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"Built Environment Flood Resilience Capability Maturity Model"

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Abstract

Capabilities are required for managing the impact of disasters on the built environment. These capabilities need to be continually improved and there should be a way of assessing them. This paper focuses on the development of a built environment flood resilience capability maturity model for micro, small and medium-sized enterprises (MSMEs). The study utilised the concept of capability maturity modelling to achieve its aim. The model developed identifies the built environment flood resilience capabilities of MSMEs. This was achieved by identifying relevant capabilities from the literature and mapping accordingly with maturity level characteristics prior to verification and refinement. This paper is limited to the development of the conceptual version of the model. The flood resilience capability maturity model is aimed at providing an assessment, improvement and benchmarking methodology for built environment flood resilience capabilities.

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Keywords: "Built environment, business, capabilities, flood, resilience"

1. Introduction

Towards achieving organisational goals which include managing and surviving crises [1, 2], Yen-Tsang, Csillag [3] described the need for capabilities and its importance in coordinating a set of activities to achieve particular goals. The capability of a firm is a combination of competencies, skills, resources, strengths, societal network used to coordinate a set of activities to achieve particular goals [3, 4], this includes disaster resilience. UNISDR [4] submitted that capacity can also be referred to as capability. The effective deployment of capabilities is still very low, flooding is still causing significant physical damage to business premises [5]. Previously, Bosher [6] declared the need to build capabilities for property resilience beyond physical attributes of the property, a similar need was identified by UN ESCAP and AIT [7]. It should be noted that the ability of the built environment to withstand, resist and absorb the impact of flood affects the speed of recovery of the business. Despite the call for the building and enhancement of capabilities, no study has developed a methodology for assessing the maturity of capabilities for enhancing built environment flood resilience and none has presented the specific capabilities for enhancing the flood resilience of the built environment. Although, studies have been conducted on flood mitigation measures generally

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(Asgary *et al.*, 2012; Bhattacharya-Mis & Lamond, 2014; CIRIA, 2010), this study is significant because it focuses specifically on capabilities for flood resilience in the context of built environment.

2. Literature review

2.1. Flooding and business organisations

The Royal Institute of British Architects identified six mechanisms of flooding [8], the mechanisms are tidal, fluvial, ground water, pluvial, flooding from sewers, and flooding from human-made infrastructures. The magnitude of damage from whichever type of flood is dependent on some factors, among these are the depth of inundation, duration of inundation, the rate of rising, the velocity of flow, flooding frequency, the presence of debris, property type, age, construction material and building use [9-18].The possession of relevant capabilities by an organisation will help the management of some of the factors and simply control the damage influence of some. Technically, flood water is controlled at the source, pathway and the receptor points [19]. The focus of this study is the receptor, business organisations fall in this category. Business organisations are classified based on turnover and number of employees, this study focuses on micro, small and medium-sized enterprises (MSME) i.e organisations with 1 – 249 employees [20]. The focus on MSMEs is simply because of the significance of this class of business to the economy of a nation. Currently, MSMEs are also highly vulnerable to disruptions basically because of the limited human and financial resources and limited risk management capability [21, 22].

2.2. Flood resilience capabilities

UNISDR [4] submitted that capacity can also be described as capability and capacity refers to infrastructure, physical facilities, institutions, societal coping mechanisms, human knowledge, skills, social relationships, as well as leadership and management. Similarly, [3] described the capability of a firm as a combination of competencies, skills and abilities used to coordinate a set of tasks or activities to achieve a goal. Capabilities determine the preparatory strength, coping response, absorptive ability, and adaptive ability; these abilities influence the disaster resilience of a system in a disaster situation. Towards achieving the aim of this study, twenty-six capabilities were identified from the literature. The capabilities extracted are presented in Table 1.

Table 1 Key Capability Areas and brief descriptions

SN	Key Capability Areas and brief descriptions	Literature source
1	Understanding of flood risk to property - This is expected to lead to a detailed mitigation survey.	[19, 23]
2	Planning or review for a flood resilience scheme - This is expected to lead to a clear, workable plan and schedule for a flood mitigation/resilience scheme.	[19, 23]
3	Survey of property - This is expected to result to a detailed design specification for the property.	[19, 23]
4	Acquisition of relevant facilities - Understanding of the purpose and function of flood resilience facilities.	[23]
5	Installation and Post-flood management scheme relationships - Management of installation period and preparations for potential disruption. Post installation relationship management with supplier and installer.	[23]
6	Operation and Maintenance - Operation, storage and maintenance requirement. Effective response readiness.	[23]
7	Organisation of disaster scenario simulations - Participation in drills and flood scenario simulations. It creates physical and mental alertness.	[19, 24]
8	Built environment related safety precautions – Switch-off power or power banks, fastening water tank and external furniture etc. To prevent complications.	[19]

Table 1 cont'd

SN	Key Capability Areas and brief descriptions	Literature source
9	Retaining the interest of customers in goods and services	[25]
10	Turn-over and cash flow management - Fund availability	[25, 26]
11	Insurance adequacy and management - Knowledge and existence of insurance. Even if steps have been taken to protect a property from flooding, there is still need for flood insurance	[19, 25]
12	Transport/delivery system - Access preservation (Accessibility)	[25, 26]
13	Utility supply - Continuity of supply through preservation of existing system or availability of alternatives.	[24, 25]
14	Communication system - Continuity of supply through preservation of existing system or availability of alternatives.	[25]
15	Flood proof store/flood proof protection for flood stock and contents *(Stocks and equipment)* - In-house protection of some contents	[25]
16	Record/Business data management - Business information and data policies and techniques. Accessibility of documents relating to premises repair/renovation.	[19, 25, 26]
17	Management of disruption to production/service/operations/processes - Culture and attitude to disruptive events. Preservation of right frame of mind.	[19, 25]
18	Crisis response budget (*Income generation and cash-flow management*) - Availability of fund for managing damages caused by a flood on one's premises.	[25-27]
19	General awareness and commitment to resilience - Training and awareness creation and appreciation of the need for built environment resilience within the organisation. Appreciation of the need for built environment resilience.	[24, 25]
20	Statutory compliance - Compliance with existing property-related standards.	[19]
21	Paper records management - Accessibility of documents relating to premises repair/renovation.	[28]
22	Decision making without recourse to superior in emergency situations - Authority to make decisions has been given to staff. Quick response to people activated prevention and protection facilities.	[24]
23	Definition of roles and responsibilities and how it changes in disaster situations - Understanding of Information flow – aids decision making	[24]
24	Post event operation, analysis and management - Plans for adapting and performing better in the future, innovativeness, lessons learnt – view sharing and documentation.	[19]
25	System and protocols for mobilising external/support resources when needed *(Network strength)* - the effective mobilisation of resources when needed e.g. contractors to assist in preserving equipment from flood water, firefighters etc.	[24]
26	Physical resilience or adaptability of premises – Sophistication of adaptation measures. Accessibility or partial usability of property. Flexible and distributed workplace enables employees, suppliers and customers' collaboration during crises.	[29]

The capabilities were used to develop a conceptual capability maturity model. The capability maturity model concept is discussed in the next section.

2.3. Capability maturity model (CMM) concept

The maturity of a process is defined as "the extent to which a specific process is explicitly defined, managed, measured, controlled, and effective" [30]. Capability maturity model is simply a concept that defines the key practices that describe the respective successive levels of process or capability maturity. In terms of maturity, the attributes at a lower maturity level always better describe a system or process than the attributes in a succeeding level. Therefore, the increase in maturity across levels remains evident. The Capability Maturity Model (CMM) developed by [30] metamorphosed into Capability Maturity Model Integration (CMMI) [31]. The CMMI emerged because of complications encountered in applying multiple models across an organisation. The complications include the need for training on several maturity models, overlaps, and some sort of confusions resulting from duplications [31]. CMMI covers 22 process areas that are a cluster of related practice directed towards fulfilling the desired goal [31]. The model contains five maturity levels presented in a stepwise progressive manner and labelled 1 to 5, 1 represents 'Initial', 2 represents 'Managed', 3 represents 'Defined', 4 represents 'Quantitatively managed', and 5 represents 'Optimising'. It should be noted that the CMMI is simply an integration of multiple CMM, the underlying concept is the same.

The sample characteristics of maturity levels are presented as follows:
Level 1 – Adhoc (referred to as 'Initial' in CMMI) - The process is best described as ad hoc and it is occasionally chaotic. Only a few processes are defined and success depends on individual effort [30, 32]. Level 2 – Repeatable (referred to as 'Managed' in CMMI) - This level is named repeatable, there are project management processes to track cost, schedule and functionality. There are process disciplines aimed at assisting a repeat of success on similar projects [30, 32]. Level 3 – Defined (referred to as 'Defined' in CMMI) - At this level, activities are standardised, documented, moulded into a standard process. The standard organisation processes are applied on all projects [30, 32]. Level 4 – Managed (referred to as 'Quantitatively managed' in CMMI) - Process and product quality are measured and documented; they are well understood and controlled in quantitative terms [30, 32]. Level 5 – Optimizing (referred to as 'Optimizing' in CMMI) - The processes are improved continuously using quantitative feedbacks and innovative skills. Concepts and best practices are embedded in all legal and operational frameworks [30, 32]. The full list of characteristics extracted for maturity level 1 is presented in Table 2 below. Tables like Table 2 were produced for the remaining maturity levels (Level 2 to level 5) with appropriate maturity level characteristics.

Table 2 Maturity level characteristics (Level 1 – Initial)

Reference code	Characteristic	Literature sources
ML1In/C1	Summary of general resilience status - Very poor	[24]
ML1In/C2	Organisations are highly reactive	[24]
ML1In/C3	Engage in very little planning	[24]
ML1In/C4	Yet to recognize/identify /task/process/resilience as strategically important	[24, 33]
ML1In/C5	No centrally coordinated support function	[33]
ML1In/C6	If policy exists, it is not enforced	[33]
ML1In/C7	Processes or related activities are generally chaotic	[31, 34-39]
ML1In/C8	There are no formal processes as there is no stable environment to support them. No standardised procedures.	[31, 35, 40, 41]
ML1In/C9	Organisation pays lip service to the activity or process	[32]
ML1In/C10	Existing processes are abandoned in times of crises. Successes cannot be sustained.	[31, 42]

Table 2 cont'd

Reference code	Characteristic	Literature sources
ML1In/C11	Success depends on individuals' efforts. Individuals act, no institutional coordination	[36, 38-43]
ML1In/C12	No attempt to identify the benefit of the activity or process	[32, 44]
ML1In/C13	No understanding of principles/task/process	[32, 41]
ML1In/C14	No tools or databases relevant to the process are in use.	[32, 44]
ML1In/C15	Budgets and schedules documented in plans are usually exceeded.	[39, 42, 45]
ML1In/C16	Unaware of the need for tasks to be undertaken.	[32]
ML1In/C17	Short-term focused strategies	[41]
ML1In/C18	Approaches/methods are applied on case-by-case basis	[41]
ML1In/C19	No monitoring or reporting	[41]
ML1In/C20	Use of basic and narrow range technology. Single and simpler products.	[44]

Note: The reference code reads "Maturity level 1, initial, characteristic 1 to 20".

The procedure for developing the capability maturity model using the identified capabilities for flood resilience and the maturity level characteristics are explained in the research methodology section.

3. Research methodology

The Capability Maturity Modelling concept was adopted in this study. The generic and specific goals and practices were carefully mapped in the context of disaster resilience to the capability areas (Table 1) identified in this study. The generic and specific goals and practices make up the maturity level characteristics referred to in Figure 1and presented in the conceptual framework (Table 3). This study commenced by identifying a set of capabilities for enhancing the flood resilience of the built environment. The capabilities were used to develop a conceptual capability maturity model (Table 3). As presented in Table 2, each of the maturity level characteristics was assigned reference codes. A mapping exercise that involves the alignment of each of the identified maturity level characteristics (Table 2) with relevant capability areas (Table 1) was done. This resulted to the production of maturity level characteristics for maturity level 1 for each of the capability areas. Tables like Table 2 were also produced for maturity levels 2 to 5 and the mapping process was repeated for all the identified capability areas and maturity levels 2-5. Table 3 presents the outcome of this exercise on one capability areas for maturity levels 1 - 5. Further processes leading to the production of the final capability maturity model will be reported in the future. In Figure 1 (procedure flowchart), the full rectangles are processes, the parallelogram is an output while the rectangle made with dots signifies future works.

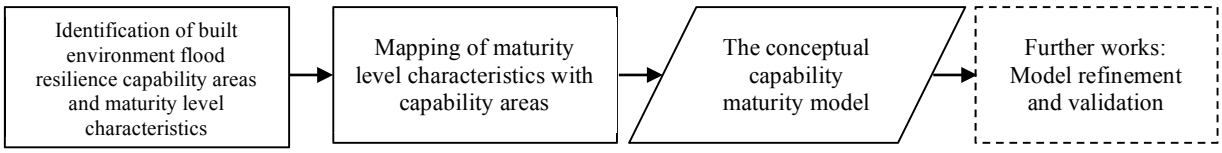

Figure 1The model development procedure

4. The conceptual model

The process for developing the conceptual built environment flood resilience capability maturity model was described in the methodology section, the model is presented in Table 3. The model contains seven columns and 26 rows (Only one is shown in Table 3), the first column is for serial identification of each capability area (SN), and the second column is the list of key capability areas. The remaining five columns describe maturity levels 1 to 5 for each capability area (Table 3). Column 2 contains the name of the capability areas as well as the coverage and the goal of each capability area. The maturity level characteristics for each capability area contains generic and specific goals and practices. The strength of an organisation on each capability area is expected to improve across maturity level 1 to 5. The maturity of an organisation on each of the capability areas is established by comparing the organisation with the descriptions in each of the maturity levels 1 to 5. The most suitable among the descriptions contained in maturity levels 1 to 5 is the maturity of the organisation on that capability area.

The code references in the current model (Table 3) shows the maturity level characteristic (Table 2) that is mapped with a specific or generic goal or activity related to a capability area. This study was aimed at providing a benchmarking and profiling methodology for the capabilities of businesses towards achieving the flood resilience of their built environment. It should be noted that the activities that defines maturity are contained in the maturity level characteristics presented against each capability area. The progression in superiority across the maturity levels can be noticed (See Table 3).

Table 3 Conceptual built environment flood resilience capability maturity model

		Capability levels				
SN	**Key Capability Areas**	**Level 1 Initial**	**Level 2 Repeatable**	**Level 3 Defined**	**Level 4 Managed**	**Level 5 Optimizing**
1	Understanding of flood risk to property Coverage - Awareness of the type, frequency of flood. Knowledge of climate projection and flood projection in the area. Periodic assessment is necessary - physical vulnerability evaluation and water entry channel survey. Initial consideration of remedial measures Understanding of hazard consequences to the organisation and all assets. Goal - This is expected to lead to a detailed mitigation survey. With information on mitigation and protection that is needed. This might influence other decisions. The effect or influence of surrounding businesses will also be established.	Yet to recognise the strategic importance of climate and flood projection in the area. ML1In/C4. No formal processes are applied as there is no stable environment to support them ML1In/C8. No attempt to identify the benefit ML1In/C12. No understanding of principles ML1In/C13. No tools or database ML1In/C14. Unaware of the need ML1In/C16.	Individual department or function makes effort but they are not shared ML2Re/C3. A senior manager may recognise the importance but resources are not allocated ML2Re/C4. Simple tools and templates are used for some activities ML2Re/C10. Importance is recognised. They are communicated verbally (within the department) ML2Re/C13. Heavy reliance on knowledge of individuals ML2Re/C16	Importance is recognised ML3De/C2. Tools, templates and relevant databases are available ML3De/C10. Standard processes are established and improved over time ML3De/C11. Relevant actions are coordinated with stakeholders (government and others) ML3De/C17. Training programme for capacity development exists ML3De/C18.	High recognition of importance ML4Ma/C2. The need for processes/tasks are highly recognised and supported with stated means of improvement ML4Ma/C9. Tools, database and records are available for statistical and managerial analysis ML4Ma/C14. The risk is identified ML4Ma/C17.	Operating environment is well-understood ML5Op/C2. They anticipate and respond to uncertainty ML5Op/C4. Quantitative approaches are used to understand internal and external variations ML5Op/C6. High recognition of importance, lessons learnt are captured and fed back into the system ML5Op/C10. High level of awareness ML5Op/C20. Active use of information ML5Op/C21.

5. Conclusion

The specific capabilities for enhancing the flood resilience of the built environment of a Micro, Small and medium sized enterprise were extracted from the literature. The capabilities were sourced based on the definitions and description of 'capability' by UNISDR (2009) and Yen-Tsang (2012) among others. According to the

aforementioned studies, capabilities are strengths, physical means, knowledge, resources, leadership, and skills among other attributes that can be deployed to achieve a specific goal. The goal in this context is the flood resilience of the built environment. Using the concept of capability maturity modelling, the capabilities were used to produce a capability maturity model. This study has provided a valuable information on flood resilience capability enhancement. The identified flood resilience capability areas, though subject to consolidation in the continuation of this study, can be adopted for planning purposes by business organisations and for use by researchers in subsequent studies. Also, the approach adopted i.e. the application of capability maturity model (CMM) methodology in disaster resilience with a focus on the built environment flood resilience is novel. This has expanded the boundary of CMM application and has contributed to the body of knowledge on capability enhancement in disaster resilience.

Currently, the model clearly provides an improvement blueprint that business organisations and regulatory bodies can consider for planning and MSME profiling purposes. The maturity model will be refined, improved and reported in the future. It will be a viable capability evaluation and improvement model.

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