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Quantifying the substantive influence of public comment on United States federal environmental decisions under NEPA

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Abstract

A citizen's right to comment on, and criticize, government decisions makes a difference. The U.S. National Environmental Policy Act of 1969 (NEPA) institutionalized public engagement in environmental review in the belief it would lead to better decisions and more sustainable outcomes. But, 50 years later, NEPA's public comment process has been criticized as costly and slow, while doing little to change outcomes. Data science now makes it possible to track progress and evaluate the influence of public participation. We examined 108 environmental impact statement (EIS) processes spanning 22 years. Our analysis revealed that public comments resulted in substantive decision alterations in 62% of cases, with 64% showing modifications to alternatives, 42% showing modifications to mitigation plans and 11% leading to the selection of an entirely new preferred alternative. When federal agencies changed project alternatives (78 EISs), 88% of the time (69 of the 78 EISs) they credited public comments as the reason. In 45 of the 108 EISs, agencies modified mitigation plans and credited public comments as the reason 100% of the time. Agencies only occasionally selected a new preferred alternative (21 out of 104 EISs), but when they did, they credited public comments as the reason 100% of the time. As the United States and the 190+ states and countries that have adopted NEPA's example consider how to address environmental change, it is important to assess the role of public participation in environmental decision making. Our data say public comments matter.

1. Introduction

Public engagement in governmental decision making is intended to increase the likelihood that decisions are made in the best interests of the people [1] by providing affected communities with the opportunity to participate in the decision-making process and to influence their government. Through public comment and engagement processes, governments can increase citizen's trust in decision-making, leading to strengthened support for policy and decision-making outcomes [2–5]. Here, we evaluate the outcomes of environmental analyses conducted under the National Environmental Policy Act (NEPA) to assess the influence of public engagement and comment processes on decision-making outcomes. The vision of NEPA was elegant—that environmental review, science and an open public comment process

result in better decisions and more sustainable environmental outcomes [6]. Now known as the environmental Magna Carta, NEPA has been emulated more than 190 times across the world, and environmental review is recognized as key a governance intervention to promote sustainability [7]. But, 50 years after NEPA's enactment, many are skeptical of the time and money invested in public comment processes associated with environmental analyses e.g. [8]. Further, scholars have expressed doubt whether U.S. agencies are actually influenced by public comments e.g. [9–11]. Whether public comments actually influence agency decisions is therefore a critical question in public policy design, not only in the United States, but in countries that have adopted NEPA's example and implemented a public comment process in environmental review. Our research shows that, in the sphere of environmental review, public engagement processes do impact decision-making outcomes.

For environmental decision making in particular, public engagement is seen to lead to more sustainable environmental outcomes and improved decisions [12–16]. For example, in a survey of Canadian environmental review experts, participants believed that stakeholder participation enhances confidence in projects and creates a sense of accountability and transparency, leading to better decisions [17, 18]. In South Korea, Campbell determined that good policy performance coupled with public engagement engenders trust [2]. By breaking down communication barriers and improving the perception of ethical conduct and competence, public comment processes facilitate government transparency—a crucial aspect to building trust [19]. Several scholars have argued that decision-making processes that lack public engagement, or are perceived as having been unsatisfactory in their public engagement, can create distrust and conflict between the public and government [20].

NEPA requires U.S. federal agencies to take a 'hard look' at their actions [21–23]. All federal actions—projects directly undertaken by agencies or private efforts that require federal permits or funding—must go through NEPA. The highest level of review, the environmental impact statement (EIS), documents an agency's scientific analysis of significant impacts to the human environment, a preferred action, alternatives and mitigation plans. The draft EIS details the analyses and is released for public comment. Agencies are encouraged to consult and inform the public of the project, and collect comments to be integrated as the agency sees fit into the final EIS. Agencies summarize public comments and explain any changes to the proposed action, or the analysis of its effects, that have been made since the draft. Public participation processes vary between agencies, as they are authorized to develop their own, individual guidelines.

Among countries that have followed NEPA's example, the practices vary. The European Union mandates public comment for strategic environmental assessments (SEAs) during scoping and review, but individual countries set environmental impact assessment (EIA) protocols. Canada, the Netherlands, Australia, Scotland, Kenya, and the Association of Southeast Asian Nations countries require early public comment in scoping and draft review [17, 24–27]. In Chile, Italy, Germany, New Zealand, and the United Kingdom (UK), public comment during the scoping period is at the discretion of the agency but is required before the final decision [28–30].

Researchers have used two lenses, procedural and substantive effectiveness, to assess the influence of public comment processes in environmental review [31–33]. The bulk of scholarship centers on procedural effectiveness—whether agencies comply with procedural legal requirements and the processes employed to do so [34]. This scholarship has argued that public comment processes may not live up to their potential [20, 35–37]. And some limited studies suggest citizens agree. In the UK, 22 stakeholders who had previously commented on waste disposal EIAs doubted that the agencies actually took their comments into account and saw their role as merely helping the agency comply with regulations [38].

We argue that measuring whether an agency follows procedures is an inadequate measure of whether public comments meaningfully contribute to the decision making process. Agencies may adhere to guidelines, giving a perception of effective engagement, however, if the comments do not influence the decision, merely following the procedures is not indicative of effective engagement. A more direct measure would assess substantive effectiveness, or the extent to which comments impel agencies to alter plans and decisions [34, 39].

To our knowledge, only four studies have attempted to examine the substantive influence of public comment on agency decisions. In a study of 117 SEA reports in England, Fischer was unable to determine whether public comments influenced decisions because the agency's rationale for changes was not explicitly stated [40]. In the United States, De'Arman concluded that public comments rarely result in substantive modifications to a final EIS [41]; the study was limited to a single agency and did not define what constitutes a 'substantive' change. Ulibarri *et al* used the percent change in the number of words (from draft to final EIS) discussing an 'impact area' as the metric for determining whether the agency substantively responded to a public comment [10]; although this measure is effective for evaluating whether an agency addressed public comments, it does not indicate whether the comment resulted in a substantive change to the decision. In contrast, Eckerd developed a definition for substantive modifications as a 'decision-altering' change [42]. In an analysis of three EIS cases in the Washington D.C.

area, Eckerd determined 99% of comments were met with boilerplate, and only 6% of comments led to 'decision-altering' changes. Although Eckerd concluded this indicates minimal public influence on agency decisions, we note that in all three cases, the agency altered their decision. Our study expands on the work done by Fischer, De'Arman and Ulibarri *et al* by analyzing a much larger sample that spans time, agencies, and project type and provides a rubric to determine not only if changes occurred, but if the changes made were substantive, or decision-altering.

The framers of NEPA hypothesized that public engagement through a public comment process would be a critical and positive force for environmental sustainability. But, to date, the view that public comment influences agency decisions has been largely absent from academic literature, likely due to the difficulty of parsing through a large number of comments and analyzing the impact. Data science now makes it possible to track progress and rigorously evaluate the influence of public participation in NEPA.

This paper tests NEPA's fundamental hypothesis about the value of public comment. We assess the rate at which agencies credit public comment as the basis for substantive changes to a decision. Agencies may credit public comment because agency officials are persuaded that modifying the project is better policy; or officials may consider the public comment to present a risk of successful litigation if no change is made [9, 11, 43, 44]. However, the subjective intent of the agency is not the focus of this paper. Our focus is the rate at which public comments are credited with leading to a substantive change in agency action.

With the enactment of the Infrastructure Investment and Jobs Act in 2021 and the Inflation Reduction Act in 2022, the United States is poised for a major wave of infrastructure development, unmatched since the post-World War II economic boom. As governments worldwide increase development, they may seek to expedite environmental reviews at the expense of public engagement [7, 8, 45]. Environmental review, as envisioned by NEPA, has set the standard around the world for over five decades as a key science-based intervention to support environmental sustainability. Here we lay aside anecdotal criticisms in favor of rigorous scientific analysis of the power of public comment.

We ask two questions. First, does public comment influence outcomes? Specifically, do agencies identify public comments as the reason for modifying alternatives or mitigation plans; or, do they credit public comment as the reason for selecting an entirely new preferred alternative? Second, are the changes that result substantive, in that decisions are altered? We consider multiple agencies and action types, and employ a broad timeframe and a detailed rubric to distinguish between substantive and non-substantive changes based on the actual change to decisions.

2. Results

2.1. Agencies credit public comments as a reason for altering decisions

We determined the frequency with which agencies in the final EIS explicitly credited public comments as a reason for modifying an existing alternative in our sample of 108 EIS processes. Seventy-two percent of the time, agencies made changes to alternatives between the draft and final EIS ($n = 78$). Of this 72%, 88% of the time agencies explicitly stated that changes were made because of public comment ($n = 69$). This fraction is 64% of the total sample. Results from a proportion test show that, more often than not, when agencies modify alternatives it is because of public comments (table 1, one-sided proportion test, H_O: $p\text{Yes} = p\text{No}$, H_A: $p\text{Yes} > p\text{No}$, $p = 0.0026$). Further, responsiveness to public comments was similar across agencies—they modify alternatives in response to public comment at similar frequencies (Fisher's exact test, $p = 0.94$).

To evaluate whether agencies modify mitigation plans because of public comment, we needed to know if the agency credits public comments on a draft EIS when it modifies mitigation plans in a final EIS. Forty-two percent of the time, agencies modified mitigation plans between the draft and final EIS ($n = 45$, table 1, one-side proportion test, H_O: $p\text{Yes} = p\text{No}$, H_A: $p\text{Yes} > p\text{No}$, $p = 0.95$). Although public comments do not have an impact on changes to mitigation plans more often than not, of the 42% that did change mitigation plans, agencies credited public comments as the reason for making changes to the mitigation plans between draft and final 100% of the time ($n = 45$, 42% of the total). There was no statistically significant association between agency and frequency of modifications to mitigation plans (Fisher's exact test, $p = 0.13$). Although the frequency with which Federal Energy Regulatory Commission (FERC) modified mitigation plans was not statistically different from other agencies, FERC had the highest proportion of processes (75%) crediting public comment as the reason to modify mitigation plans.

We evaluated whether agencies select an entirely new preferred alternative more often than not because of public comment by looking at the reasons agencies gave when selecting a new preferred alternative. Between the draft and final EIS, agencies selected a new preferred alternative only 11% of the time ($n = 11$). But 100% of these credited public comment as the reason. Additionally, there were four cases where a preferred alternative was not declared in the draft or final EIS. Therefore, of all the processes we surveyed with a preferred alternative identified, 20%

Table 1. Results: frequency with which agencies credit public comments.

	Do agencies credit public comment when modifying alternatives? ($n = 108$)		Do agencies credit public comment when modifying mitigation plans? ($n = 108$)		Do agencies credit public comment as the reason for selecting an entirely new preferred alternative? ($n = 104$)	
Agency, action-type	Yes	No	Yes	No	Yes	No
BLM CRB, EGT, MRE	23	13	15	21	11	25
FERC EGT, MRE	7	5	9	3	1	11
USACE CRB, MRE	9	3	5	7	2	8
USFS CRB, EGT, MRE	22	14	13	23	5	29
USFWS CRB, EGT	8	4	3	9	2	10
Total	69	39	45	63	21	83
Proportion test (pYes > pNo)	p-value = 0.0026		p-value = 0.95		p-value = 1	
Fisher's exact test (by agency, pYes > pNo)	p-value = 0.94		p-value = 0.13		p-value = 0.45	

Counts of 'yes' and 'no' responses. The far-left column denotes the agency and action type. Our three research questions are in the top row. We focus on the three most common EIS action-types (conservation, restoration and biological resource use (CRB); energy generation and transmission (EGT); and mineral resource extraction (MRE)) and the agencies that produced the highest number of EISs within each action-type (Bureau of Land Management (BLM), Federal Energy Regulatory Commission (FERC), U.S. Army Corps of Engineers (USACE), U.S. Forest Service (USFS), and U.S. Fish and Wildlife Service (USFWS)). We used proportion tests to determine if agencies make changes more often than not, and if the changes were substantive more often than not. We used Fisher's exact tests to determine if agencies behave differently from one another.

of the time the agency specifically credited the public as steering the choice of preferred alternative ($n = 21$, table 1, one-side proportion test, H_O: pYes = pNo, H_A: pYes > pNo, $p = 1$). Although we did not find a statistically significant difference in behavior across agencies (Fisher's exact test, $p = 0.45$), it is notable that BLM had the highest frequency of selecting a new preferred alternative in response to public comments (nearly 30% of the time).

2.2. Public comments are often credited for decision-altering, substantive changes

The results indicate that, more often than not (62% of the time), when agencies credit public comment as the reason for modifications to alternatives, the changes are substantive (table 3, one-side proportion test, H_O: pS = pNS, H_A: pS > pNS, $p = 0.04$). We found that three agencies stand out (table 3, Fisher's exact test, $p = 0.01$). When the U.S. Forest Service (USFS) and the U.S. Fish and Wildlife Service (USFWS) made such modifications, 73% and 75% of the time (respectively), the changes made were substantive. Similarly, in all seven cases (100%) where FERC credited public comment in modifying an alternative, the changes were substantive. Refer to table 2 for definitions of substantive versus non-substantive.

3. Discussion

In our evaluation of 108 environmental review processes from the U.S.'s NEPA, we found public comment often influences outcomes and results in substantive changes in agency decision-making. More often than not, when agencies modified alternatives, they identified public comments as the reason for the change. In our sample, agencies did not typically change mitigation plans between the draft and final EIS, but when they did, they credited public comment. Further, when agencies selected a new preferred alternative, they explicitly credited public comments. Most importantly, the agencies' changes were substantive—not simple textual changes to the document, but decision-altering modifications. Our results indicate anecdotal criticisms of the efficacy of public engagement may be unfounded, and that prior research, which focused merely on agencies satisfying process, may offer limited insights. Our approach also demonstrates the power of data science to elucidate the effectiveness of policy interventions for environmental sustainability.

Based on the current perceptions of public engagement from existing scholarly literature, we would have expected public engagement to have little to no impact on agency decisions [9, 11, 35–38,

Table 2. Substantive versus non-substantive modifications.

Substantive		
	Definition	Example
(i) Partial modifications of an aspect of the proposed project	An aspect of the original alternative is modified, but nothing is completely removed or added.	As part of an alternative, a temporary road is being set up to redirect traffic. A public comment expressed concern over the path of the roadway, the agency decides to slightly modify its path to accommodate the concern.
(ii) Partial modification involving the addition or removal of an aspect of the proposed project	The agency removes an entire aspect of the alternative, but overall, the alternative remains.	Addition: as part of an alternative, the agency adds a temporary roadway to account for public concerns regarding traffic caused by the project. Removal: As part of an alternative, the agency removes a temporary roadway, as comments have expressed concern of the temporary roadway being close to a school zone.
(iii) Entirely new alternative created	A new alternative (combination or brand new) is created.	The agency decides to create an entirely new alternative that includes several new aspects, plans, or constructions.
Non-substantive		
(iv) Basic text changes	Basic changes to text for clarity, conciseness, or grammar errors.	'In response to comments received on the Draft EIS, we have reduced descriptions of certain elements of the proposed covered activities, removing some redundant text and unnecessary detail.'
(v) Unclear	Determined alternatives were modified in response to public comments, but it is unclear what the exact change is.	An agency responds to a comment indicating the alternatives have been modified in response, however there is no specific demarcation or explicit statement on the exact change made in the entirety of the document or attached documents.

We compared the draft EIS and final EIS of each process where a modification was credited to public comment and coded each as substantive (i.e., decision-altering) or non-substantive following Eckerd's definition of substantive modification [42].

Table 3. Are the changes that are credited to public comments substantive?.

Are the changes made in response to public comments substantive or non-substantive? ($n = 69$)		
Agency, action-type	Substantive (S)	Non-substantive (NS)
BLM CRB, EGT, MRE	12	11
FERC EGT, MRE	7	0
USACE CRB, MRE	2	7
USFS CRB, EGT, MRE	16	6
USFWS CRB, EGT	6	2
Total	43	26
Proportion test p-value	0.04	
Fisher's exact test p-value	0.01	

Total counts by agency and action type of substantive (i.e. decision-altering) and non-substantive modifications to alternatives that are credited to public comment (refer to definitions in table 2). When agencies modified alternatives, 62% of the time the changes are substantive.

44, 46]. But as several researchers have pointed out, most of the scholarship has focused on procedural effectiveness [34, 39]. Here, we argue that the extent to which agencies credit public comments when altering decisions should be the primary measure of the influence of public comments. Our study expands on the

findings of Eckerd, who found evidence for 'decision-altering' public comments in a small sample [42]. Our results provide support for the notion that public comments can substantively affect agency decisions using a larger, statistically robust sample.

The point of this study was to explore the role public comment plays in agency decision making. Therefore, we have focused on identifying explicit attributions to public comments for changes. We recognize that there may be circumstances in which an agency has multiple motivations for making a change: re-analysis by staff; high-level re-evaluation or judgments of political acceptability. We also acknowledge that attribution in final EIS documents may be subject to reporting bias. An agency may decide to modify a project in a fashion that is consistent with public comment for additional reasons, and point to the public comment as justification in the final EIS. Agencies may also be more inclined to report changes aligned with public comment to demonstrate responsiveness, enhance legitimacy, or mitigate litigation risk—even when other factors were more influential. Such pretextual reasoning would, however, not appear to reduce the risk of successful litigation and could enhance such risk if it can be demonstrated that the agency has provided a false justification. Other scholars have noted that officials may seek to comply with the letter of the law to avoid litigation and simultaneously be responsive to public comment [9, 11, 43, 44]. We argue it does not eliminate the role of public input; but, rather, it highlights the complexity of its influence. So long as public comment contributed to the change, the comment has had a meaningful effect.

Public engagement is widely accepted as vital in the practice of environmental review around the world e.g. [7, 17, 27]. Regulations vary, but in most countries where environmental review has been adopted, the public must be involved prior to decision-making. In the United States, some have argued for limiting or eliminating public comment in NEPA, questioning whether it is worth the time and cost [8, 47]. For similar reasons, in India, lawmakers have pushed to revise EIA regulations and limit public comment from certain project types—including highway, irrigation, defense, and national security projects [45]. These views have been largely based on anecdotes. Our research demonstrates that public comment matters.

Lawmakers who are concerned with empowering citizens may wish to focus on improving public engagement practices. Researchers from around the world have called for improvements to public engagement including best practices, clearer guidelines on how to conduct transparent communication with stakeholders, and greater allocation of resources not only to inform citizens but also to create engagement processes that empower the public [25, 35, 40, 48–51]. In particular, scholars emphasize the need to clarify the goals for each phase of public engagement in order for public engagement to have maximal influence on planning and decisions [28].

Several scholars have proposed metrics for evaluating the quality of public engagement [20, 28, 31]—e.g. the number of public meetings, accessibility of meetings, number of attendees, number and types of efforts to notify the public, the types of groups involved, and the length of the comment period. As part of the study, we had initially planned to extract information about these metrics. Although agencies may be undertaking high-quality engagement, in the 108 EISs we examined, information about the accessibility of meetings, number of attendees and the number and types of efforts to notify the public was not reported. To guide agencies, scholars and policymakers in determining the most effective strategies for more meaningful and efficient public engagement, we encourage U.S. federal agencies to report and track the quality of their public engagement efforts.

When the regulations that guide NEPA reviews were revised in 2023 by the Biden administration, improving public engagement practices was one of the specified goals. Our results indicate that public engagement results in substantive changes to agency decisions. Our work on the substantive effect of public comments, and the work of other scholars on the procedural effect of engagement [20, 31, 40–42] would be useful in guiding improvements to the public engagement process.

A common assumption in many liberal democracies is that individual citizens have limited power to influence government decisions. This assumption is often wrong. Not only in that it implies that public engagement with the government is not effective, but also that it implies engagement with government is inherently adversarial. The U.S. Congress' vision of NEPA was to promote harmony between humankind and the environment and to foster collaborative engagement between the government and its people [52]. Our results provide support for the idea that collaboration can work.

As we enter a new wave of development in the United States and world-wide, it is more important than ever that we 'look before we leap' and ensure decisions are made with people and the environment in mind. Our study provides evidence that public comment influences agency decisions and is a valuable tool for agencies to gather information and refine plans, which could lead to more sustainable outcomes for affected communities and the natural world. Ultimately, the true impact and lasting power

of public engagement depends not just on its implementation by government agencies, but on the active participation of the public itself.

4. Materials and methods

To examine the influence of public engagement on agency decisions, we determined the frequency with which agencies explicitly credited public comments as their reason for modifying an existing alternative, modifying mitigation plans, or selecting a new preferred alternative between the draft and final EIS. To determine if these changes were substantive, we drew upon the literature to develop a rubric for distinguishing substantive versus non-substantive changes based on whether or not the comment was 'decision-altering.' We used proportion tests to determine if agencies make changes more often than not, and if the changes were substantive more often than not. We used Fisher's exact tests to determine if agencies act on public comments differently from one another. To be able to make consistent comparisons across agencies and action-types, we studied EIS processes from the three most common action-types and five agencies.

4.1. Data source

We used nepaccess.org, a knowledge, discovery, and engagement platform for NEPA, to find EISs completed between 2000 and 2022. NEPAccess covers the period from 1970 to the present, and contains full-text searchable PDFs of EISs, U.S. Environmental Protection Agency (EPA) metadata records since 2012, and additional metadata developed by NEPAccess. At the time this search was conducted in October 2022, nepacess.org was the most comprehensive source of NEPA documentation in the United States. [https://about.nepaccess.org/nepaccess-2021–2024/;] [53]. NEPAccess contained 3,012 of the 4,149 final EISs (73%) that were published during the study period (according to the Federal Register). A logistic regression comparing the 3,012 final EISs in NEPAccess against the total completed during the period showed no statistical bias in the NEPAccess repository with respect to agency (coefficient of determination = 0.99).

NEPAccess uses natural language processing techniques to categorize documents by action-type. The platform parses the text of each EIS document to find keywords identifying action-types and assigns each EIS the most relevant action-type from a list of 11 possibilities [54]. The most common action-types pertain to conservation, restoration and biological resource use; energy generation and transmission; and mineral resource extraction (MRE).

4.2. Study sample: selection of action type and agency

Our goal was to analyze EIS processes from the top EIS-producing agencies that carried out multiple types of actions. We used NEPAccess to identify EIS processes between 2000 and 2022 with published draft and final impact statements (a total of 2,293 processes). As public participation guidelines issued by the Council on Environmental Quality (CEQ) have remained relatively unchanged to date, we selected a wide timespan to analyze a broad range of EISs while also including recent documents. We then chose agencies that completed a high volume of projects of the three most common action-types: conservation/restoration/biological resource use, energy generation/transmission, and MRE. We selected agency-action-type combinations with at least six EIS processes each. This resulted in five agencies: BLM, FERC, U.S. Army Corps of Engineers (USACE), USFS, and USFWS. We excluded from our sample some top EIS-producing agencies (e.g. department of transportation) because those agencies lacked variation in action-types (table 4). For those agencies that annually produce a large number of EISs (BLM and USFS), we coded public engagement data on twelve randomly selected EIS processes per three action types. For agencies that produce fewer EISs (FERC, USACE AND USFWS), we coded six EIS processes per two action types

To select the sample of EIS processes, we used the following random sampling procedure:

1. For each qualifying agency-action-type combination, we identified all matching EIS processes using NEPAccess.
2. If there were more processes than needed (e.g. more than six for smaller agencies or more than twelve for larger agencies), we assigned each process a unique number.
3. We then used a random number generator to select the required number of EISs for that combination. For BLM and USFS (high-volume agencies), we selected 12 EISs for each of the three relevant action types. For FERC, USACE, and USFWS (lower-volume agencies), we selected six EISs for each of two relevant action types.
4. If an agency-action-type combination had only six processes, we included all of them.

We ultimately selected 108 EIS processes and coded public engagement data from 216 documents (i.e. 108 draft EIS and 108 final EIS documents). To ensure consistency in the coding, all documents were coded by the lead author using a rubric developed by coding a test batch of representative EIS documents and reviewed by the co-authors.

Table 4. Agency and action-type selection.

Agency	Action-type
Bureau of Land Management ($3 \times 12 = 36$ EIS processes)	Conservation/restoration/biological resource use Energy generation/transmission Mineral resource extraction
Federal Energy Regulatory Commission ($2 \times 6 = 12$ EIS processes)	Energy generation/transmission Mineral resource extraction
U.S. Army Corps of Engineers ($2 \times 6 = 12$ EIS processes)	Conservation/restoration/biological resource use Mineral resource extraction
U.S. Forest Service ($3 \times 12 = 36$ EIS processes)	Conservation/restoration/biological resource use Energy generation/transmission Mineral resource Extraction
U.S. Fish and Wildlife Service ($2 \times 6 = 12$ EIS processes)	Conservation/restoration/biological resource use Energy generation/transmission

Selected agency and action type combination.

4.3. Do agencies credit public comment for modifications?

To examine the influence of public engagement on agency decisions, we determined the frequency with which agencies explicitly credited public comments as a reason for modifying an existing alternative, modifying mitigation plans or selecting a new preferred alternative between draft and final EISs.

In final EISs, agencies report changes to alternatives or mitigation plans and note whether the changes were in response to public comment. These changes are typically discussed in a dedicated section summarizing modifications from the draft EIS. However, in some cases the changes may be noted in the comment and agency response section, alternatives section, or mitigation section.

We reviewed the aforementioned sections for each final EIS and coded for changes between draft and final. If the language indicated that alternatives or mitigation plans were modified because of public comment, the final EIS was coded as 'yes'; otherwise, it was coded as 'no'. If, between the draft and final, a new preferred alternative was chosen and it was explicitly noted that the change was because of public comment, we coded the final EIS as 'yes'. Otherwise, it was coded as 'no'.

4.4. Are the modifications substantive?

To assess if changes were substantive, we created a rubric based on Eckerd [42]. A comment was addressed substantively if it is 'decision-altering'. In addition, we conducted our own systematic documentation of changes between draft and final EISs. We identified three categories of substantive modifications: (i) partial modifications of an aspect of the proposed project; (ii) partial modification involving the addition or removal of an aspect of the proposed project; and (iii) creation of an entirely new alternative. We also assessed for two categories of non-substantive modifications: (iv) simple textual modifications; and (v) cases where the agency did not explicitly explain what was changed in response to public comment. We compared the draft EIS and final EIS and coded each modification as substantive or non-substantive. The rubric was developed iteratively based on a test batch of 12 EISs representing the diversity of our sample. The lead author initially drafted categories and decision rules guided by the work of [42] and refined through feedback from the co-authors. Refer to table 2 for examples of what constitutes a substantive versus non-substantive modification.

4.5. Proportion tests to determine (1) how often agencies make changes and (2) if the changes were substantive

To examine the influence of public engagement on agency decisions, we used proportion tests to evaluate whether, more often than not, agencies explicitly credited public comments as their reason for modifying an existing alternative, modifying mitigation plans, or selecting a new preferred alternative. In four of the 108 processes, a preferred alternative was never declared. We thus excluded the corresponding EISs from the analysis of the influence of public engagement on the preferred alternative, but they were included in the analysis of the influence of public engagement on alternatives and mitigation. We also used proportion tests to determine if the frequency of substantive modifications was greater than non-substantive modifications across agencies and action-types.

4.6. Fisher's test to determine if agencies behave differently from one another

We used Fisher's exact tests to determine if agencies act on public comments differently from one another when making modifications to alternatives, making modifications to mitigation, or selecting a new preferred alternative in response to public comment, and

whether these modifications were substantive. Both Fisher's exact and chi-squared tests are commonly used statistical methods for identifying significant associations between variables in a contingency table. When sample sizes are small, the Fisher's exact test calculates the exact probability of observing a given contingency table whereas the Chi-squared provides an approximation. Thus, we elected to use Fisher's exact test as they are more appropriate for the small sample sizes in our study.

Fisher's exact test requires a random sample and independent observations, and each observation must fit into only one category (i.e. categories must be mutually exclusive). These conditions hold for our dataset. We note, however, that some EISs are co-authored by multiple agencies and are therefore not mutually exclusive. For instance, the BLM and FERC could co-author an EIS for energy transmission along wildlife corridors through BLM land. However, such EISs did not occur in our randomly selected dataset.

In most cases, the randomly selected EISs were a subset of the available EISs per combination agency and action type. In other words, there were more EIS processes per agency-action-type combination than we needed for the study. However, for the combinations of USFWS and energy generation/transmission, there were only six EISs; therefore, it was not possible to expand the dataset. Nevertheless our dataset represents a sizable fraction of available EISs.

We note that in the contingency table of agency, action-type, and all possible responses, several cells had counts of 5 or fewer (e.g. of the 12 USFS conservation/ restoration/biological resource use projects in our sample, there were only four cases where alternatives were modified in response to public comment). Fisher's exact tests appropriately accommodate these situations with low-count observations.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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Disclaimer

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Author contributions

A S, L L H, R M wrote the manuscript. A S, L L H, R M, and W E T designed the statistical analysis and sampling design. S B, E L, and F C developed the underlying machine learning and NLP algorithms. B S, C W and K R C helped with data analysis and visualization. A S, L L H, R M, W E T, A L, S B, K E, M M, J D and E M conceived the overall study goals and questions. All authors reviewed and commented on the final manuscript.

Conflict of interest

No competing interests.

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Social science, minor classification options: Environmental Sciences.

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