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REVIEW

Adaptation frameworks used by US decision-makers: a literature review

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Abstract Many government officials and organizations have begun to consider climate resilience efforts to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events. Unfortunately, decision-makers have not yet developed a standardized approach. Since choosing a framework often requires significant time and resources, obtaining a better understanding of how often, and in what context, frameworks are currently used will likely save time for future decision-makers. In this literature review, we seek to determine whether certain commonly referenced frameworks ("triple value," "triple bottom line," "pressure state response (PSR)," "vulnerability," and "risk") are implemented more frequently than others, and if so, assess which attributes contribute to framework implementation. We obtained 212 relevant documents from one climate adaptation database, the Georgetown Climate Center's Adaptation Clearinghouse. We then implemented a simplified text classifier and employed statistical analysis to identify the use and frequency of key terms linked to specific frameworks. We found that four of the five frameworks ("triple bottom line," "risk," "vulnerability," and "PSR") appear in at least 7 % of the documents, suggesting that they are commonly used by decision-makers. On the other hand, the "triple value" framework does not appear to be frequently implemented by practitioners. Date of publication, discussion of social/cultural/financial sectors, discussion of the environmental sector, discussion of the infrastructure sector, discussion of human health/safety impacts, and discussion of ecosystem/biological impacts are all statistically significant factors in determining the implementation of the above frameworks. While current practices do not necessarily translate into future practices, the understanding of current practices as described in this study may help inform this future resilience framework.

Keywords Climate change · Adaptation · Framework · Resilience · Triple bottom line

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1 Introduction

Global record-breaking events in the past decade include extreme heat, drought, precipitation, storm activity, and sea ice extent (Coumou and Rahmstorf 2012; NOAA 2015; Blunden and Arndt 2014). Many of these events are likely linked to climate change, and scientists anticipate that the intensity, frequency, duration, and predictability of weather patterns and extreme weather events will continue to vary as climate change progresses (Meehl et al. 2007; Field et al. 2012).

In response to the increasing threat and uncertainty posed by climate change, many government officials and organizations have begun to consider climate resilience efforts to prepare and plan for, absorb, recover from, or more

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successfully adapt to adverse events. Efforts span a variety of risk reduction strategies such as reducing greenhouse gas emissions, adapting to climate impacts, and improving emergency response (e.g., Hoss et al. 2014; Bradford et al. 2015; Canfield et al. 2015) and allow many decision-makers to bridge the gaps between disaster risk reduction, hazard mitigation, and climate adaptation (Klima and Jerolleman 2014a, b). The increasing shift in emphasis toward climate resilience and adaptation is further illustrated by recent policies and initiatives implemented by the federal government: Executive Order #13653 (Office of the President of the United States 2013), the Department of Transportation's Climate Adaptation Plan (U.S. DOT 2014), FEMA's IdeaScale and Climate Change Adaptation Policy Statement (U.S. Federal Emergency Management Agency 2012, 2015), and the Environmental Protection Agency's Climate Ready Estuaries and Climate Ready Water Utilities Toolkits (U.S. EPA 2015a, b). Furthermore, decision-makers have begun to network between cities: Over 450 local governments have joined the International Council for Local Government Initiatives (ICLEI—Local Governments for Sustainability) (ICLEI 2015), over 1000 mayors have committed to the US Conference of Mayors Climate Protection Agreement (U.S. Conference of Mayors 2008), 14 cities in North America have joined the C40 network of global cities striving to reduce GHG emissions (C40 Cities 2015), and over 180 mayors and county leaders have signed the "Resilient Communities for America Agreement" (Resilient Communities for America 2015).

Despite these networking efforts, decision-makers continue to use a variety of different frameworks to measure climate adaptation. We conducted an extensive literature review and identified five common frameworks (and their aliases) as listed in Table 1. Each framework provides a different way to think about the goals, indicators, and metrics needed to solve the problem. Specifically, the triple bottom line framework seeks to evaluate social, environmental, and economic consequences of a plan (Daly 1973). This framework has been applied extensively in many techno-economic assessments, but may be difficult to use when qualitative metrics are most commonly used. It can also be difficult to quantify and compare the economic, social, and environmental consequences in an equal and consistent manner—usually the social component will be added as a secondary thought to the economic and/or environmental consequences (Scerri and James 2010). Additionally, the differences in the time dimension are often not fully incorporated. For example, the economic consequences of a plan may be evaluated on a quarterly or annual scale, while the environmental and social consequences may take years or decades to fully develop (Robins 2006). Finally, by keeping environmental, economic, and social consequences as three separate pillars, the triple bottom line framework can sometimes struggle to recognize and capture the synergies between these three components (Fiksel et al. 2014).

The triple value framework differs from triple bottom line because it is a systems-level framework applied to the entire process, including outcomes, resource flow, system condition, and value creation (US EPA 2012). Used in manufacturing, industry, and other sectors where life cycle assessment can provide insight (e.g., Onat et al. 2014), this framework is often highly specific to a given task and therefore not always directly comparable to other methods. Under the typical "stock and flow" concept of the framework, the natural environment ("natural capital") is viewed primarily as a provider of resources and amenities to economic capital and human/social capital (Fiksel et al. 2014). However, in the context of climate change adaptation and resilience, this "stock and flow" concept may not be as applicable, because the natural environment becomes more of a potentially disruptive force to the economy and society.

Similarly, the pressure, state, response framework (PSR) is a systems-level framework with particular focus on impacts in the causal chain (OECD 2003). This framework helps to understand how a system might rebound after an impact, but not necessarily how the system could transform to a different state (e.g., through a change in adaptive capacity). A version of the PSR framework developed by the European Environmental Agency (EEA) called Driving Forces/Pressures/States/Impacts/Responses (DPSIR) (Agu 2007), has also been criticized for its complexity and occasional lack of consistency (Fiksel et al. 2014).

The vulnerability framework focuses just on hazards and threats (e.g., flooding, drought) that are of primary concern to a particular location or population subset. This framework is excellent at understanding vulnerability, but equity issues can arise, and this framework does not always encompass a hazard or exposure assessment that would be necessary to understand where the return on investments could be the highest. Additionally, risk-hazard (RH) models of vulnerability do not always capture the manner in which the impacts of the hazard may be enhanced or dampened by the system in question, nor do they fully consider the way in which societal structures and institutions can influence different states of exposure and different levels of consequence (Turner et al. 2003; Kasperson et al. 1988; Mitchell et al. 1989; Palm 1990). Similarly, pressure and release (PAR) models of vulnerability focus do not adequately assess vulnerability of biological systems and fail to fully capture interactions and feedbacks within a given system of interest (Turner et al. 2003; Kasperson et al. 2003; Kates et al. 1985).

Table 1 Description and common aliases of the five adaptation frameworks analyzed

Name	Description	Aliases and references
Triple bottom line framework	Integrated evaluation of social, environmental, and economic consequences of a plan of action	Three Pillars Model (EPA 2012); Holistic-Systems (National Research Council 2011); Industrial/Societal/Ecological Systems (Fiksel 2009); Built Environment/Natural Environment/People (City of Chicago 2008); Daly's Triangle (Daly 1973); The Three E's (Environment, Equity, and Economy) (Daly 1973)
Pressure, state, response framework (PSR)	Impact-related framework that identifies clear steps is the causal chain (European Commission 1999)	Driver/Pressure/State/Impact/Response (DPSIR) (European Commission 1999); Driver/Pressure/State/Exposure/Effects/Action (DPSEEA) (Kjellstrom and Corvalan 1995); Multiple Exposures Multiple Effects (MEME) (World Health Organization 2015)
Triple value framework (3V)	System-based framework that can be applied to adverse outcomes, resource flow, system condition, and value creation (EPA 2012). More specifically, this framework "helps to capture the dynamic interactions among industrial, societal, and ecological systems (Fiksel 2009)"	Analyze/Develop/Assess/Prioritize/Act (ADAPT) (Amado et al. 2012)
Vulnerability framework	Used to identify hazards and threats (e.g., flooding, drought) that of primary concern to a particular location or population subset	Threat Hazard Identification (FEMA 2013); Multi-Hazard Mitigation Planning (FEMA 2015a, b); Vulnerability Framework; Resistant/Absorptive/Restorative (Ouyang et al. 2012); Resilience Framework (Robustness/Redundancy/Resourcefulness/Rapidity) (Bruneau et al. 2003)
Risk framework	Assesses the risk of a particular area or population subset to a particular threat. A complete risk assessment must include an assessment of the type and severity of the hazard in question, an assessment of exposure to the hazard, and an assessment of how vulnerable people/infrastructure are to the hazard (Glickman and Gough 1990; National Resources Council 2011)	Resilience of agents, resilience of institutions, resilience of systems (Tyler and Moench 2012); level of embedding/adaptive capacity/effectiveness of actions/degree of flexibility preserved (DEFRA 2012); effectiveness now/sustainability of project/effectiveness after project ends (Srinivasan 2009)

Finally, the risk framework looks at a complete risk assessment, including an assessment of the type and severity of the hazard in question, an assessment of exposure to the hazard, and an assessment of how vulnerable people/infrastructure are to the hazard. While comprehensive in understanding risks, this framework also may not allow for changes in the system (e.g., via a change in adaptive capacity). Additionally, risk assessment and risk management inherently involve uncertainty and probability—issues with which decision-makers may not have much experience or comfort.

All of these frameworks are plausible ways to consider how to measure resilience. However, not all of these approaches are directly comparable, and thus, it can be difficult to identify best practices that decision-makers can replicate or scale to fit their needs. As new decision-makers continue to enter the arena, they may require significant time and resources to choose between frameworks. Thus, obtaining a better understanding of how often, and in what context, these frameworks are currently used may save time for these future decision-makers. In this literature review, we answer two questions. First, how often are proposed frameworks actually used? Second, how are the demographics (date, length, area, type of document, topic, etc.) correlated with the frequency of framework usage? We anticipate this information will help future decision-makers save valuable time and resources when confronted with the resilience decision.

2 Methods

This section outlines the methods we employed to assess the use of the adaptation frameworks mentioned above. Broadly speaking, we first collected relevant documents from the preeminent database in this area: Georgetown Climate Center's Adaptation Clearinghouse (Georgetown Climate Center 2014). Next, we implemented a text classifier to identify the use and frequency of key terms within the document set.[1] Then, we validated the reliability of our text classifier against our original document set. Finally, we

[1] Note, a text classifier and a topic model are different. A text classifier is simply a sophisticated search engine that looks for user-supplied words or phrases. A topic model is a sophisticated frequency count algorithm that searches for how often certain terms occur and how they appear in relation to each other. We briefly examined a topic model for this work, but found our search terms were occurring too infrequently to make use of this, and therefore, we relied on a text classifier.

performed statistical analysis to assess how often the given frameworks are actually used and determine how certain factors are correlated with the frequency of framework usage.

2.1 Data collection and description

Databases of climate adaptation documents, tools, and Web sites include, but are not limited to, the Climate Adaptation Knowledge Exchange (CAKE), Notre Dame Global Adaptation Index (NDGain), Climate Voices, the American Society of Adaptation Professionals (ASAP), the World Council on City Data (WCCD), and Georgetown Climate Center (GCC)'s Adaptation Clearinghouse (Climate Adaptation Knowledge Exchange 2015; ND-GAIN 2015; Climate Voices Science Speakers Network 2014; ASAP 2015; World Council on City Data 2015; Georgetown Climate Center 2014). For this study, we used the Adaptation Clearinghouse. The selection of resources and creation of resource entries are done by GCC staff and contractors. The documents within the Adaptation Clearinghouse are deliberately selected based on what the staff view as most valuable and useful to their audience.

When uploading a document, staff members self-identify various characteristics of the document: date, location, sector type, impact type, etc. We spot verified this self-reporting by reviewing over 15 % (36 of 212) of the documents. Of these spot-verified documents, 29 of the 36 had complete accuracy in the self-identification of dates and locations. Of the 7 documents that were not self-identified completely accurately, 2 had incorrect dates, and 5 had missing locations (i.e., we found locations discussed in the document that were not reported by the GCC). With the exception of two documents, only one state was found to be missing from the self-identified classifications produced by the GCC. Overall, the inaccuracies in the GCC self-identification were found to be relatively infrequent and minor. Thus, we found the GCC to provide a fairly reliable baseline for developing our simple text classification tool.

Overall, the documents within the Clearinghouse can be classified into 30 "resource types," 21 "sectors," and 38 "impacts" (Georgetown Climate Center 2014). The documents are also associated with any of 68 different locations, including US States, Territories, and broader regions (e.g., Great Lakes, Gulf Coast). According to GCC affiliates, the resource types, sectors, and impacts identified among the documents are currently being revised and expected to be updated in Fall 2015.

We analyzed 212 documents from within one of the following resource types, as defined by the Clearinghouse: Adaptation Plan/Strategy, Assessment Guidance, Climate Science, Education/Training, and Monitoring. These documents cover a wide range of stakeholders, time frames, geographic locations, and impacts. The authors of the documents we analyzed include local and state governments, NGOs, and federal agencies (i.e., the US Environmental Protection Agency, the US Department of the Interior, the US Geological Survey). The geographic scope of the documents includes all 50 states, American Samoa, Guam, Puerto Rico, and the US Virgin Islands. The publication dates of the documents range from 1999 to 2014. As classified by the Clearinghouse, the documents cover 21 sectors (e.g., air, energy, transportation) and 38 impacts (e.g., air temperature, drought, flooding, precipitation). The page length for these documents ranged between 1 and 1569 pages, and the word count ranged between 495 and 774,331 words. Documents were all stored in portable document format (.pdf). More detailed information about the documents and their breakdown by sector, impact, geography, and publication date are included in section SI.1 of the Supplementary Information.

2.2 Text classification

We used text classification to understand our documents. According to Fairclough in *Analysing Discourse: Textual Analysis for Social Research*, a detailed text analysis allows one to "identify keywords in a corpus of texts, and to investigate distinctive patterns of co-occurrence or collocation between keywords and other words (Fairclough 2003)." We began the study doing a detailed text analysis, but were finding that documents varied greatly. Thus we chose to perform a simplified text analysis using a computer.

We started by identifying five sets of commonly used frameworks. The five general frameworks that we searched for are those that were discussed in the introduction: "triple bottom line," "pressure state response," "triple value," "vulnerability framework," and "risk framework." These frameworks were identified in our given set of documents by searching the text for key words and phrases. Following standard data mining and statistical learning methods (James et al. 2013; Hastie et al. 2009), we created a text classifier to identify framework usage in our dataset. This search approach allowed us to collect key information from the documents, such as the documents that applied a certain framework or the number of times a certain location was mentioned in a given document.

The database of 212 files from the Georgetown Climate Center, described above, is sufficiently large to test a set of five subjects. Since .pdf documents are stored as some combination of regular computer-readable text and scanned images, we first converted all documents to regular computer-readable text. For each page of each document, we dump the raw text and also run optical character recognition (OCR). Taking the text directly is more accurate than

OCR, so we favor it when possible. Only when OCR generates 10 or more times as much text as the raw text dump do we favor the OCR results. Setting such a high threshold eliminates noise while easily identifying a scanned page stored as an image rather than as text. We empirically checked several documents to verify this technique.

Finally we identified the frequency of the different frameworks, as well as their correlation with certain demographic variables. Since we lacked a compelling reason to weight some documents higher than others, all documents were weighted equally. For this frequency identification, we used a MySQL database to query the documents for the five frameworks listed in Table 1.[2] For each framework, we searched for the occurrence of the phrases in Column 1 or the aliases in Column 3. Since authors might pluralize nouns or conjugate verbs, we searched for the word stems for each word of a phrase. We also allowed some terms to appear in any order on a page, thus allowing more flexibility in matching a series of terms without imposing the order in which they are used (e.g., "people planet profit" but not "triple bottom line"). This method also allows us to find a match even in the event of unexpected noise such as whitespace and punctuation. Requiring them to appear on the same page as opposed to anywhere in the document gives us better confidence that the terms are related.[3] The resulting set of search terms is given in section SI.2 in the Supplementary Information.

For each page of each document, our algorithm returned a "Yes" or a "No" for the presence of the framework. For example, a document was determined to use the triple bottom line framework if the text search found the phrase "triple bottom line" anywhere in the document, or if the words "people planet profit" were all found on the same page (in any order or context). More details about our framework search criteria are included in the Supplementary Information.

2.3 Text classification verification

We performed a Kuder–Richardson Formula 20 (KR-20) reliability test (Kuder and Richardson 1937)[4] to verify our text classification with what we consider to be the best available resource: the documents in the Clearinghouse. Figure 1 shows how the KR-20 values change as a function of the "mentions threshold." In this case, the "mentions threshold" is normalized by the number of times a certain state is mentioned per page within a given document. Any document that met or exceeded the "mentions threshold" was given a binary value of 1. Otherwise, any document that did not meet the "mentions threshold" was given a binary value of 0. In Fig. 1, the maximum x-axis value of 1 is based on the particular document that had the highest occurrence of state mentions per page (19 occurrences per page). The minimum x-axis value is based on dividing the minimum occurrence rate (0.19 occurrences per page) for a given document by the maximum overall occurrence rate (19 occurrences per page). For these varying threshold values, the corresponding KR-20 value is between 0.87 and 0.93, and thus, the self-reported values from the Clearinghouse can be considered reliable.

These results hold regardless of the type of normalization (by number of mentions per page, or by number of mentions per total document word count) applied. We performed sensitivity analysis on this threshold value, and the general results remained unchanged. See Supplementary Information.

3 Results

This section highlights the results of the statistical analyses we performed. We performed a t test to determine how often different frameworks are actually used. Additionally, we performed regression analysis to determine whether certain factors contribute to the implementation of a given framework.

3.1 How often are proposed frameworks actually used?

A one-tailed t test was used to determine whether or not the mentions of a given framework are statistically significantly greater than zero. A document cannot have negative mentions of a given framework, so a one-tailed test appeared more appropriate than a two-tailed test in this case. Table 2 contains information about the total number of mentions a given framework received, the total number of documents containing a given framework, and the t value for each test. We found four of the five frameworks to be statistically significant at the 98 % level or higher. In other words, all but the "triple value" framework are used statistically higher than the "white noise" level.

Of the four statistically significantly used frameworks, the "PSR" framework had the lowest appearance rate

[2] Initially we searched the papers for a specific phrase. This is the simplest technique, but is "rigid" in that any unexpected variation on the use of the phrase will not be counted. Thus we moved to a more complicated search algorithm.

[3] While we considered nearness criterion that would check across multiple pages, we found this unnecessarily complicated the code. Since the probability of these events is similar across documents, we can still use this analysis to compare differences between papers.

[4] KR-20 is a measure of internal consistency reliability for measures with dichotomous choices. Values can range from 0.00 to 1.00, where high values (e.g., >0.70 or >0.90) indicate that homogeneity is likely.

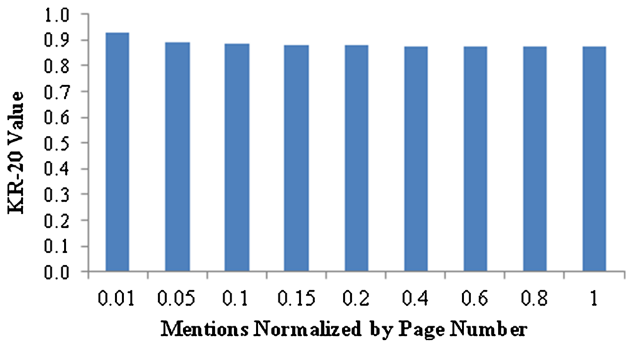

Fig. 1 KR-20 values at different "mention thresholds" normalized by number of occurrences per page. For example, a normalized mention threshold value of 1 means that a particular state had to be mentioned at least 19 times per page in a given document in order to receive a binary value of 1. Conversely, a normalized mention threshold value of 0.01 means that a particular state had to be mentioned at least 0.19 times per page in a given document in order to receive a binary value of 1

within the total document set—15 of the 212 documents contained the "PSR" framework. Therefore, it appears that an appearance in 7 % or more of the documents is the threshold for having at least a 95 % confidence level that a given framework is used at a statistically higher rate than the average "white noise" level. These results suggest that the "triple bottom line," "risk," "vulnerability," and "PSR" frameworks are commonly used by decision-makers. Conversely, the "triple value" framework does not appear to be commonly implemented by practitioners.

3.2 How do demographics (date, length, area, type of document, topic, etc.) affect the frequency of framework usage?

Next we examined whether the presence of certain descriptive features (e.g., number of pages, number of words, location, date of publication, impacts, sectors) was related to the frequency of each framework.

Independent variables we considered in the regression include number of pages in a given document, date of publication, state/territory the document applies to, sectors discussed in the document, and impacts discussed in the document. After testing for multi-collinearity between variables (through visual inspection and reliability tests described above), we identified and amalgamated correlated variables, thus reducing the number of parameters. For example, states were amalgamated to their census region. A full description of the different amalgamations can be found in SI.3.

Given these factors, we conducted a regression analysis for four of the frameworks (excluding "triple value" since its use does not appear to be statistically significant). The highest R^2 value for each set of regressions is included in Table 3. Each of the regressions indicated above had at least one independent variable that was statistically significant at the 90 % confidence level. Table 3 indicates the statistically significant independent variables for each regression performed. The independent variables are based on self-reported date, sector, and impact data from GCC. More details about the variables and the results for each regression can be found in SI.3 in the Supplementary Information.

The number of pages, discussion of the infrastructure sector, and publication during 2003 are statistically significant factors in determining the use of the "triple bottom line" framework. All of these variables have a positive impact on the use of the framework, and the number of pages has the highest level of significance with a 1 % significance level.

Discussion of social/cultural/financial sectors, the number of pages, publication in years 2000 or 1999, and discussion of human health/safety impacts are statistically significant factors in determining the use of the "risk framework." All of these variables have a positive impact on the use of the framework, and the social/cultural/financial sector variable has the highest level of significance with a 0.3 % significance level.

Discussion of the environment sector, human health/safety impacts, infrastructure sector, and water impacts are statistically significant factors in determining the use of the "PSR" framework. The environment and infrastructure variables have a negative impact on the use of the

Table 2 One-sided t test results for each of the five frameworks

Framework	Total phrase count for each framework	No. of documents containing framework	t value
Triple bottom line	453	160	14.8**
Risk framework	253	118	12.5**
Vulnerability framework	491	106	5.1**
Pressure, state, response (PSR)	34	15	2.4*
Triple value (3V)	1	1	1

* Significant for at the 95 % confidence interval

** Significant at the 99.99 % confidence interval

Table 3 Summary of statistically significant (at the 90 % level) independent variables for each of the regressions performed

Dependent variable	Statistically significant independent variables (positive/negative impact)	Highest R^2 value for set of variables
Triple bottom line	Page Numbers (+)	0.37
	Infrastructure Sector (+)	
	Year 2003 (+)	
Risk framework	SocialCulturalFinancial Sector (+)	0.31
	Page Numbers (+)	
	Year 2000 (+)	
	HumanHealthSafety Impact (+)	
	Year 1999 (+)	
Pressure, state, response	Environment Sector (−)	0.15
	HumanHealthSafety Impact (+)	
	Infrastructure Sector (−)	
	Water Impact (+)	
Vulnerability framework	EcosystemsBiological Impact (−)	0.12
	HumanHealthSafety Impact (+)	

These results are based on the regression for each framework that had the highest R^2 value. The independent variables are listed in order of significance (i.e., the independent variable with the highest level of significance is listed at the top of the list for each regression iteration). (+) signs next to independent variables indicate a positive impact on the dependent variable. (−) signs next to the independent variables indicate a negative impact on the dependent variable

framework, while the human health/safety and water variables have a positive impact on the use of the framework. The environment sector variable has the highest level of significance with a 0.2 % significance level.

Finally, discussion of ecosystem/biological impacts and human health/safety impacts are statistically significant factors in determining the use of the "vulnerability" framework. The ecosystems/biological impact variable has a negative impact on the use of the framework, while the human health/safety variable has a positive impact on the use of the framework. The ecosystem/biological impact variable has the highest level of significance with a 3.1 % significance level.

Upon further analysis of the results above, a few surprising results emerge when looking at the statistically significant independent variables for each framework. First, one would assume that documents containing the "triple bottom line" framework would include references to economic, environmental, and social impacts. However, only the "Infrastructure Sector" was found to be a statistically significant independent variable—variables like "SocialCulturalFinancial Sector" and "Environment Sector" were not found to be statistically significant in the "triple bottom line" framework. Similarly, one might expect the "Infrastructure Sector" to be a statistically significant independent variable for the "risk" framework, but that was not found to be the case. Overall, these results might indicate that practitioners are not always using key words such as "environment" or "social" when developing their frameworks, or the key words used to develop the independent variables in our analysis do not match the key words commonly used by practitioners.

Another surprise from the results is the sign associated with the impacts of some of the independent variables. For example, the "Environment Sector" and "Infrastructure Sector" variables were found to have a negative impact on the implementation of the "PSR" framework (i.e., the more these sectors appear, the less likely a given document is to discuss the PSR framework). Given the nature of the framework, one would expect these variables to lead to an increase in the use of the framework, but at least based on the documents we reviewed, the "PSR" framework appears to be applied more to human, health, and safety issues and water impacts. Similarly, the "EcosystemsBiological Impact" independent variable was found to have a negative impact on the implementation of the "vulnerability" framework. Therefore, at least in the documents we analyzed, the "vulnerability" framework appears to be applied more to human, health, and safety impacts and less to ecosystem impacts.

4 Discussion and conclusion

In this paper, we developed a method for analyzing the implementation of five commonly used adaptation frameworks: "triple bottom line," "pressure, state, response," "triple value," "vulnerability framework," and "risk framework." We collected documents from the Georgetown Climate Center Adaptation Clearinghouse, employed a simplified text analysis to identify key terms, and evaluated the frequency with which these frameworks were applied and the some characteristics that were correlated with this use. While a reliability analysis suggests that our simplified text analysis matches well with authors' descriptions as reported to the GCC, a caveat is that we cannot determine whether people who use the same term are in fact doing similar analyses.

Our analysis indicates that the "triple bottom line," "risk framework," and "vulnerability framework" are the frameworks most commonly used within the Georgetown Climate Center database. Reusing an existing framework could save a decision-maker valuable time and resources, and thus, a decision-maker might consider using these more commonly applied frameworks, especially if one of their networked connections has relevant experience. However, we note this approach can be problematic. Specifically, we suggest that there may be considerable degree of standardization in uses of terminology in connection with research methods not because they are more appropriate methods, but rather that a decision-maker wants to appear respectable and use these kinds of terms as a point of reference. This would slow the onset of use of frameworks which may be a more optimal choice for a given situation, which may be why the "triple value" framework is less commonly used.

Staw (1976) suggests that many disciplines experience "muddying through," which here would suggest as certain goals, indicators, or metrics become more common, decision-makers may begin to settle on some common frameworks for resilience. While our simple text classifier is not capable of investigating these, we would like to hypothesize additional characteristics that may be investigated through future work. In the context of adapting to climate change, a "risk" framework may be best suited for identifying and reacting to any potential impacts from climate change. On the other hand, given that it works best in the context of evaluating a specific product or decision, the "triple bottom line" framework may be better suited for general sustainability analysis and less suited for climate change adaptation—especially considering the lack of systems-level and causal analysis that can sometimes be associated with "triple bottom line." As climate adaptation efforts continue to grow and evolve, it may be important for practitioners to shift toward a "risk" framework. In doing so, efforts will need to be made to ensure that the analysis incorporates the ability to change adaptive capacity and to consider the full extent (i.e., social and environmental implications in addition to economic and infrastructure implications) of certain risks and decisions.

To address these and other hypotheses, we suggest two avenues of future research. First, a future extension of this work could include broadening the time horizon, focus, and number of documents assessed. With this expansion of the dataset, one could continue to refine the simplified text classifier, perhaps allowing use of a full statistical model. We may then be able to determine whether different frameworks are more likely to be applied for certain topic areas such as discussion of social, cultural, financial, infrastructure, and environmental issues or discussion of human health/safety, water, and ecosystem/biological impacts. This method may also allow for a better understanding of statistical relations between document characteristics and frameworks. Alternatively, researchers could conduct a survey, focus-group study, influence diagram interview, or other elicitation method to help inform whether these relations are causal, correlated, or mediated. This could help illuminate if certain documents are more important than others, and if so, how to identify them and possibly weight them differently.

Just as climate change mitigation experts chose organically to focus on life cycle assessment and the related metric of greenhouse gas emissions, resilience experts may begin to focus on one type of framework to better compare projects and exchange best practices. While current practices do not necessarily translate into future practices, the understanding of current practices as described in this study may help inform this future resilience framework.

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