A Biomimetic Framework for Evaluating the Functional Trait Diversity and Adaptive Capacity of the Firm

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Abstract

Organizations suffer economic losses from operational disruptions (see Rice and Caniato 2003, Chopra and Sodhi, 2004 Greising and Johnsson 2007, Essuman et al. 2020, Haraguchi and Lall 2015, Pettit et al. 2013). Thus, there is a pressing imperative to determine alternative modalities of enhancing the operational resilience of organizations that will allow firms to become "naturally" more tolerant to operational disruptions. In ecosystem research, functional diversity, functional redundancy, response diversity and adaptive capacity have been argued and proved to promote ecosystem stability, resilience and tolerance against natural and anthropogenic perturbations (see Nystrom and Folke, 2001; Folke et al. 2002; Mouillot et al. 2005; De Bello et al. 2007; Naeem 1998; Galland et al. 2020; Walker 1995; Desjardins et al. 2015; Elmqvist et al. 2003; Baskett et al. 2014; Leslie and McCabe. 2013; Mori et al. 2013, etc.). Owing to ecological thinking which supposes that organizational ecosystems function similarly as biological systems (Mars et al. 2012), it is hypothesized that firms can similarly leverage on functional trait diversity to enhance their potential operational resilience. To substantiate such postulation, this paper presents a biomimetic framework for qualifying and quantifying the functional trait diversity and adaptive capacity of organizations for the purpose of drawing insights that may prove useful in fortifying a firm's posture against operational disruption.

Keywords
Operational Resilience, Functional Diversity, Functional Redundancy, Response Diversity, Adaptive Capacity

1. Introduction

The financial impact of operational disruptions
Operational Disruptions refer to events that interrupt the regular delivery of goods and services within a system (Blackhurst et al. 2011) The estimated daily economic loss due to operational disruption ranges from $50 to $100 million (Rice and Caniat 2003). Ericsson reported a $400 million loss due to a 10-minute fire incident in one of the plants of its chip supplier, Philips (Chopra and Sodhi 2004) while Boeing 787 Dreamliner program lost roughly $2.5 billion loss due to the inability of Advanced Integration Technology to deliver supplies (Greising and Johnsson, 2007). (Essuman et al. 2020) cited that Honda, Toyota, and Nissan halted their operations due to a Tsunami that hit Japan in 2011 (Haraguchi and Lall, 2015) where Toyota lost an estimated $72 million per day (Pettitet al. 2013). Similarly, Tesla, Ford, and Nissan had to halt production in China in 2020 due to the COVID-19 outbreak where Apple suffered a US$34 billion loss in its market value during the same period (Essuman et al. 2020). This paper recognizes the debilitating impact of operational disruption on the financial viability of firms and hereby proposes an approach to evaluating a firm's potential operational resilience based on its functional trait diversity—a characteristic exemplified by ecosystems to withstand natural and anthropogenic perturbations.

The Research Imperative: An Ecological Approach to Examining Operational Resilience
To readily react to operational disruptions, incidents, crises and disasters, many organizations have made Business Continuity Management (BCM) an integral part of their resilience planning (Charoenthammachoke et al. 2020). However, business continuity plans (BCP) are not infallible and are susceptible to all forms of failure (see Grimaldi, 2002). It is therefore worth investigating, *what alternative modalities of enhancing operational resilience can firms employ that diminishes their dependence on BCP?* More specifically, *what can firms deliberately alter to improve their posture against operational disruptions?* Considering that for centuries mankind has mimicked nature to solve

human problems (Celep et al. 2017, Vincent et al. 2006), this research posits that nature may provide an elegant answer to these questions. This paper takes inspiration from the structure, function, process, and mechanism of ecosystems to initiate the development of a sustainable solution (Bae and Lee 2019) for fortifying the operational resilience of firms based on functional trait diversity of ecosystems. This 'mimicry of natural systems' which is commonly known as Biomimicry (Helmrich et al. 2020) creates solutions based on the patterns and strategies observed in nature that have evolved over 3.8 billion years (Benyus 2002) that inherently relied on *evolutionary optimization* (MacKinnon et al. 2020). It is from such notion of 'natural optimization' that this paper substantiates the imperative to search for resilience-augmenting solutions from nature.

The Research Problem

Ecosystem research has argued and proved that *functional diversity, functional redundancy, response diversity* and *adaptive capacity* promote ecosystem stability, resilience and tolerance against natural and anthropogenic perturbations (see Baskett et al. 2014; de Bello et al. 2007; Desjardins et al., 2015; Elmqvist et al., 2003; Folke et al., 2002; Leslie & Mccabe, n.d.; Mason et al.2005; Mori et al. 2013; Nyström & Folke 2001; Naeem 1998; Galland et al, 2020; Walker 1995). It is thus academically diligent to inquire, *how can organizations similarly leverage on functional diversity, functional redundancy, and response diversity to enhance the adaptive capacity of firms for withstanding operational disruptions, much like how ecosystems exemplify such characteristic?*

While several studies relate organizational resilience with business continuity management (e.g. Sahebjamnia et al, 2014; Niemimaa et al. 2019) and disaster recovery management (e.g. Comfort et al. 2009; Horn, 2021), very little studies have associated diversity with organizational resilience (Duchek et al. 2020) and more specifically, no prior studies were found that link operational resilience with functional trait diversity. Although research on biomimicry abounds, many focused largely on form, behavior, and process imitation and not on *ecosystem-level mimicry* (Helmrich et al. 2020). Moreover, there remains a scarce body of research done on 'biomimicry-management' relationship (Celep et al. 2017). To fill this void in the research literature, this paper presents a *novel ecology level and management oriented biomimetic approach* for qualifying and quantifying the functional trait diversity and adaptive capacity of organizations for responding to operational disruptions.

1.1 Objectives

The study recognizes (a) the crippling effect operational disruptions on organizations and (b) the resilience exemplified by ecological systems through their functional trait diversity. Thus, there is justifiable motive to uncover alternate modalities of building resilience based on ecosystem characteristics. In response to such research imperative, the primary objective of this paper is to present a novel biomimetic framework that will allow organizations to (a) empirically examine their degree of functional trait diversity and (b) theoretically estimate their adaptive capacity for responding to operational disruptions. The proposed evaluation framework is poised to offer a method for qualifying and quantifying the organizational analogs of several functional trait diversity characteristics that substantiates the postulation that an organization comprised of diverse groups of functional clusters (i.e. functional richness) that are equally abundant (i.e. functional evenness) will naturally have better buffering capacity (i.e. functional redundancy) and higher response potential against operational disruptions (i.e. response diversity) which will consequently maximize the resource capacity it can deploy to respond, continue and restore its operations (i.e. its adaptive capacity) thereby enhancing its potential operational resilience. Ultimately, the insights drawn from the use of the proposed biomimetic framework will provide the basis for the effective distribution and allocation of a firm's functional resources to fortify its potential operational resilience through the deliberate alteration of its functional trait diversity.

2. Literature Review

This section presents the review of the research literature related to (a) resilience particularly organizational resilience, operational resilience, ecological resilience, engineering resilience, and adaptive capacity, and (b) attributes that are hypothesized to influence resilience, specifically functional diversity, functional redundancy, and response diversity both in the ecological and organizational context.

Resilience

The term Resilience can be traced back to the latin word "resilire" which means "to bounce back" (Klein et al, 2003; Song et al. 2015; Xiao and Cao 2017). Many scholars have defined and operationalized the concept of 'resilience' in various but closely related ways (see Hillmann & Guenther 2021; Norris et al. 2008; Ruiz-Martin et al. 2018; Barasa et al. 2018; Duchek 2020; Ganin et al. 2016; Mcmanus et al. 2008; Tierney 2003; Brand & Jax 2007; Manyena 2006, Hollnagel 2010; Powley 2009; Gilly et al. 2014; Alexiou 2014; Kamalahmadi & Parast 2016; Ortiz-de-Mandojana & Bansal 2015; Proag 2014; Castet and Saleh 2012). Among the different ways resilience is defined, this paper espoused the concept of resilience as the *ability of a system to return to a stable condition after a disturbance if it can function at a sufficient level of capacity* (Asbjørnslett and Rausand 1999).

Ecological and Engineering Resilience

Among many scholars, the theoretical ecologist C.S. Holling, introduced the term "resilience" in the research literature (Gunderson 2000). Holling (1996) explains 'The Two Faces of Resilience' where he distinguished ecological resilience from engineering resilience, with the latter measured in terms of (a) degree of resistance to, and (b) speed of recovery from disturbance. In comparison to engineering resilience which focuses on recoverability (e.g. Richards (2009) and rate of return ((Baskett et al. 2014; Haydon 1994), ecological resilience is characterized as resistance to stress, absorption of shock (Gunderson and Holling 2002; Gunderson et al. 1997) and maintenance of state (Holling, 1973; Peterson et al. 1998). While the proposed evaluation framework draws its theoretical basis of resilience drivers from ecology, it patterned its conceptualization and examination of operational resilience from engineering.

Organizational and Operational Resilience

While both organizational resilience and operational resilience relate to the ability to maintain and sustain business operations in the event of disruptive events (Leo, 2020), they differ in coverage. Organizational resilience is deemed as a combination of capital, strategic, relationship, cultural and learning resilience (Chen et al. 2021) while operational resilience covers the resilience of systems and processes (Leo 2020). It also deemed that organizational resilience is a result of designing structures (Weick 1996) and stems from the ability to adjust structure to prevent disasters (Mafabi et al., 2015). Similarly, Bradenburg et al. (2019) and Stolker et al. (2008) present the notion that the goal of operational resilience is partly "disruption prevention". Relatedly, the proposed evaluation framework aims to facilitate a better way of designing functional structures and allocating operational resources that will allow organizations to withstand the effects of disasters and help prevent operational disruption.

Adaptive Capacity

The capacity of an ecosystem to maintain its stability and resilience reflects its adaptive capacity (Gunderson et al. 1996). While resilience is characterized as a state, adaptive capacity is the ability to change the state (Colombi & Smith 2012). Salehi & Veitch (2020) recognizes adaptive capacity as a vital part of resilience which reflects the internal capacity of systems to adjust to disruptions and "retrieve system performance *without any recovery activities*". In ecological systems, resilience is dependent on (a) the required *variety in functional groups* and (b) the *amount of resources needed for recovery* (Gunderson et al. 1996). Owing to such characterization, the study posits that the resilience of an organization *can be altered* to improve its adaptive capacity *by enhancing its functional diversity* which is hoped to consequently *increase the number of operable resources that facilitate (not perform) recovery*. Relatedly, both Engle (2011) and Rahi (2019) characterized adaptive capacity simply as the ability to *mobilize resources* to anticipate or respond to disturbance. Moreover, Rahi (2019) defined adaptive capacity as "the organization's capacity *to transform its structure* for recovering once faced with a disruptive event". Such definition lends support to the objective of the proposed evaluation framework which is to trigger the needed alteration of the firm's functional structure and the re-configuration of its functional resources to adjust its adaptive capacity.

Functional Trait Diversity and Resilience

Two related hypotheses define the relationship between resilience and diversity. The *Diversity-Stability Hypothesis* posits that a system with greater diversity tends to be more stable (Tilman 2001, Desjardins et al. 2015). It was based on the observation that ecological communities that are less diverse are easily disrupted and are more vulnerable to disturbances (Elton, 1958). The *Insurance Hypothesis* on the other hand implies that increasing biodiversity insures the ecosystem from loss of functionality caused by perturbations (Yachi and Loreu 1999). It posits the notion increasing species diversity (a) also increases the odds that some species within the ecosystem will respond differently to perturbations, and (b) the ecosystem will contain species that are capable of functionally replacing important species (McCann 2000). In other words, an ecosystem creates a buffering effect when it consists of species that perform similar functions but respond differently to environmental disturbances (Galland et al. 2020). As cited in the succeeding sections, several studies provide evidence that a similar dynamic exists within organizational ecosystems that lends support to both the Diversity-Stability Hypothesis and Insurance Hypothesis.

Functional Diversity

Simply, *functional diversity* is the range of organismal traits that contribute to ecosystem functioning (Tilman 2001; Goswami et al. 2017), and thus it can be plainly understood as *functional trait diversity* (Petchey & Gaston 2002). *Functional traits* refer to characteristics of an organism that influence ecosystem functioning (Lauretoa et al, 2015). In ecology, the diversity of functional groups of species in a system has been theorized to play a significant role in sustaining ecosystem resilience (Folke et al. 2002). While functional diversity technically is a measure of the functional traits (Goswami et al. 2017), it may be commonly measured by the *number of functional groups* (Petchey & Gaston, 2002). *Functional Groups* are sets of species that perform similar ecological roles (e.g. pollinators) whose actions contribute in maintaining ecological processes (Nystrom 2006).

Studies on Functional Diversity in an organizational context mostly referred to the diverse attributes of people. To cite, Duchek (2020)defined "diversity" as the *heterogeneity of members* within organizational work units, which seemed to take various forms. For instance, *demographic diversity* refers to the differences in demographic traits among employees e.g. age, gender, ethnicity and race (Baugh and Graen 1997) while *experiential diversity* refer to differences in the education, professional background, industry experience among workers (Milliken and Martins 1996). In the case of functional diversity, it may be defined as the *differences in employee functional traits* (Bunderson & Sutcliffe, 2002) or differences in functional backgrounds among employees (Shemla et al. 2020).

Functional Richness and Functional Evenness

Mason et al. (2005) defined *functional diversity* as "the distribution of the species and abundance of a community in niche space", which relatedly according to Mouillot et al. (2005) can be decomposed into two components of *functional richness* (distribution) and *functional evenness* (abundance). Functional Richness is defined as "the amount of functional trait space occupied by the species" (Mason et al. 2005) while Functional Evenness relates to "how regularly species abundances are distributed in the functional space." (Mouchet et al. 2010).

While several studies link diversity to team performance, very little studies have examined how diversity can enhance an organization's capacity for resilience. For one, Duchek (2020) explained how diversity can conceptually enhance anticipation, coping and adaptation capabilities to build organizational resilience. Another study was conducted by Garmestani et al. (2006) which examined the effects of *functional richness* across firm size on the survivability of industries to employment volatility. This study is particularly relevant to the proposed research since it is the only study found that related organizational resilience to the ecological concept of *functional richness*. In Kahiluoto and Makinen (2019) on the other hand, response diversity was operationalized in terms of (a) *diversity among personnel sizes* of slaughterhouses in response to a domestic strike and (b) *evenness in the proportions* of food oil supply under a global price volatility—both traits as being comparable to 'functional evenness'.

Functional Redundancy and Response Diversity

In ecology, there is consensus that biological diversity tends to enhance ecosystem resilience when *redundancy is built into functional groups* (Leslie & Mccabe 2013). During a disturbance, the vulnerability of functional groups to species loss is related to the redundancy of species within each group (Nyström & Folke 2001). Functional Redundancy refers to a diverse set of species in the same functional group that when one species is lost, others can continue ecological functioning (Desjardins et al. 2015). On the other hand, Response Diversity is defined by Elmqvist et al. (2003) as "the diversity of responses to environmental change among species that contribute to the same ecosystem function" and deems that such *diversity of responses to disturbances* among species within a functional group is a key driver of its resilience. It is considered as an element of diversity that drives ecological resilience (Baskett et al. 2014a). Functional Redundancy and Response Diversity are inherently connected. Stavert et al. (2017) suggest that ecosystem functioning is ascertained if functionally redundant species also demonstrate *diversity in response traits* against disturbance. In other words, functional redundancy is useful only when species with similar effect traits differ in response traits to disturbances (Oliver et al. 2015) and such as, functional redundancy will be insufficient to establish resilience without response diversity (Desjardins et al. 2015).

In the context of supply chain resilience, Choi and Krause (2006) argue that resilience-producing diversification (i.e. response diversity) of suppliers with a similar function (i.e. functional redundancy) creates *resilience potential*. Relatedly, the study of Kahiluoto and Makinen (2019) indicated that less 'supplier type diversity' is required to enhance supply chain resilience within a functional group (i.e. functional redundancy) when response diversity is applied. Similarly, Choi and Krause (2006) found that it is response diversity, and *not diversity per se*, that enhances supply chain resilience.

Relationship among the Functional Trait Diversity Attributes

The reaction of ecosystems to disturbance including buffering (i.e. functional redundancy) depend on the species' functional responses to perturbations which is contingent on the diversity of traits (i.e. functional diversity) thereby creating a range of response capabilities against disturbances (i.e. response diversity), thus implying how functional diversity cause response diversity (Angeler et al. 2019). Relatedly, the study of Leslie & Mccabe (2013) discussed how response diversity produce functional diversity and suggest that multi-level response diversity bears influence on the role of functional redundancy and functional diversity in system resilience and adaptive capacity. Leslie & Mccabe (2013) cites that biodiversity enhances adaptive capacity, where the distribution, diversity and redundancy of functional traits can be used as *surrogate measures of adaptive capacity* (Angeler et al. 2019).

3. Methods

Owing to ecological thinking, organizational ecosystems are deemed to function similarly as biological systems considering that many organizational properties are similar with those observed in nature which include diversity and nestedness which then create redundancies and resilience (Mars et al. 2012). Based on such logic, the metaphorical process mentioned in Parisot and Isckia (2013, p. 46) is adopted to develop the organizational analogs of the ecological functional diversity characteristics. The result of the process yields the Operational Definitions and Attribute Indicators which respectively represent the *qualification* and *quantification* of functional diversity, functional redundancy, response diversity and adaptive capacity. The metaphorical process consists of three stages.

1. **Structural alignment.** The structural alignment of the ecological attributes of functional diversity, functional redundancy, response diversity and adaptive capacity to their organizational analogs is demonstrated by citing conditions and circumstances in BPO operations *that illustrates their metaphorical similarities* with a particular functional diversity attribute.
2. **Re-representation:** Considering the metaphorical similarities, each of the ecological attributes are *re-represented into their organizational equivalent* in a qualitative and quantitative context in the form Operational Definition and Attribute Indicators (i.e. indices and scores), respectively.
3. **New Explanatory Framework:** The resulting Operational Definition and Attribute Indicators for functional diversity, functional redundancy, response diversity and adaptive capacity accordingly provide the basis for the *development of a novel biomimetic framework* for examining the functional trait diversity and adaptive capacity of an organization.

4. Data Collection

A semi-hypothetical data set is applied to the proposed formulations to demonstrate the utility of the framework. The data set consisting of information about the campaigns (i.e. functional clusters), accounts (i.e. functional divisions) and agents (i.e. functional units) of a hypothetical multi-national, multi-site and multi-service business process outsourcing BPO firm was derived from interviews with executives of several BPO organizations combined with the professional experience of the researcher working for the industry. Such approach mimics the method used by Aviso et al. (2018) which used hypothetical data to demonstrate the application of a fuzzy input-output optimization modeling framework for allocating human resources of a BPO organization operating under crisis conditions.

5. Results and Discussion

This section presents the proposed *Operational Definitions* and the *Attribute Indices and Scores* for functional richness, functional evenness, functional redundancy, response diversity and adaptive capacity as composite elements of the proposed biomimetic framework. The operational definitions and Attribute Indices and Scores are designed to be *generic* so they can be applied to any form of *multi-service* and *multi-site* organization provided that their functional structure finds equivalence to the variables of the attribute indices. The design of the proposed Attribute Indices and Scores follows Yodo and Wang (2016) who pointed that most resilience metrics are scaled to values between 0 and 1 or expressed as a percentage to reduce the complexity in resilience measurement thereby expanding its applicability. As similarly fashioned in ecological studies, (Mason et al. 2005) used indices to standardize functional diversity measures to allow for comparison. Other ecological scholars similarly used indices to quantitatively express functional richness and functional evenness (see Schleuter et al. 2010, Table 01, p.472), functional redundancy (see Galland et al. 2020, Table 01, p.3) and response diversity (e.g. Ross et al. 2022).

5.1. Results: Metaphorical Equivalents

A simple analysis of the organizational structure of many BPO companies will reveal that their service delivery operations are organized into specific campaigns (i.e. service types) that deliver outsourcing services to a group of clients (i.e. accounts, campaigns) that are largely composed of service delivery associates (i.e. agents, associates). The terms Functional Cluster, Functional Division and Functional Units are used specifically in the study to mean the following:

a. **Functional Clusters** are operational groups of an organization that each perform specific and often unique functions that relate directly to the purpose of the organization. Functional Clusters are analogous to a *functional group of species* that contribute to ecological functioning. They are composed of functional divisions that perform a common function.
b. **Functional Divisions** are operational units within a functional cluster that share a common but specific function. They are analogous to *different species that have the same functional effect on the ecosystem*. They are composed of functional units.
c. **Functional Units** are operational resources that produce the outputs expected from functional divisions. They are analogous to *organisms that belong to a particular species*. A functional unit represents a combination of resources (e.g. person, technologies, procedure) that are collectively utilized to perform a specific function much like any organism that possess a unique set of characteristics that it utilizes to contribute to ecological processes.

Table 1: Metaphorical equivalent of Ecological terms

Ecological Term	Organizational Term	BPO Term
Ecosystem	Organization	Company
Functional Group	Functional Cluster	Campaign
Species	Functional Division	Account
Organism	Functional Unit	Agents

For additional clarity, the concept of *ecological function* and *ecological process* are metaphorically equivalent to an organization's intended *firm function* (e.g. generate revenue) and the *service or production processes* it operates to dispense its function, respectively. The term *functional resource* is used in the study to generically mean a functional cluster, a functional division or functional unit. Collectively, functional resources perform a particular function for the organization (e.g. generate revenue through invoice processing outsourcing). The concept of functional clusters, functional divisions and functional units will be fairly different when used in a different type of organization (e.g. a university, hospital, government agency).

Operational Definition and Measurement Indices

This section discusses the theoretical constructs that form the basis of the operational definitions of functional richness, functional evenness, functional redundancy, response diversity and adaptive capacity, and the formulation of the respective attribute measures. For ease of discussion, the concepts will be illustrated in the context of BPO operations.

Operational Functional Richness

In ecology, Functional Richness of a given community is determined by how much functional trait space that the species occupy within a community (Mason et al. 2005); where the functional trait space (or niche) is determined by the number of functional traits which would permit the species to thrive and exist indefinitely (Blonder et al., 2014; Hutchinson 1957). This intraspecific trait variability is found to have a strong impact on population stability (Legras et al. 2018). A single organism of any species that occupies a niche section of a community is deemed to contribute to functional richness (Keeney and Poulin 2007).

Structural Alignment

Many large BPO companies operate across multiple sites thus forming their own respective internal community. Every Account Team possesses a particular *set of functional traits* that contribute to revenue generation (i.e. their *function*). For instance, an account team will have knowledge of its customer's processes (trait 1), the skill to render a particular service (trait 2) and the ability to work remotely (trait 3). Here, the functional trait space is represented by 3 functional traits as its dimensions. The account teams (i.e. *species*) that commonly possess all 3 functional traits form a functional cluster. BPO sites normally host different service verticals (i.e. functional clusters) depending on the pool of clients they serve and their workspace capacity, thus their degree of functional richness will also vary. If in ecological terms functional richness relates to the amount of functional trait space occupied by the species (Mason et al. 2005), then Operational Functional Richness is thus deemed metaphorically equivalent to the *diversity of functional clusters that a particular site host*.

Re-representation

Operational Definition of Functional Richness: The study proposes to define Operational Functional Richness simply as the *capacity of the organization to host several functional clusters*. It is determined by the number of its functional clusters, and not the number of its functional divisions (i.e. '*species'*) or functional units (i.e. '*organisms'*). Correspondingly, it reflects a firm's latent potential to sustain its functionality during disturbances through diversification of functional (e.g. revenue generating) capabilities. Owing to the diversity-stability hypothesis it is argued that an organization that hosts more functional clusters is more functionally diverse and more operationally stable than those that have less.

Attribute Index for Operational Functional Richness: The functional richness of a firm is represented by the percentage of functional groups operating on the site. It is measured using a Firm Functional Richness Score (FRR1).

The Firm Functional Richness Score (FFR1) of a site is postulated to be the proportion of the functional clusters operating within a firm (FFg) relative to the total number of functional clusters of the entire organization (OFg). This score represents the percentage of functional clusters of the site. This metric represents firm-level functional richness and represented as:

$$FFR1 \quad = \frac{Total\ Number\ of\ Functional\ Groups\ in\ a\ Site}{Total\ Number\ of\ Functional\ Groups\ in\ the\ Organization}$$

$$FFR1 \quad = \frac{FFc}{OFc}$$

A firm will obtain a Functional Richness (FFR1) score of one (1) if all functional clusters of the organization operate within the site. A score of one (1) implies that the firm possesses the maximum degree of functional richness that a firm can realistically obtain.

Operational Functional Regularity

In ecology, Functional Evenness represents how evenly distributed the species are in a niche space (Goswami et al. 2017; Mouchet et al.. 2010). It is based on the *evenness of the distribution of organisms across all occupied niche sections* (Keeney and Poulin 2007). Higher functional regularity results in higher stability and resilience in communities if there is an even distribution of resources in functional space (Loreau et al. 2001; Kinzig et al. 2002; Mouillot et al. 2005). Functional Regularity is a measure of functional evenness (Mouillot et al. 2005).

Structural Alignment

A stable ecological community usually hosts many species that are almost evenly distributed (Fedor and Zvaríková 2019). Its functional evenness is defined by its biomass distribution across a niche space that will allow the effective utilization of a range of available resources in its ecosystem (Goswami et al. 2017). While a typical BPO company manages a diverse group of accounts (i.e. 'species'), there is normally an uneven distribution of agents (i.e. uneven 'biomass' of agents) across its campaigns (i.e. functional groups). Such unevenness in the agent population consequently causes an uneven allocation of resources (e.g. workspace, budget). If in ecological terms functional evenness relates to the regularity of the distribution of organisms across all occupied niche sections (Keeney and Poulin 2007), then Operational Functional Evenness is thus deemed to be metaphorically equivalent to *degree of evenness in the distribution of functional units across all functional clusters*.

Re-representation

Operational Definition of Functional Evenness: The study proposes to define Operational Functional Regularity as the *relative resource capacity allocated to functional divisions across functional clusters*. Correspondingly, it reflects a firm's latent potential to minimize the risk of resource loss during a disruption through balanced distribution of functional units. Owing to the diversity-stability hypothesis it is argued that an organization that maintains a relatively even number of functional units across functional clusters is more functionally diverse and thus more operationally stable than those that have uneven abundance.

Attribute Indices and Scores for Operational Functional Regularity: The functional regularity of a firm is represented by the *relative functional evenness* of a functional cluster and the *average functional evenness traits among the functional clusters operating within the site*. These metrics are respectively measured using the *Group Functional Regularity Index* (GFR2) which is used to calculate the *Firm Functional Regularity Score* (FFR2).

The *Group Functional Regularity Index* (GFR2) of a functional cluster is calculated as the ratio between the actual functional cluster abundance (AFai) and the average functional cluster abundance (MFu). This score represents the *functional evenness ratio* of a functional cluster. This metric represents cluster-level functional evenness.

$$GFR2_i = \frac{AFu_i}{MFu} = \frac{AFu_i}{\frac{FFu}{FFc}}$$

Where MFu is calculated simply as the ratio between the functional unit abundance (i.e. population) of the entire site (FFu) i.e. the total population of the site and the total number of functional clusters operating in the site (FFc).

The *Firm Functional Regularity Score* (FFR2) of a site is computed as the *average functional evenness traits among the functional cluster operating within the site* (GFR2). This metric represents firm-level functional evenness and expressed as:

$$FFR2 \quad = geometric\ mean\ (all\ Group\ Functional\ Evenness\ Scores\ in\ the\ site)$$

$$\text{FFR2} \quad = \sqrt[n]{\prod_{j=1}^{n} GFR2_1\ x\ GFR2_2\ x\ GFR2_3\ x \ldots GFR2_n}$$

A firm will obtain a Functional Regularity (FFR2) score of one (1) if all functional clusters host an equal number of functional units. This score is agnostic to the number of functional divisions per functional cluster. A score of one (1) implies that the firm possesses the maximum degree of functional evenness that a firm can realistically obtain.

Operational Functional Redundancy

In ecology, *functional redundancy* relates to a diverse group of species that can perform the same ecological function (Desjardins et al. 2015). It essentially represents the functional similarity of species (De Bello et al. 2007) thereby allowing species to be substitutable (Blüthgen and Klein. 2011) such that a loss in one species can be compensated by the contribution of the remaining species to sustain ecosystem functioning (Oliver et al. 2015). Functional Redundancy is possible only if multiple species possess the same effect traits but different response traits against a disturbance (Oliver et al. 2015). While there is no consensus on the mathematical definition of functional redundancy (Galland et al, 2020), Laliberté et al. (2010) proposed that it can be represented by the number of species that contribute similarly to an ecosystem function, and hence can be measured by the *average number of species per functional group*.

Structural Alignment

Like in ecological environments where species that perform similar ecological roles are categorized into functional groups (Nystrom 2006), many large BPO firms organize their service delivery teams into functional clusters that are sometimes colloquially called 'campaigns'. These campaigns may be grouped by service type (e.g. call, email or chat technical support, software testing), or process (e.g. executive recruitment, invoice processing) or industry (e.g. automotive, high-tech, healthcare), or region (e.g. Asia, Europe, Americas) or some other pre-defined category. Each campaign contributes to revenue generation, being their primary function for the firm. Owing to the Insurance

Hypothesis, a campaign comprised of several service delivery teams is likely to continue generating revenue even when one (or few) teams become inoperable provided the remaining teams can resume operating. If in ecological terms functional redundancy relates to the number of species that contribute similarly to an ecosystem function (Laliberté et al., 2010), then Operational Functional Redundancy is thus deemed to be metaphorically equivalent to the *number of functional divisions in a functional cluster* that creates a buffering effect when some fail to operate.

Re-representation

Operational Definition of Functional Redundancy: The study proposes to define Operational Functional Redundancy as simply as the *capacity a functional cluster to buffer against operational shocks by maintaining several functional divisions that function similarly but respond differently to disruptions*. Correspondingly, it reflects a firm's inherent latent potential to buffer its operations against disruption through replicated functions. Functional redundancy does not imply that inoperable functional divisions are replaced by another.

Attribute Indices and Scores for Operational Functional Redundancy: The functional redundancy of the firm is represented by the *percent functional redundancy of a functional cluster* and the *average functional redundancy traits of all functional cluster operating within the site*. These metrics are respectively measured using the *Group Functional Redundancy Index* (GFR3) that is used to compute the *Firm Functional Redundancy Score* (FFR3) of a site.

The *Group Functional Redundancy Index* (GFR3) of a functional cluster is proposed to represent the ratio between the number of functional divisions within a functional cluster of a firm (FFdi) and the total number of functional divisions across the organization for the same functional cluster (OFdi). This score represents the *percent functional redundancy* of a functional cluster. This metric represents cluster-level functional redundancy.

$$GFR3_i = \frac{FFd_i}{OFd_i}$$

The *Firm Functional Redundancy Score* (FFR3) of a site is postulated to be the *average functional redundancy traits of all functional clusters operating within the site*. It is simply the aggregated cluster-specific functional redundancy traits (GFR3) normalized by the number of functional clusters operating in the site (FFc). This metric represents firm-level functional redundancy and expressed as:

$$FFR3 \quad = \frac{Sum\ of\ functional\ redundancy\ scores\ of\ all\ functional\ groups\ in\ the\ site}{Total\ Number\ of\ Functional\ Clusters\ in\ the\ site}$$

$$\text{FFR3} = \frac{\sum_{i=1}^{n} GFR3_i}{FFc} = \frac{GFR3_1 + GFR3_2 + GFR3_3 + \cdots GFR3_n}{FFc}$$

A firm will obtain a Functional Redundancy (FFR3) score of one (1) if it hosts all the functional divisions associated with the functional cluster. This score is agnostic to the number of functional units hosted by functional divisions. A score of one (1) implies that the firm possesses the maximum degree of functional redundancy that a firm can realistically obtain.

Operational Functional Response

In ecology, Response Diversity refers to the diversity of species within the same functional effect group (i.e. similar effect trait) but possess different capacities to respond to perturbations (i.e. different response traits) thereby protecting the ecosystem from degradation and collapse (Elmqvist et al. 2003, Mori et al. 2013). Response diversity is demonstrated by organisms that respond differently to a given disturbance (Desjardins et al. 2015) and tends to decline at higher stress levels which could constrain the remaining organisms to sustain ecosystem functioning (Elmqvist et al. 2003). Thus, it can be construed that response diversity is stress-specific and degree-dependent. Moreover, response diversity has a cross-scale component wherein the removal of species in a functional group will tend to reduce the response diversity across scales (Elmqvist et al. 2003). This implies that response diversity at one scale can either be enhanced or degraded by the degree of diversity in another scale (Leslie and McCabe 2013) which indicates the synergistic relationship between functional diversity and response diversity.

Structural Alignment

An ecosystem where entire functional groups become ecologically insignificant following a disturbance is typified as having low response diversity (Elmqvist et al. 2003). Similarly, if the majority of the account teams of a particular campaign of a BPO firm become inoperable due to an operational disruption, then such campaign may be characterized by low response diversity. Strictly, response diversity does not essentially refer to the variety of ways functional divisions can respond to a disturbance (i.e. not the number of continuity, recovery or response strategies), rather response diversity is attributable to the *variety of traits of the various functional divisions* that will allow it to tolerate the disturbance. Their susceptibility to failure depends on their *inherent response traits* (not capabilities) that would allow them to withstand adverse events. For instance, an account team may either utilize an on-premise infrastructure or a cloud-based solution to deliver its outsourced services.

The account team that utilizes a cloud-based solution may be more tolerant to a ransomware attack compared to one that is dependent on an on-premise system but is more vulnerable to an Internet outage. Thus, a campaign that hosts several account teams that operate a mix of on-premise and cloud-based systems will be assured of continual (although degraded) functioning even if it falls victim to a ransomware attack or an internet outage *without necessarily initiating its recovery procedure.* The campaign will continue to generate revenue amidst a disruption owing to the 'surviving' account teams. However, the entire campaign, may be totally immobilized if it suffers from an internal network outage or prolonged power outage since such threats warrant a different set of response traits. Owing to the Insurance Hypothesis, a campaign comprised of several service delivery teams with diverse set of response traits can continue functioning even when one (or few) teams become inoperable. If in ecological terms, response diversity is demonstrated by surviving species in the same functional group which maintained ecological functioning (Elmqvist et al. 2003) then Operational Functional Response Diversity is thus deemed to be metaphorically equivalent to the *survivability of the functional divisions of a functional cluster against a particular type of disruption*.

Re-representation

Operational Definition of Functional Response: The study proposes to define Operational Response Diversity as the *capacity of a functional cluster to remain operable after a disturbance given the propensity of its functional divisions to tolerate the effects of a particular type of disruption.* Correspondingly, it reflects a firm's latent potential to continue functioning through a diverse set of inherent response traits that will ensure the survival of several (if not all) production units during a disruption. For consistency with the nomenclature of the other functional trait diversity attributes, response diversity is alternatively labelled as *functional response*, that is derived from the term *functional response diversity* used in Craven et al. (2016).

Attribute Indices and Scores for Functional Response: The functional response diversity of the firm is represented by the *survival probability* of a functional cluster and the *average response diversity traits of all functional cluster operating within the site*. These metrics are respectively measured using the *Group Functional Response Diversity Score* (GFR4) of a functional cluster and the *Firm Response Diversity Score* (FFR4) of a site.

The *Group Functional Response Diversity Index* (GFR4) of a functional cluster is proposed to represent the proportion of surviving functional divisions of a functional cluster (SFd) relative to total number of functional divisions in the same functional cluster (FFd) that can continue to operate amidst an operational disruption. This score represents the *percent disruption-tolerance* of a functional cluster. The differing tolerances of the functional divisions across the various functional cluster will yield varying GFR4 scores which thereby reflect the diversity of responses against a particular form of operational disruption. As such, this metric represents cluster-level response diversity. This score is computed as:

$$GFR4_i = \frac{SFd_i}{FFd_i}$$

The *Firm Response Diversity Score* (FFR4) of the site is postulated to be the *average response diversity traits of all functional clusters operating within the site*. It is simply the aggregated cluster-specific response diversity traits (GFR4) normalized by the number of functional clusters operating in the site (FFc). This metric represents firm-level response diversity and expressed as:

$$FFR4 = \frac{Sum\ of\ response\ diversity\ scores\ of\ all\ the\ functional\ clusters\ in\ the\ site}{Total\ Number\ of\ Functional\ Clusters\ in\ the\ site}$$

$$\text{FFR4} = \frac{\sum_{i=1}^{n} GFR4_i}{FFc} = \frac{GFR4_1 + GFR4_2 + GFR4_3 + \cdots GFR4_n}{FFc}$$

A firm will obtain a Firm Response Diversity Score of one (1) if all the functional divisions in all the functional clusters it hosts are disruption-tolerant i.e. capable of being operable during a crisis. A score of one (1) implies that the firm possesses the maximum degree of disruption tolerance that a firm can realistically obtain. This metric represents firm-level response diversity.

Operational Adaptive Capacity

In a socio-ecological sense, resilience is often associated with adaptive capacity (Carpenter et al. 2001). However, Adaptive Capacity is different from resilience in a way that adaptive capacity is deemed as an ability whereas resilience is a state (Colombi and Smith 2012). Adaptive Capacity is related to the capacity of a system to recover its performance *without the need for any recover activities* (Salehi and Veitch (2020)

Structural Alignment

The adaptive capacity of an ecosystem relates to its latent ability to adapt its degree of resilience against perturbations (Angeler et al. 2019) or its capacity to maintain its stability and resilience (Gunderson et al. 1996). As seen among many BPO firms, their operational activities are sustained during a disruption according to defined recovery procedures. Campaigns and their account teams possess varying types of vulnerabilities (e.g. lack of a fail-over site, inability to work from home) and a range of tolerances to disruptions (e.g. affordability to remain inoperable ranges from 2 hours to 2 days) due to their inherently dissimilar characteristics and dependencies. Their respective vulnerabilities and tolerances essentially determine how many among their agents they can effectively mobilize to continue functioning during an operational disruption. If adaptive capacity is construed as the number of functional resources that can be potentially mobilized to allow the organization to function in an alternate state of operations during a disruption, then under a type (e.g. natural, technological) and magnitude (i.e. low, moderate, extreme) of a disturbance, all, some, or even none of the account teams will be operable. As such, campaigns are expected to demonstrate varying levels of adaptive capacities across a range of disruptive events. If in a socio-ecological context, adaptive capacity relates to a system's ability to adapt, or its the ability to mobilize scarce resources to anticipate or respond to a disturbance (Engle 2011) then Operational Adaptive Capacity is thus deemed to be metaphorically equivalent to the *capacity of the organization to operate in an alternate operational state using its remaining operable resources* during an operational disruption.

5.2.5b *Re-representation*

Operational Definition of Operational Adaptive Capacity: The study proposes to define Operational Adaptive Capacity as the maximum possible capacity of operable resources that can be potentially deployed to restore the system back to its previous or an alternate stable state after a disruption. Correspondingly, it reflects a firm's latent potential to sustain the operations and enable the recovery efforts of an organization through the availability of operable functional resources.

Attribute Indices and Scores for Operational Adaptive Capacity: The operational adaptive capacity of a firm is represented by the *percentage of disruption operable functional units in a functional cluster* and the *percentage adaptive capacity of the site*. These metrics are respectively measured using the *Group Adaptive Capacity Index* (GAC) of a functional cluster and the *Firm Adaptive Capacity Score* (FACS) of a site.

The *Group Adaptive Capacity Score* (GAC) of a functional cluster is proposed to represent the proportion of functional units from surviving functional units of a functional cluster (SFu) to the total number of functional units in the same functional cluster (CFu). This score represents the *percentage of disruption operable functional units* per functional cluster. This metric represents cluster-level adaptive capacity and calculated as:

$$GAC_i = \frac{\sum_{j=1}^{m} SFu_{ji}}{CFu_i} = \frac{SFu_{1i} + SFu_{2i} + SFu_{3i} + \cdots SFu_{mi}}{CFu_i}$$

The aggregated number of functional units from all disruption-tolerant (i.e. surviving) functional divisions across all the functional cluster (SFu) in a site is the overall Firm Adaptive Capacity (FAC). The FAC represents the maximum number of operable resources that a firm can dispense to continue operating during a disruptive event. The *Firm Adaptive Capacity Score* (FACS) of a site is proposed to represent the ratio between the site adaptive capacity (FAC) to the total population of functional units of the entire firm (FFu). Equivalently, it is simply the *percentage adaptive capacity of the site* and calculated as:

$$\text{FACS} = \frac{Total\ Adaptive\ Capacity\ of\ the\ site}{Total\ Number\ of\ Functional\ Units\ in\ the\ site}$$

$$\text{FACS} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} TFu_{ji}}{FFu}$$

A firm will obtain an Operational Adaptive Capacity Score of one (1) if all its functional units across all functional divisions and functional clusters can be mobilized to continue operations during a disruption. This metric represents firm-level adaptive capacity. Depending on the type and magnitude of the disaster, it is assumed that not all functional units will be operable. Thus, the resulting adaptive capacity estimate is *hypothetical and theoretical at best* and should be simply construed as the maximum number of *potentially operable* functional units. Considering the *risk of losing potentially operable functional units* at the onset of the disaster will provide a more realistic estimate of adaptive capacity during a disaster. Such risk of loss of resources may be represented by a Survival Probability estimate. This resulting attribute can be construed as a risk-adjusted measure of adaptive capacity which may be used as a measure of the *Potential Operational Resilience* of the firm.

5.2 Results: Simulation and Analysis

This section provides a straightforward demonstration of the application of the proposed Attribute Indices and Scores. The objective is to exemplify the simplicity and practicality of quantifying the operational analogs of functional richness, functional evenness, functional redundancy, response diversity and adaptive capacity through the proposed Attribute Indices and Scores.

Functional Richness

Context of the Simulation: Consider a BPO company that provides a total of 9 outsourcing services across 5 sites. Each outsourcing service equates to a Campaign that caters to a range of clients. Every client is supported by dedicated service delivery teams (i.e. account teams) composed of processors or associates (i.e. account agents). The core function of *Campaigns* is to generate revenue for the BPO company. Campaigns manage their own profit and loss (P&L) and comprise the Service Portfolio of the BPO company. Each campaign possesses a set of functional traits that allows its account teams to generate revenue (effect trait) and continue generating revenue amidst an operational disruption (response trait). Functional *effect traits* are attributes of account teams and agents that underlie their impact on system functioning or processes, while functional *response traits* are attributes that influence their persistence to function amidst a perturbation (Oliver et al. 2015). As an example, the account teams and agents supporting the Payroll Administration Campaign essentially possess the knowledge of payroll related processes and regulations (effect trait 1), the skill to operate a payroll process software (effect trait 2) and capacity to deliver payroll processing services either on-site or remotely (response trait). In this respect, a campaign is equivalent to a functional cluster or functional cluster. Table 2a provides the details needed to estimate the functional richness of each of the sites. The *Campaigns per Site* is simply the sum of all the campaigns in a particular site (FFc) while the *Total Company Campaigns* is the total number campaigns managed by the BPO organization (OFc). The *Firm Functional Richness* (FFR1) is simply the *percentage of campaigns* operating on the site relative to the entire service portfolio of the BPO company.

Table 2. Example estimation for Functional Richness

Campaigns	Site B	Site B	Site C	Site D	Site E
1. Executive Recruitment		x		x	
2. Payroll Administration			x	x	x
3. Human Capital Analytics			x	x	
4. IT Technical Support	x	x		x	
5. Security Operations	x			x	
6. Software Testing	x	x			
7. Accounts Payable	x	x	x	x	x
8. Accounts Receivable	x		x	x	
9. Financial Reporting	x		x	x	
Campaigns per Site (FFc)	6	4	5	8	2
Total Company Campaigns (OFc)	9				
Firm Functional Richness (FFR1)	0.67	0.44	0.56	0.89	0.22

Results and Interpretation: Computing for the FFR1 score of each of the BPO sites will indicate that Site D is the most functionally diverse in terms of functional richness among the 5 sites considering that it hosts the most number of campaigns (i.e. functional clusters). An FFR1 score of 0.89 indicates that Site D hosts 89% of the campaigns of the entire company. The high functional richness of Site D implies that it has the highest propensity to generate the greatest number of operable resources during a disruptive event (i.e. high adaptive capacity) assuming that it also possess high functional evenness, functional redundancy and response diversity.

Functional Evenness

Context of the Simulation: Consider the same BPO company wherein one of its facilities, Site B supports 4 service verticals (FFc) using a total of 1600 agents. Table 2b presents a summary of the information required to estimate the functional evenness of Site B. The *Campaigns* represent the firm's revenue-generating groups or functional clusters (FFc). The *Agents per Campaign per Site* is the total number of agents supporting the operations of a particular service vertical. It corresponds to the number of functional units per functional cluster (AFu). The *Total Agents on the Site* is simply the agent population of site which corresponds to the total number of functional units of the firm (FFu). The *Average Agents per Campaign* is the average number of agents across all service verticals in the site. It corresponds to the mean functional units (MFu) relative to the number of functional clusters (i.e. service verticals). The *Group Functional Evenness Index* (GFR2) represents the functional evenness ratio of a particular campaign which indicates their relative deviation of agent abundance from the ideal (i.e. equally proportionate) size. The *Firm Functional Evenness Score* (FFR2) on the other hand, represents the average functional evenness of the all campaigns in the site.

Table 3. Example estimation for Functional Evenness

Site B				
Campaigns (FFc)	Executive Recruitment	Technical Support	Software Testing	Accounts Payable
Agents per Campaign per Site (AFu)	200	700	400	300
Total Agents in the Site (FFu)	1600			
Average Agents per Service Vertical (MFu)	1600 / 4 = 400			
Group Functional Evenness Index (GFR2)	0.5	1.75	1.0	0.75

Firm Functional Evenness Score (FFR2)	Geomean (0.5 x 1.75 x 1.0 x 0.75) = 0.900

Results and Interpretation: Computing for the GFR2 scores of each of the campaigns will indicate that the Software Testing campaign, having a score of 1.00 is ideally sized assuming that an equitable distribution of agents among the 4 campaigns ascertains the site's optimal resilience against disruptions. Conversely, the Technical Support campaign, having a score of 1.75 implies that it has 75% more agents than the target agent population, while the Executive Recruitment campaign hosts 50% fewer agents compared to the target agent population. An FFR2 score of 0.9 implies that the site possesses a high evenness in its agent population across its campaigns. While the FFR2 computationally represents the average functional evenness ratio, its formulation provides a precise measure of agent population evenness. The use of arithmetic averaging will yield an evenness score of 1.0 which will imply perfect evenness; hence the geometric mean is used to account for the slightest degree of unevenness in agent distribution.

Functional Redundancy

Context of the Simulation: Consider the same BPO company wherein one of its facilities, Site B hosts a total of 20 account teams that support 4 campaigns. Table 2c presents a summary of the information required to estimate the functional redundancy of Site B. The Campaigns represent the firm's revenue-generating groups or functional clusters (FFc). The Accounts per Campaign is the number of account teams supporting a particular service vertical which corresponds to the number of functional divisions of the firm (FFd). The Total Accounts per Campaign is simply the total number of account teams supporting a particular campaign across all the 5 sites where it is present. It corresponds to the total number of functional divisions of the entire organization (OFu). The Group Functional Redundancy Index (GFR3) represents the percent functional redundancy of a campaign. The Firm Functional Redundancy Score (FFR3) is the average functional redundancy traits of all campaigns operating within the site.

Table 4. Example estimation for Functional Redundancy

Site B				
Campaigns (FFc)	Executive Recruitment	IT Technical Support	Software Testing	Accounts Payable
Accounts per Campaign (FFd)	7	3	4	6
Total Accounts per Campaign (OFd)	10	6	6	8
Group Functional Redundancy Score (GFR3)	0.70	0.50	0.67	0.75
Firm Functional Redundancy Index (FFR3)	(0.70 + 0.50 + 0.67 + 0.75) / 4 = 0.655			

Results and Interpretation: Comparing the GFR3 scores of 4 campaigns may create the impression that the Accounts Payable campaign is the most functionally redundant and hence may prove to be the most stable and resilient; but it may not be the case. A GFR3 of 0.75 simply implies that the Accounts Payable campaign in Site B hosts 75% of all the possible Accounts Payable service delivery teams of the BPO company. Technically, while the Executive Recruitment campaign may have a slightly lower GRF3 score, it hosts the largest number of account teams. It should be noted that GFR3 is simply a proportion score. Rather than comparing the GFR3 scores among the campaigns in the same site, it may be more meaningful to compare the GFR3 scores of a specific campaign with those in other sites to determine which site a particular campaign has the highest buffering potential. As a measure of functional redundancy, the GFR3 depicts how well a functional cluster can maximize its buffering capacity based on the number of functionally replicable functional divisions that it can possibly accommodate. On the other hand, the FFR3 score simply provides a normalized (averaged) measure of the functional redundancy of the entire site based on the buffering potential of all the functional clusters measured through their respective GFR3 scores. The FFR3 value of 0.655 implies that on average, the campaigns in Site B are 65.5% functionally redundant.

Response Diversity

Context of the Simulation: Consider the same BPO company wherein one of its facilities, Site B hosts a total of 20 account teams that support 4 campaigns. Table 2d presents a summary of the information required to estimate the response diversity of Site B. The *Campaigns* represent the firm's revenue-generating campaigns or functional clusters (FFc). The *Accounts per Campaign* is the number of account teams supporting a particular service vertical which corresponds to the number of functional divisions of the firm (FFd). The *Disruption Tolerant Accounts* is the number of account teams that are expected to continue functioning during a disaster of a particular type and magnitude. It corresponds to the number of surviving functional divisions (SFd) in each functional cluster that were identified during business continuity planning. The identified surviving account teams operate a virtual desktop environment (response trait 1) where agents are permitted by clients to work-from-home when required (response trait 2) that will allow the account teams to adapt their service delivery operations during a site-wide ransomware attack. The *Group Functional Response Diversity Index* (GFR4) represents the survival probability of a particular campaign, while the *Firm Functional Response Score* (FFR4) is the average survival probability of all campaigns operating on the site.

Table 5. Example estimation for Functional Response (Response Diversity)

Site B (*Disruption Scenario:* Site-wide Ransomware Attack)				
Campaigns (FFc)	Executive Recruitment	Technical Support	Software Testing	Accounts Payable
Accounts per Campaigns (FFc)	7	3	4	6
Disruption Tolerant Accounts (SFd)	6	3	2	1
Group Response Diversity Index (GFR4)	0.86	1.00	0.50	0.17
Firm Functional Response Score (FFR4)	(0.86 + 1.00 + 0.50 + 0.17) / 4 = 0.632			

Results and Interpretation: Computing for the GFR4 scores of each of the campaigns indicates that the 100% of the service delivery teams of the Technical Support campaign in Site B can be expected to continue operating during a ransomware attack while the Software Testing campaign is expected to operate only at 50% of its normal capacity. It should be noted that this score presents the percentage of account teams, and not that of agents. The GFR4 as a measure of response diversity depicts how well a functional cluster can maximize its buffering capacity based on the anticipated number of its surviving functional divisions considering the response traits they possess that will allow them to continue operating during an operational disruption. On the other hand, the FFR4 score of 0.632 simply implies that on average, the percentage of surviving account teams across all 4 campaigns in the entire site during a ransomware attack is only 63.2%. The FFR4 score simply provides a normalized (averaged) measure of the response diversity of the entire site based on the survival probability of all the functional clusters measured using the GFR4 index. The entire analysis is based on a Ransomware Attack as the disaster scenario. The GFR4 and FFR4 scores are expected to vary when a different disaster scenario is considered (e.g. massive power outage).

Adaptive Capacity

Context of the Simulation: Consider the same BPO company wherein one of its facilities, Site B hosts a total of 1600 account agents across 4 campaigns. Table 2c presents a summary of the information required to estimate the adaptive capacity of Site B. The *Disruption Tolerant Accounts* is the number of account teams that are expected to continue functioning during a disaster of a particular type and magnitude. It corresponds to the number of surviving functional divisions (SFd) in each functional cluster. The *Total Agents from Disruption Tolerant Accounts* (TFu) is the number of account agents in every account team that can potentially render work during an operational disruption. It does not consider the potential losses in agent population due to unforeseen reasons or unfavorable circumstances that transpire at the onset (or during) of the disruption. The *Agents per Campaign per Site* is the total number of agents supporting the operations of a particular campaign in the site. It corresponds to the number of functional units per functional cluster (AFu). The *Total Agents on the Site* is simply the site agent population which corresponds to the total number of functional units of the firm (FFu). The *Group Adaptive Capacity Index* (GAC) represents the proportion of account agents from disruption-tolerant account teams that can render work for a given campaign. The *Total Adaptive Capacity of the Site* (FAC) is simply the total number of account agents that can potentially remain operable during a particular type of disaster. The number of account agents is derived purely from disruption-tolerant account teams. The *Firm Adaptive Capacity Score* (FACS) is simply the percentage adaptive capacity of the site. It is simply the expected proportion of account agents across all campaigns that can remain operable during a disaster.

Table 6. Example estimation for Adaptive Capacity

Site B				
Campaigns	Executive Recruitment	Technical Support	Software Testing	Accounts Payable
Disruption Tolerant Accounts (SFd)	6	3	2	1
Total Agents from Disruption Tolerant Accounts (TFu)	120	700	380	200
Agents per Campaign per Site (AFu)	200	700	400	300
Group Adaptive Capacity Index (GAC)	0.60	1.00	0.95	0.83
Total Adaptive Capacity of the Site	(120 + 700 + 580 + 200) = 1400			
Total Agents in the Site (FFu)	1600			
Firm Adaptive Capacity Score (FACS)	1400 / 1600 = 0.875			

Results and Interpretation: Computing for the GAC scores of each of the campaigns will indicate that the Technical Support campaign will contribute the greatest number of account agents that can be used to hedge the site from the revenue losses brought about by a ransomware attack. This condition is expected since the campaign possesses a maximum response capacity index (GFR4 = 1.00) which means that all its account teams have the response traits to withstand the effects of a ransomware attack. Similarly, the Software Testing campaign with a GAC score of 0.95 can be expected to provide a large number of operable account agents to sustain the revenue-generation efforts of the site even though only 50% of its account teams (GFR4 = 0.50) can potentially operate during a ransomware attack. It can be deduced from its GAC score and its GFR4 score that the remaining 50% of its account teams possess a very small number of account agents. The Executive Recruitment campaign with a GAC score of 0.60 implies that only 60% of its account agents can be expected to remain operable during a site-wide ransomware attack. On the other hand, a FACS of 0.875 simply indicates that about 87.5% of the site's operating capacity can be sustained during a site-wide ransomware attack. Depending on the anticipated duration of the disaster, the remaining 12.5% can be recovered by employing the campaigns' respective business continuity plan (BCP) and disaster recovery plan (DRP), if warranted.

5.4 A Biomimetic Framework for Evaluating Functional Trait Diversity and Adaptive Capacity

As the third and final stage in the Metaphorical Process described in Parisot and Isckia (2013), Figure 01 below presents the proposed Biomimetic Framework for Evaluating the Functional Trait Diversity and Adaptive Capacity of Organization as the New Explanatory Framework.

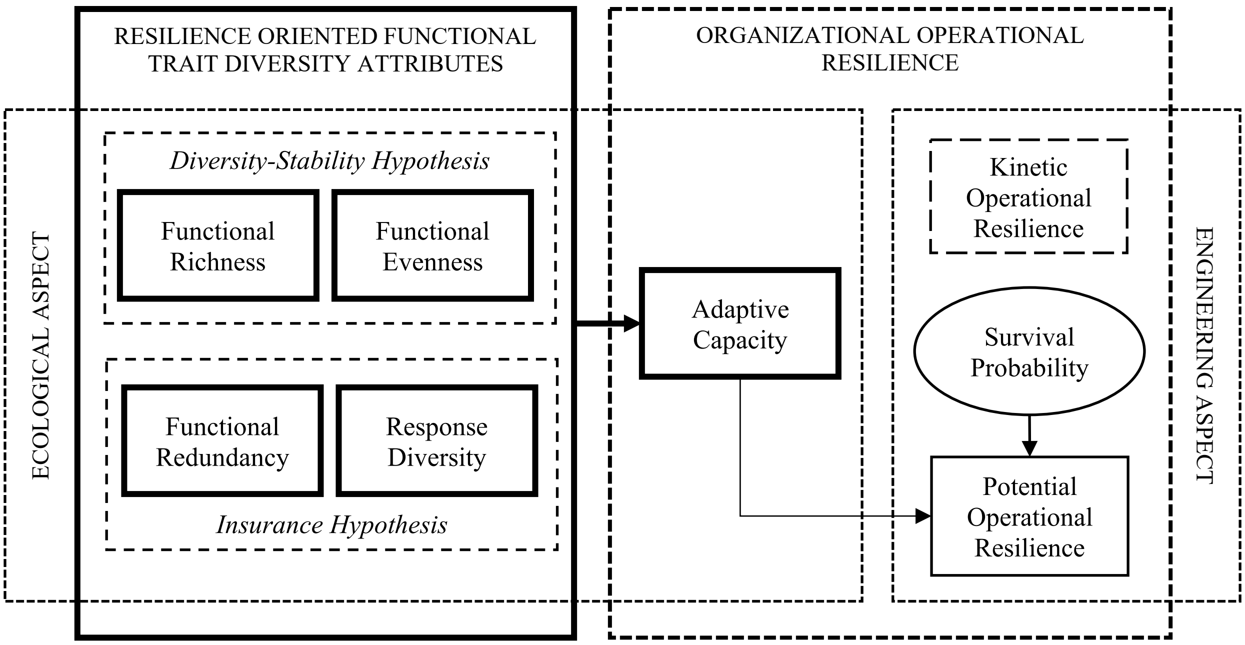

Figure 01. Biomimetic Framework for Evaluating Functional Trait Diversity and Adaptive Capacity of Organization

The proposed biomimetic framework essentially implies that adaptive capacity of a firm for withstanding operational disruption is contingent on the functional trait diversity of the firm (i.e. functional richness, functional evenness, functional redundancy and response diversity) and that a deliberate adjustment in the firm's functional diversity thru the optimal (re)allocation of functional resources (e.g. abundance of employees across divisions and offices, number of services rendered by the firm, and number of service delivery teams operating in a site) is supposed to improve the firm's adaptive capacity and potential operational resilience. Conceptually, a *diversity-stability composite indicator* can be formed from the functional richness and functional evenness indices, while an *insurance composite indicator* can be created by combining the functional redundancy and functional response indices.

The model also implies that much like energy, *organizational operational resilience* is composed of a kinetic and potential aspect. On the one hand, the *kinetic operational resilience* is operationalized through business continuity and recovery efforts. On the other hand, the *potential operational resilience* aspect is simply a *risk-adjusted adaptive capacity* that is intended to supplement the kinetic operational resilience aspect. The aforementioned concept is not discussed in this paper.

5.3 Proposed Improvements

The academic value of the research may be extended by exploring the statistical association between the functional trait diversity attributes and operational resilience if adequate empirical data can be collected. Moreover, the study will yield a more realistic representation of potential operational resilience if survival probability can be incorporated with the proposed formulation for adaptive capacity, as previously suggested. At present, the utility of the proposed evaluation framework remains purely theoretical until its validity is sufficiently tested. While the use of semi-hypothetical data may be suitable for theory development, the application of empirical data in model validation should provide more academically acceptable results and conclusions.

5.5 Validation

The biomimetic evaluation framework presented in this paper is a theoretical construct that represents a conceptual framework that is part of an ongoing academic investigation on potential operational resilience that will be subjected to subsequent validation. While the soundness of the assumptions used in formulating the Operational Definitions and Attribute Indicators have been verified through interviews with several operations managers from select BPO firms, confidence in the relevance and applicability of the proposed resilience evaluation framework can be enhanced by employing *a robust validation approach* which the present study aims to pursue.

To wit, the proposed framework shall apply the Case Approach to demonstrate the application of the proposed model as similarly employed by numerous proponents of resilience evaluation frameworks in the recent years (e.g. Jiang et al. 2022; Zhou Wenmei et al. 2022; León-Mateos et al. 2021; Córdoba et al. 2020; AminShokravi et al. 2020; Terblanche et al. 2022; Lichte et al. 2022; Tariq et al. 2021; Ramzy et al. 2022). Three BPO companies of varying sizes will form part of the case study to assess the sensitivity of the proposed metrics on firm size. Following the validation approach suggested by Bockstaller and Girardin (2003), the study is poised to undergo (a) Design or Construct Validation using a Global Expert Validation, (b) Output Validation through Structural Equation Modelling (SEM) using simulated data and (c) End-Use Validation by way of BPO industry conference presentations and structured interviews with BPO executive

6. Conclusion

The study presents a biomimetic framework for evaluating the functional trait diversity and adaptive capacity of an organization owing to the ecological theories and concepts from which it was built upon. It is the maiden investigation that transmuted the ecological concepts of functional diversity, functional redundancy, response diversity and adaptive capacity into an organizational context. More specifically, the study offers a novel method for conceptually qualifying and hypothetically quantifying the functional richness, functional evenness, functional redundancy, response diversity and adaptive capacity of organizations. The operational definitions and attribute indicators proposed in this study will be subsequently used to simulate the effects of deliberately altering functional trait diversity on adaptive capacity. Results of the simulations is hoped to provide organizations useful insights on ideating *functional diversity based biomimetic strategies* that would augment their business continuity and disaster recovery capabilities thereby further enhancing their inherent tolerance against operational disruptions.

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