developed in order to achieve a better resilient against disaster disruption such as earthquake and tsunami.

4. Conclusion

This paper attempts to structure disaster resilience attributes of SMEs in Padang city. From 202 resilience attributes identified through the extensive literatures review, it was narrowed down to be a suitable disaster resilience attributes for SMEs in Padang city. The significant reduction is due to the number of resilience attributes that are not related or weakly related to disaster resilience and SME context. Using fuzzy Delphi method, the final list of disaster resilience attributes comprises 26 attributes and the attributes rank were obtained by employing BWM method. These 26 attributes are now can be used as representatives of the interests of the different stakeholders (i.e., policy-makers, academics and disaster NGO) who are high-level decision-makers with vast experiences in the disaster management.

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