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Science and Federal Environmental Decisions

A Survey of Interactions, Successes, and Difficulties

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Abstract

Successful interactions between science and federal decisionmaking are important because of the public interest in informed, rational action on the part of our environmental institutions. Based on interviews with federal employees, the study gives a broad overview of interactions and coordination between US government decisionmakers and science programs. We identify a range of features and practices that contribute to the success or failure of decision-oriented scientific input. The study also holds lessons for science-oriented federal partners (e.g., NGOs, philanthropies, academic institutions, and businesses) and identifies ways they can most usefully contribute to federal decisionmaking.

Key Words: environmental research, federal government, decisionmaking

Contents

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James Boyd and Jonathan Kramer *

1. Introduction

Federal agencies are important producers of scientific research on the status of natural resources and ways they can be managed and protected. A typical federal agency employs dozens if not hundreds of environmental researchers and funds or interacts with a wide range of external natural resource–related research partners. Federal agencies are also important demanders of research to inform decisionmaking. In their trustee, regulatory, and policy roles, agencies have significant ability to apply research in practice.

Successful interactions between science and federal decisionmaking are important because of the public interest in informed, rational action on the part of our environmental institutions. The purpose of this study is to depict the status of those interactions and identify features and practices that contribute to success or failure. The study is informed by structured interviews conducted with 35 federal scientists and decisionmakers. The participants reflect a broad cross section of job descriptions, agency affiliations, and expertise relating to environmental science and decisionmaking. They were asked to define their sense of "successful" versus "unsuccessful" science-decision interactions, identify examples of both, and identify factors that in their view contributed to the success or failure of interactions.[1] The interview protocol is provided in the appendix.

Beyond providing a description of current practice, the goals of the interviews and this summary are to identify recommendations for improved science-decision interactions within the

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[1] We do not reference specific individuals, agencies, or programs, both because our participants were guaranteed anonymity and because our purpose is to draw broad conclusions rather than provide specific critiques of past practice.

federal government and to help science-oriented federal partners (e.g., nongovernmental organizations [NGOs], philanthropies, academic institutions, and businesses) identify ways they can most usefully contribute to federal decisionmaking.

This study is not an exhaustive survey of federal science-decision interactions, a point we stress. We are personally aware of numerous science-decision interactions not identified by our survey, many of them considered to be successes. However, our sample did not target practitioners of those successes for input.

While our interviews conveyed the sense that federal science-decision interactions are in need of substantial improvement, they also provided a diverse set of success stories with transferable lessons for the future. Common to all the successes was a deliberate focus on the inherent difficulty of incorporating science input into practical decision contexts. Knowing there is a challenge is the first step in overcoming it.

In practice, a variety of factors can generate mismatches between the supply of and demand for policy-relevant science. A generalization (with many exceptions) is that researchers and decisionmakers are often intellectually and institutionally isolated from each other, even when in the same organization (Jahn et al. 2012). Long-standing administrative practices—from hiring to organizational structures to performance assessment and incentives—can fail to promote effective science-decision interactions (Cash et al. 2003).

These problems are by no means unique to the federal sector. The traditional approach to applied science has been described as "linear" and often ineffective (Weichselgartner and Kasperson 2010; Pielke 2007; Sarewitz and Pielke 2007). In linear interactions, there is little or no feedback between decision audiences and science practitioners: the science is conducted, an attempt is made to translate results into practical terms, and then decisionmakers are asked to apply the results given to them. This is ineffective for a variety of reasons (Bell et al. 2011). Most obviously, researchers may have little understanding of the choices or decisions being informed. For example, science providers may not understand political, legal, financial, and other real-world factors that affect how knowledge will be interpreted and used. Unexposed to those factors, it is easy for researchers to misinterpret the kinds of information that would be useful and applicable to decisions. Also, the linear model's emphasis on "translation" underappreciates the semantic, philosophical, and cognitive challenges that arise when the research-to-application divide must be crossed (van Kerkhoff and Lebel 2006; Lauber et al. 2011). A challenge beyond the translation of knowledge is the translation of trust and legitimacy. The linear approach to applied research leaves knowledge users uninvolved in, and uninformed about, the semantics, values, and methods associated with the science delivered to them.

Our success stories almost always involve a "nonlinear" approach to interactions. Nonlinear interactions are iterative and cultivate both interpersonal and intellectual relationships between scientists and decisionmakers, often over long periods of time. This finding—that successful interactions are those that involve communication both to and from decision audiences—is consistent with recommendations made by others, including Rowe and Lee (2012) and Clark et al. (2010, 2016a, b).[2]

The next section reflects on broad themes that emerged from the interviews. Section 3 identifies specific factors that were commonly associated with successful science-decision interactions. Section 4 describes issues associated with alignment of decision needs and science input. Sections 5 and 6 focus, respectively, on place-based science-decision interactions and the relative strengths of internally versus externally provided science input. Section 7 describes the need for national-scale, synthetic science capability. Section 8 provides a set of overall conclusions.

2. "Success" and "Failure": Broad Themes

What Are "Successful" Interactions?

Many participants judged success in terms of a *process* that had desirable properties, in particular, a high degree of interaction and communication between government managers and scientists. Other participants emphasized particular *outcomes* as signifying success. Interactions were judged successful when they led to science "having influence on decisions," "changing the outcome," "reducing conflict," or reducing the likelihood of decisions being legally challenged in the future. A small subset of participants provided a particularly specific outcome-based test of whether science input was successful—namely, when it led to policy choices that increased the well-being of stakeholders. Either way, nearly all participants noted a linkage between desirable processes and outcomes. For example, those emphasizing outcomes as a measure of success noted the dependence of such outcomes on a process that fostered communication and coordination between scientists and managers.

One point of divergence, among a small number of participants, related to whether scientific consensus arising from the interaction was a signal of success. One participant, for

[2] Rowe and Lee (2012), for example, emphasize that "knowledge is useful and used when it is jointly produced by participants in the decision process and experts with technical and domain knowledge."

example, associated success with "agreement in a civil, transparent manner, with consensus among scientists." And several mentioned the desirability of synthesized science, which can reflect consensus. But one participant explicitly identified the need to avoid a "consensus trap" in science guidance, equating consensus to groupthink or inadequate appreciation of new scientific results.

Successful Science-Policy Interactions Are Rare

While nearly all participants described an institutional need and desire to better link science to decisionmaking, and all were able to identify examples of success, successes were described as rare. One political appointee who oversees a large federal science program observed, "I am not interacting with science much at all in this job." Another director of a large federal program refused to participate in an interview because he felt the majority of the decisions he faced had nothing to do with science but were more about management, politics, and budget—even though his program was devoted to science analysis.

One explanation, and another clear finding, is that federal agencies rarely institutionalize science-decision interactions. One career employee in a major environmental agency said she had "a hard time thinking of a great example of an established practice or process that really got science folks and decisionmakers to coordinate." A political appointee in another, when asked for an example of a program or process to bring scientists and policymakers together to improve interactions, responded, "There must be, but I can't think of one." Participants were able to point to advisory-specific bodies (e.g., the Congressional Research Service or the National Academies) as institutionalized mechanisms for interaction. And several were aware of external organizations capable of brokering science-decision interactions. But within agencies with regulatory and management missions, in all but a couple of cases participants had a difficult time identifying mechanisms that institutionalize science input into decisionmaking.

Many participants described the lack of established mechanisms as leading not only to poor communication and design of science input but also to problems with the budgeting, planning, and implementation of science initiatives.

Issues with Scientists' Understanding of Decisionmaking

The lack of deliberate strategies to improve interactions is problematic given several other themes that emerged. Decisionmakers consistently identified scientists' poor understanding of decisionmaker needs and the nature of policy evaluation. One respondent caricatured the science community by asking, "Who is the policymaker? What is a policymaker? What is a decision even? People don't know this." Others referenced scientists' "hubris" or "groupthink" and said that "many scientists don't get the difference between science and policy." The frequent isolation (physically and administratively) of federal scientists from program offices was often mentioned as an explanation for why scientists don't understand decisionmakers' needs and why federal managers and policymakers do not make use of science input.

Scientists outside the federal government were also called out by several participants as having a poor understanding of science input that would be useful to decisionmaking. And again, this failure was explained by a lack of attention to processes that would deliberately engage scientists and decisionmakers. A large, well-funded science initiative was deemed a "colossal failure" by one participant because it was led by academic scientists who failed to interact with the policy community and advanced "self-serving," rather than policy-relevant, science. Another participant nominated as a failure a science-driven policy initiative led by a philanthropic organization that failed to engage and nurture support from federal decisionmakers.

Authority and Incentive Issues

One set of participants identified a lack of policy-related management authority over federal science programs as an explanation for the rarity of successful interactions. While there may be advantages to independent science programs and staff, the division of administrative and budgetary authority can create management and incentive problems. "There is no incentive!" for science-policy interactions, exclaimed one participant. According to one scientist, "You can always find a program office person to say the [science] is relevant or get an external advisory board to sprinkle holy water on stuff. But there is no real authority. The status quo always wins."

A high-level political appointee explained that he can't just "tell the science program to work on *x*" because he has no management and budget authority to do so. Another participant remarked that policy program managers have "no real ability to change researchers' agendas," except over the very long term through hiring, and that feels like "turning a tanker." Another expressed frustration that he couldn't get analysis out of a science program because "no one there found it compelling enough to do research on it." Yet another depicted the placement of science capability in an independent arm of the agency as "making it harder for those scientists to be policy relevant, practical, and timely."

Science program leaders have authority over their own science programs. However, one participant noted that politically appointed science program leaders "change every two years." Another described "the lack of continuity" of science program leadership as a major barrier to effective science-decision interactions, because sustained leadership is necessary when there is "no line of [policy program] authority." Institutional knowledge, long-term relationships, and the ability to navigate within their institutions' opportunities and constraints are all essential to the success of science program leaders.

Issues with Policymakers' Approach to Science

Many participants noted that decisionmakers, not just scientists, create barriers to successful interaction. Some expressed frustration with decisionmakers' inability or unwillingness to articulate scientifically answerable questions, even when such input seems as though it would be relevant to policy questions. Also, several participants noted that decisionmakers could do a better job of informing scientists when their analyses are in fact used and about the ways in which their science was influential. Communicating with scientists about their work's relevance not only has a motivational benefit (it shows the science community that its interactions with policy are worth the effort) but also helps the science community better understand the decision process and provide more relevant science in future.

Another source of frustration for several participants was decisionmakers' asking for scientific analysis to justify actions already made for other reasons (e.g., political, bureaucratic motivations). Science used to justify decisions after the fact troubles scientists—first, because it can trigger the perception (if not the reality) of bias, and second, because it underscores that the science was not actually relevant to the policy choice.

Several examples described situations in which the politics of a decision trumped scientific conclusions. This is not surprising, or necessarily troubling, since science is often just one factor in decisionmaking. However, in a couple of cases, participants described political efforts to distort the science, rather than simply ignore it. One described pressure to alter risk assessments. Another talked of a case that "was the only time in 30 years of federal service that I have been directed to do bad science." Though relatively rare in our sample, such pressures pollute and undermine relationships between federal scientists and decisionmakers.

Decisionmakers who ignore, or fail to support, independent science reviews were mentioned by several participants as undermining successful interactions with the science community. One participant highlighted a case where an agency leader ignored high-level external science advice and used a procedural argument (that there was not enough time) to forestall a planned external advisory review that was expected to disagree with the politically preferred policy choice.

Finally, several participants talked of cases where new scientific findings met with bureaucratic resistance because the science was "threatening," it "undermined existing practices," or it would complicate relationships with the agencies' constituents. One participant suggested that willful ignorance of new scientific information works to the advantage of some decisionmakers. Another participant described how managerial resistance to a new, broadly held, scientific consensus on effective natural resource management practices created in her agency "a generation of scientists who didn't trust managers."

3. What Factors Explain Success?

Our diverse set of federal practitioners conveyed the sense that constructive interactions between science providers and decisionmakers are rare and that science—whether provided internally by federal agencies or externally by the academic, NGO, and business communities—has less of an impact on decisionmaking than many would expect or hope. And as noted earlier, there was little or no awareness of routine, embedded institutional approaches to science-decision interaction, despite broad expressions of the need for such mechanisms.[3]

Nevertheless, the vast majority of practitioners were able to identify successful exceptions to that rule. We turn now to participants' explanations for how successful science-decision interactions were achieved.

The most consistently voiced explanation for success can be boiled down to this: a combination of high-level leadership asking, and providing resources, for effective science-decision interactions; mid-level leaders able to manage across the science-decision "boundary"; and adequate time and financial resources. Time and again, success was attributed to key people at an executive level playing the role of science demanders and management-oriented stewards with the ability—and personality—to match policy demand with science supply by fostering communication and trust.[4]

High-Level Leadership Vision and Support

High-level champions—including, but not limited to department secretaries, assistant administrators, or service directors—create top-down pressure and opportunities for good science-decision interactions.[5] Typically, these champions are not involved in the day-to-day management of interactions but provide several necessary functions.

[3] The perception these mechanisms do not exist should not be taken to imply that they do not in fact exist in some form.

[4] We use the term "executive" loosely and not necessarily to connote members of the federal Senior Executive Service.

[5] It was noted that within several agencies, there has been a growth in the number of assistant and deputy assistant administrators with science backgrounds.

First, their authority is important to signal real policy demand for science. Several participants noted the importance of such things as "clear," "active," or "compelling" demand for science input in order to energize and redirect science activities. One example of this type of champion was an agency leader who established a regular program of "dialogues" between the agency's executive team and its science programs. The dialogues were designed to convey management's interest in new science developments, but also to communicate managers' ideas and concerns in order to influence science program activities. Because the process was deliberate and personally involved the highest levels of leadership, it was described as having a significant long-run impact on the morale and decision relevance of the science programs.

Second, mid-level risk aversion and bureaucratic inertia were identified as barriers to science interactions. High-level leadership's blessing of new science input, and support for what might be considered risk taking, can help overcome resistance on the part of lower-level decisionmakers. The importance of supervisory "cover" for program managers worried about meeting status quo performance goals or other bureaucratic criteria was mentioned by a number of participants.

Third, executive authority over budgets and personnel allows high-level champions to put in place deliberate mechanisms for interaction. As noted earlier, deliberate mechanisms in the agencies don't exist as a matter of course. Rather, they tend to be created by individual leaders.[6] For example, one success story was explained in the following terms: It was successful "because this one guy designed [an interaction mechanism] in. It took leadership to create the positions … and it takes money and leadership to say [an interaction mechanism] is important." Another participant explained another success as arising "because a senior decisionmaker insisted on [science interaction] happening." Specific mechanisms include the creation of science-policy "positions" within an agency and routine lines of communication between science and program offices. Also noted as important by many was budget control. Budgetary authority is important not only to finance new positions and staff time for interactions but also to incentivize development of policy-relevant science. One participant described an agency leader's success in promoting successful interactions as a combination of (1) a decade-long effort to engage field resource managers with agency scientists and (2) the leader's ability to wield direct

[6] Once created, such mechanisms do not necessarily endure. High-level leadership changes frequently, as do the specific decision or science needs associated with a given initiative.

administrative control over the agency's science programs. In many cases, however, budget authority over federal science programs is disconnected from policy and program offices.

Fourth, in several cases, high-level champions were identified as being effective at creating relationships with and getting input from external science providers (from the academic, business, and NGO sectors).

Another theme that emerged was related to high-level "pressure"—from Congress, the courts, or the White House—that generates high-level agency attention. Several success stories were about efforts prompted by congressional action that authorized or required science-decision interactions on the part of agencies. One participant described a congressional mandate "with teeth" as creating a "captive audience of [science] demanders" within her agency. From the agency administrator on down the chain of command, there was clarity about the need to make the science-decisionmaking relationship work.

Other participants noted the power of litigation to induce more (or different) science input into agency decisions. One judge was paraphrased as telling an agency, "If you don't [figure out the science pertinent to the case,] I'm going to use a meat cleaver and decide myself." This statement prompted the agency develop a multiyear program to address the questions associated with that litigation.

One participant argued that the factor that makes the biggest difference is sustained attention from the Office of Management and Budget (OMB), in part because it signals the relevance of science to the White House, and in part because of OMB's influence over agency budgets. Also, one of OMB's core functions is to review analysis (scientific and otherwise) and its application to policy and budget decisions. That function makes OMB a relatively sophisticated reviewer of science input into decisions. In the (salty) opinion of one participant, "Sunshine is the best disinfectant … it's easy for [an agency] to bullshit itself. But if OMB is really paying attention that's harder." OMB's oversight role, combined with its political and budget authority, gives it the ability (at times, anyway) to stimulate improved science-decision interactions from the agencies.

Finally, several participants attributed successful science-decision interactions to the political importance of the decision at hand. High-profile issues generate high-profile attention from the White House and Congress, which in turn puts pressure on agency leaders to bring their best managers, communicators, and scientists to the problem. In such cases, agency leaders were described as having "an incentive to get good people in those roles" because it would be "painful to fail." We turn now to the importance and characteristics of such "good people."

Science-Decision Stewards

The second key component of success, described over and over by participants, is a day-to-day leader able to motivate and manage science-decision interactions within the agency. Most of the success stories featured a single individual who acted as a catalyst, liaison, and knowledge manager. Several successful stewardship figures were mentioned repeatedly, reinforcing the impression that to date, success is attributed more to successful individuals than to a more institutionalized approach.

Who are these successful stewards? Some were quite senior, others less so. They were rarely formally trained in interdisciplinary science management or science-to-policy management skills.[7] Most, but not all, had some science background. Many were agency PhD scientists who had transitioned into management roles over the course of their careers. Many had worked their way up from field office positions where they applied science to more resource management issues.[8] Beyond scientific credibility, several participants noted the importance of choosing stewards who "understand the pressures of leadership" because "the more politically or managerially sophisticated they are, the more aware they are of the pressure points" for decisionmaking.

Other successful stewards were identified as well-known senior figures who may have retired from agency work or other high-profile positions (e.g., as legislators or NGO leaders) and who were personally committed to a particular decision or natural resource issue.

Stewards were described as successfully performing three key functions: identification of pertinent science capacity and personnel, science-policy translation, and management of an effective collaboration process.

Frequently mentioned was a successful steward's ability to *identify* pertinent, existing scientific knowledge and the best individual scientists to involve in the interaction. Stewards tend to have a broad knowledge of science capacities both within their own agencies and across government programs. Also, a set of participants emphasized successful stewards' ability to identify and cultivate input from the external (nongovernmental) science community.

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[7] However, several participants mentioned the training provided by the AAAS Science and Technology Policy Fellowship program as an exception.

[8] Scientists who provided technical support to field offices were often described as being less disconnected from practice, more aware of constraints on management, and thus better able to understand decision needs.

They tend to have broad cross-disciplinary and cross-institutional knowledge. (In principle, an agency's chief scientist would be well positioned to play this role, though only one of the successful stewards identified in our sample was a chief scientist.) Moreover, they tend to come by that knowledge via a history of personal relationships and interactions.[9] Those relationships allow them to identify not only pertinent science but also those scientists most "predisposed" to working effectively with decisionmakers. Even when a steward was new to an agency, he or she was described as being good at identifying the right scientists to bring to the table.

The *translation* of decision needs to the science community and science capability and results to decisionmakers is another important function. One participant described the stewardship role as being scientists' "eyes and ears in the policy process," "creating demand-driven engagements between policymakers and scientists," or "getting a decision problem on the science agenda." Successful stewards encourage administrators to communicate with scientists not only about decision needs but also about how scientific input will be used, including what has worked effectively in the past.

In other cases, translation flows the other direction: from the science community to the decisionmaker. Successful stewards help decisionmakers understand and appreciate the relevance of available science and perhaps think about their decisions in new ways. In some cases, this form of translation is used to advocate for new science programs and funding, pertinent to decision needs.

This translation function is related to the identification function, such as when stewards identify not just the most expert science professionals but also those who are the best translators and communicators. In several cases, stewards were described as science "filters," not in terms of censorship, but in terms of identifying the most decision-relevant level of detail, methodological rigor, and expressions of scientific uncertainty and consensus.

Finally, successful stewards are effective *managers of collaboration*. Stewards are responsible for the necessary—frequent and iterative—interactions between scientists and policy-oriented science demanders. That process requires sustained, deliberate management. They may also manage collaboration within and between agencies, effectively connecting and brokering resources and communicating science.

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[9] A virtue of repeated science-decision interactions is that it allows an agency to identify science staff best able to engage in policy interactions.

Also, decision-relevant science analysis often requires multidisciplinary or multi-institutional expertise. Thus, stewards also tend to be responsible for collaborations within the relevant science community, a community that often is dispersed across various line offices, programs, and agencies or includes science providers external to the government. This challenge should not be understated. Stewards may lack direct authority (financial or managerial) over relevant staff expertise. Diverse expertise is also often accompanied by diversity in methodology, models, language, worldviews, and approaches to data. Sustained, deliberate management is necessary to reconcile and coordinate that diversity. High-level leadership often looks to science-decision stewards not simply to deliver an answer, but to do so in a way that establishes credibility and, when possible, consensus. Successful stewards were described as having the management and interpersonal skills needed to address that challenge.

Finally, we conclude that effective stewards not only play these multiple roles but also have the ability to successfully navigate their agencies' complex bureaucratic and institutional settings and "work the system." Creativity and deep institutional knowledge are needed to adaptively respond to what are often unique bureaucratic opportunities and barriers.

Relationships and Trust

The importance of stewards' personalities was mentioned over and over. Successful stewards were described not only as good communicators but also as "trustworthy," "fair," "respectful," "inclusive," and good at face-to-face interaction. The ability to impartially listen and respond to conflicts and disagreement around science—as opposed to taking a more activist, one-sided stance on a science issue—was viewed as important by several participants.

Participants also frequently related issues of trust to the interaction process. The development of trust was depicted as a desirable by-product of repeated, long-term interactions between scientists and decisionmakers. In contrast, a lack of trust—and corresponding failures to productively engage scientists—was often explained by inadequate interaction among scientists, stakeholders, and decisionmakers. In regard to an unsuccessful interaction, one participant observed that "interactions with top influential individuals who were the decisionmakers had not been direct and had also been rare. … Had we had a face to face meeting, things may have been different." Several failures of agency science to influence decisions were explained by "a lack of relationships between scientists and stakeholder or management folks."

A lack of trust was also related to the emergence of what has been termed "combat science," in which political interests handpick and elevate science supportive of their predetermined policy preferences. One participant argued that Congress's lack of trust in agency science leads it to seek external science input and thereby generates the "problem of pocket science." Another described poor engagement between decisionmakers and scientists as "creating a generation of combat scientists." Participants viewed combat science as an unproductive approach to interactions. For example, several participants argued that combat science inhibits development of scientific consensus and that lack of consensus limits the influence of science on decisions.

Financial Resources

Not surprisingly, success stories typically featured an adequate and consistent funding source. Also not surprisingly, many attributed poor science-decision interactions in part to inadequate funding (for the interactions, for new science programs, and in support of external research).

As noted earlier, high-level leadership and science demand are important in part because they are accompanied by budget authority: budgets not only to support science but also for the management of science-decision interactions. Several success stories featured significant amounts of dedicated funding, which both enabled activity and signaled that science-decision interactions were a leadership priority. Budget flexibility played a role in several cases, where an agency was able to reallocate funds when a collaborative opportunity arose. Others mentioned the inability to reallocate funds as a barrier to effective interactions. Most successes were financed with federal dollars, but a couple of cases also featured cofinancing involving, for example, state governments. One participant felt that public-private partnership financing of decision-relevant science deserves more attention by agencies.

In general, adequate funding goes hand in hand with high-level policy demand for science. However, several participants called attention to the budget process itself. The budget cycle can influence whether science-decisionmaker interactions last long enough to develop trust and mutual understanding. Durable budget authorizations (those likely to persist over a period of years) were mentioned by several as being important. One success involved authority for a series of 3-year-long research programs that were rotated around an agency's regions, in a way that facilitated learning and collaboration across those regions as the program was deployed over time. Another involved a congressionally authorized 10-year-long policy-driven research endeavor. In contrast, several participants cited continuing resolutions, instead of the regular annual appropriations process, as being detrimental to the iterative planning and long-term research needed for successful interactions. Travel restrictions associated with austerity measures and continuing resolutions were also cited as a barrier to science-decision interactions.

Timing

Adequate time was mentioned as an enabling factor for good integration of science in decisionmaking. Participants spoke of "timing mismatches" and the time frames of science being "very different from the time frame for regulation and policy." For example, one participant lamented a situation in which a new regulatory rulemaking, with significant political backing, was launched at the same time that the agency's pertinent science efforts were just getting under way. In the participant's view, if more time had been available, there would have been "a ton of science to build a credible case" for the regulation. But because there wasn't, the regulation was (and continues to be) shelved.

New congressional legislation or a new presidential administration's priorities are often difficult to predict and driven by a short-term political calendar. Similarly, court-imposed deadlines associated with settlement agreements and consent decrees generate demand for quick-turnaround science.

In a few cases, these "short fuses" were viewed as a positive driver of science-decision interactions because they "forced" a scientific consensus and generated hard deadlines for the science community. And indeed, some participants identified successful interactions achieved during short time periods. However, those examples were the exception and depended on other factors. For example, one short-fuse case serendipitously benefited from a tight match between a relatively clear, simply policy question (involving risks to a specific species) and the existence of an established group of scientists with abundant data and stakeholder relationships going back years. Another short-fuse case presented a clear, geographically confined policy decision that was also one of significant, immediate political importance to the Office of the President. The case's political salience generated a distinctively flexible, well-financed, and timely response.

However, the general view of participants was that better science-policy integration requires longer (multiyear) time frames to develop relationships between science demanders and suppliers, reprogram for or otherwise solicit evidence, and generate adequate scientific consensus and legitimacy. In the words of one participant, "Mediation for agreement over long time frames is a preferred and promising way to improve science-decisionmaking interactions."

A Typology of Science-Decision Interactions

Federal science-decision interactions exhibit a great deal of diversity. One aspect of that diversity relates to who is prompting the interaction. In some cases, decisionmakers prompt the need for interaction. In other cases, science does so. The following typology was revealed by our interviews.

Decision Leads, Scientific Community Responds: Scientific input is needed to inform an existing decision context. This is often termed "demand-driven" science. Policymakers recognize that scientific analysis and input are desirable or required to inform a decision. The demand may be urgent or extend over much longer time frames, depending on the decision context

Science Leads, Decisionmakers Respond: Scientific findings present an imperative for new or refined policy or decisions. The science may emerge unexpectedly or as a result of long-term research investments, with implications important enough to compel a policy response.

Science Leads, Agencies Create Programs: Scientific or technological developments create an opportunity to provide information that will inform multiple decisions, potentially over long durations. Translating these developments into federal programs can lead to sustained capacity to inform decisionmaking.

Science and Stakeholders Coproduce Knowledge for Decisionmaking: Sustained, often regional organizational structures link scientific capacity and stakeholders to develop highly relevant information to inform decisionmaking. Close proximity to where decisions are made and who will be affected often create a strong incentive for a transparent process and successful outcome.

4. The Alignment of Decision Needs and Science Input

A consistent theme from the survey was that successful science-decision interactions require a kind of matchmaking, between the questions asked by policymakers (demand) and the questions scientists feel they can legitimately address (supply). In a few of the success stories we heard, policies and laws were described as having decision-relevant science questions already "cooked in." More often, however, participants described a need to work through the alignment of policy-relevant and scientifically answerable questions.[10]

A central benefit of high-level leadership, stewardship, and deliberate, durable science-policy interactions is that they allow decisionmakers to say, "This is what we need," and scientists to say, "This is what we can provide," and then identify areas of overlap. Participants

[10] This underscores Sarewitz and Pielke's observation that "in contrast to the canonical portrayal of fundamental science contributing to application because it is free to advance in isolation from consideration of application, studies of technological innovation have often shown exactly the opposite—that it is the awareness of potential application and utility that ensure the contribution of fundamental research to innovation" (2007, 8).

highlighted three broad issues related to alignment: specificity vs. ambiguity, facts vs. values, and certainty vs. complexity.

Specificity vs. Ambiguity

Several participants described success as being related to specific, incremental, or limited science applications, as opposed to more ambiguous, general, or diffuse science questions. Overly diffuse science questions were related by several participants to "grand" initiatives, some mandated by Congress, where the demand may have come from diverse outside advocates (such as NGOs, special interests, or philanthropies). These efforts generated science questions, and conclusions, that were viewed as not closely enough tied to agency missions and authority to be actionable. In contrast, participants regularly noted that success was associated with processes that allowed policymakers and scientists to clearly "identify," "form," "define," and "specify" policy-relevant science questions.

Facts vs. Values

Another theme was the importance of separating fact-based empirical questions from value-based political questions. For example, difficulties can arise when scientists are asked to define what is environmentally "healthy" or "desirable," since those definitions implicitly involve broader ethical and political judgments. To be clear, participants did not have a problem with scientists introducing new opportunities or problems into the policy agenda. Rather, the concern is with the intermingling of fact-based and value-based decision input—intermingling that can undermine trust in science input.[11]

Several participants drew a distinction between the broader social questions that arise when we produce new laws and regulations and the science questions that arise when those rules are implemented. The former, questions relating to laws and regulations, typically involve deliberation around and resolution of value conflicts. Science questions relating to specific management guidance, targets, standards, and so forth arise more often during the implementation phase and are constrained by the values reflected in the overarching rules.

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[11] We also note that the distinction between facts and values is not always perfectly clear. For example, expressions of scientific consensus intermingle facts with values related to the meaning and definition of "consensus." The way facts are framed and given context can also muddy the distinction.

The distinction between rules-related questions and implementation-related questions can help policymakers and scientists clarify roles. However, several participants noted a problem that arises in some cases where science is the sole determining factor for a policy decision (perhaps because of a statutory mandate). In such cases, "the science" can become a proxy for political conflict. That can lead to the problems of combat science described earlier, where it becomes more difficult to establish scientific consensus and useful input. These participants argued that the science-decision process would improve if there were clearer political accountability for the value conflicts in play, thus taking value-laden judgments off scientists' shoulders. Some participants argued that inclusion of more nonscientific decision criteria in statutes, such as consideration of costs or other social outcomes, would have a similar salutary effect. Perhaps counterintuitively, inclusion of nonscience factors in decisionmaking was perceived by these respondents as being good for scientific debate, learning, and impact, because it helps isolate the scientific question from values-based conflict.

Also, several participants noted that as scientists become more involved in science communication and policy engagement, and as more scientists are put in federal leadership roles, the line between independent, objective science and advocacy can blur—in perception if not reality. Training of scientists, and the opinion leaders who use science, could help sensitize them to the implications of being seen as advocates in a polarized political environment.

As a general rule, participants felt that adversarial decision contexts inhibited successful science-decision interactions because they inhibited the development of scientific consensus necessary to decision relevance, and also because adversarial contexts are often ones in which science is being used not to inform, but to justify decisions after the fact.

Certainty vs. Complexity

As a broad generalization, decisionmakers tend to desire certainty, while scientists see, and are more comfortable with, complexity and ambiguity. According to one participant, "Researchers see much more complexity than is useful to management." Decisionmakers tend to complain that scientists underappreciate the rigidities, constraints, and boundaries associated with policymaking, management, and implementation. For example, one participant described the challenge of setting water management rules to reflect temporal variability in water availability and demands in the face of stakeholder pressure to "flatten out the rules" because the stakeholders "can't live with the up and down year after year, month after month."

Science presented to decisionmakers was often described as too complex, too detailed, too abundant, or too technical. One participant complained that decisionmakers get "ten pages of analysis, not three bullet points." Others complained that they see "ten thousand pages" of "incomprehensible" analysis or "huge reports that have only a small amount of information that is useful." Another complained about policy presentations that featured mathematical equations and said that "if you let the scientists do the talking it doesn't go well, you're always screwed." Another participant noted that "uncertain messages" undermine trust in the science. Instead, there is demand for readable "distilled science" and "summaries and consensus statements tied to particular management decisions." One described a manager's requirement that any science analysis be presented in no more than 10 pages. Among this group, there was a feeling that short, readable summaries should not be equated with "dumbing down" the science.

While simplicity and certainty are valued in the decisionmaking realm, scientists tend to—accurately—view environmental systems, processes, and outcomes as complex and uncertain. They often push for uncertainty to be reflected in analysis or even built into "adaptive" approaches to management. One participant described uncertainty as a positive feature of analysis because depictions of uncertainty may be necessary to achieve scientific consensus. Also, the reality of uncertain environmental drivers and outcomes can generate support for flexible, adaptive trial-and-error approaches to management that stimulate new science and learning. Another participant described situations in which policymakers were able to "cherry pick" among possible policy outcomes because of uncertainty in the science.

This divergence in needs and perspectives creates a need for balance. Overly simplified science that does not reflect uncertainty can strike scientists as illegitimate. Scientific input that emphasizes uncertainty and ambiguity can strike decisionmakers as unhelpful. Successful stewards and good science communicators were described as being able to convert complex, uncertain science into more focused, concise messages that retained scientific legitimacy. Another way to strike an effective balance is for decisionmakers to contemplate whether the questions they are asking invite complex, ambiguous, or uncertain answers.

5. Place-Based Science-Decision Interactions

A large number of participants associated successful interactions with place-based, local, or field-level decision contexts. Most federal agencies are subdivided into regional offices, and a great deal of federal decisionmaking takes place at regional scales. A notable number of success stories involved field-oriented science programs geographically co-located with regional-scale decisionmaking. Many participants expressed the sentiment that the "geographic relevance" of place-based environmental decisionmaking presents more tangible, practical, and focused decision needs. That tangibility and focus can make it easier to align decision needs with science capability. One participant argued that "the easiest way to reach a decisionmaker is to go local, go to an actual community."

Another consequence of place-based decision contexts is that they tend to encourage, if not require, interaction between multiple agencies. Practical, place-based decisionmaking works against "siloed" science input. The pressure to interact and resolve practical issues was seen by several participants as contributing to collaborative agency relationships. Successes were associated with a "partnership culture" or "culture of contribution," though such a culture needs to be developed and reinforced by leadership and science-decision stewards.

Place-based decision contexts were also associated with relatively strong, durable stakeholder relationships. According to one high-level policymaker, "If I were looking to invest in science that is impactful I would look for multistakeholder science."[12] Another argued that when both research and management are decentralized, it puts both "close to the real resources" and leads to science "engagement in [management] projects" and "continuous dialogues." All of this facilitates "good relationships with the science community in the field."

"Stakeholder science" involves diverse scientific partners external to government who can help identify relevant data, existing studies, and experts in a way that complements federal capability. It also involves listening to communities and other groups affected by decisions. That input helps reveal trade-offs and conflicts early in a science-decision interaction and thereby helps identify science gaps, needs, and pertinent areas of consensus or disagreement. Given enough time, place-based stakeholder science was described as helping resolving conflicts by developing trust and consensus among science and decision participants. According to one (headquarters-level) participant, this kind of interaction "generated a collaborative view of [the] challenges and helped build a consensus around conservation [approaches]," whereas without such interaction, there would have been "more conflict, fewer solutions on the table, [and] fewer areas of agreement identified on where to focus money and attention." One participant also noted that stakeholder partnerships can help provide significant co-funding for decision-relevant science and that "public-private funding opportunities are something we do not think enough about."

[12] We note, however, that one participant referred to the "too many stakeholders problem," which he associated with decision paralysis due to "varying levels of knowledge and oversimplification of issues."

Cooperative governmental institutes and laboratories co-located with universities were described as helping build relationships and communication with the external science community. Field office science capacity, because it is directed at local issues, was depicted as fostering relationships and collaboration with private sector, NGO, and other stakeholders—and in a way that helps direct science input into decisionmaking needs.

6. Internal vs. External Science and Review

Do successful science-decision interactions typically involve federal, as opposed to external, scientists? In general, yes. According to one participant, "To come in from outside with science is nearly impossible." Others noted the different motivations and "cultures" of federal versus academic scientists.

While most federal scientists have academic research interests, they also tend to have tighter links to federal science demanders, relatively speaking. Because academic (nonfederal) scientists are one step removed from the decisionmaking process, they often lack a specific understanding of how to be useful.[13] Several participants expressed the view that academics don't pay attention to practical applications because such science is not viewed as pathbreaking, publishable, or important within academia. In contrast, federal scientists, particularly those associated with specific management and field programs, do a better job of responding to decision needs.[14] One participant preferred internal expertise because "federal scientists have an understanding of [land] management and an applied focus—their science fits." More prosaically, others noted that federal scientists are "easier to find" when a question arises.

That said, several success stories did involve external scientists. One participant noted that his search for science support "went all over the place" (including to universities, NGOs, and think tanks) and that he didn't see much distinction between internally and externally sourced research. Another noted that external science collaborations usually take time to develop, require support over long time frames, and arise when federal scientists lack the capacity to address critical questions in the early stages of a program. The involvement of external science partners also requires federal leadership to promote and sustain the interactions.

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[13] This is a crude generalization. First, not all federal scientists know how to be useful. Second, participants noted that many nonfederal scientists work effectively with decisionmakers.

[14] Federal scientists embedded in more purely research-oriented offices, however, were thought to be more akin to academic researchers, disengaged from decisionmaking.

A distinction was also drawn between "NGO science" and more deliberative science, whether internal or external. NGOs were praised by one participant for providing "timely science" but with the important caveat that "what they have is imperfect." This participant noted that agency science takes too long because it is concerned with "perfect accuracy" and that can undermine the influence, budgets, and reputation of federal researchers among policymakers. This attitude was caricatured as "What is your value [federal scientist] if you tell us 'we can't answer for 6 months'?" As noted earlier, the time available to align policy demands and science supply is a major predictor of success.

External science input was also seen as critical to the review of federal science. Nearly all participants saw strong peer review as an essential part of any science-decision interaction. Both interagency review and external peer review were recommended. One respondent mentioned the conflict of interest that can arise when agency scientists are asked to review science conducted by others in their agency. Several participants noted the perception that federal scientists are "partial" or "biased" and that nonfederal scientists are more independent (a perception we view as pure conjecture). One participant indicated that even external peer review may be seen as biased if the review is funded and managed by an agency. Another participant attributed her agency's "history of science failures" to a lack of peer review, a failure that in her view has been addressed by "ingraining peer review to the lowest levels of the agency."

Several peer review alternatives were mentioned. National Academy of Science (NAS) and National Research Council (NRC) reviews were perceived as generating scientific credibility and influence, including with Congress. One participant said that this is due in large part to the inclusion of divergent views in the review process. On the other hand, another participant suggested that while the NAS and NRC help with "big conflicts," they did not always provide the right "level" of science input. Several pointed out the length of time and expense associated with NAS and NRC reviews. Federal Advisory Committee Act (FACA) reviews were also mentioned as a great way to "get external eyes" involved, though some felt that FACAs were expensive and slow and not always good at fostering "give and take" among federal scientists, policymakers, and external experts. Another respondent noted that peer review does not always result in the review's conclusions being adequately addressed in subsequent analysis and suggested that an external "referee" be appointed to ensure that agency scientists incorporate peer reviewer recommendations after the review is concluded.

A virtue of the stakeholder science decision contexts described in the previous section is that they foster continuous, long-term external interactions. Although not necessarily considered a formal peer review process, these interactions have much the same effect.

A general theme was the desirability, and rarity, of "neutral intermediaries" with an institutional reputation for bipartisanship and objectivity. One participant noted that he can't use input if "it's only NRDC or a stakeholder group doing it." Another wished for independent, nonpartisan NGOs to "serve as a platform for putting diverse experts together, presenting the [federal] science and modeling work, and to kick the tires." Examples of specific NGOs capable of playing such a role were provided, though some participants expressed concern that the number of politically independent, science-based NGOs is shrinking. No particular barriers to such external institutional relationships were noted.

7. Investment in Forward-Looking National-Scale Data and Science Synthesis

Perhaps the greatest gap between science availability and demand arises in contexts where a national policy issue requires scientific input. Requests from Congress or the Executive Office of the President commonly seek some kind of broad national insight or analysis. But a comment consistently heard from policymakers was that they couldn't find "any kind of national estimate" or that it was "hard to tie science to national-scale assessments because science tends to be place-based." Participants related this problem to scientists' incentives and desire to do "detailed studies of one place," rather than conduct evaluations at larger scales. According to one participant, "Academics don't have the motivation (to do national scope research)" and "[the agency's] scientists do a really small detailed study of one place, but aren't thinking about national-scale stuff and what programs need." Another complained, "What am I supposed to do with this [place-specific] science? It happens all the time." Yet another called for more "distilled science" ("That would be amazing!") as opposed to primary research whose broad applicability can be difficult for policymakers to evaluate. Several expressed a sense of disconnection between the level of geographic holism required of data in a decisionmaking context and the fragmentation that dominates scientific research.

The problem is compounded when national-scale analysis is required in time frames denominated by months rather than years. One high-level political appointee described the common difficulty of getting science analysis in a three- to six-month time frame. As he noted, in those time frames, "you can't do 'real sampling' or 'new science,' you have to rely on synthesis and proxy measures." Several participants mentioned the lack of decision-ready syntheses of science issues. According to one manager, there is a bias against synthetic, applied science work because it is considered "not academic," and "the idea that synthesis is not science or is not valued drives me crazy."

Others described a need for policy-ready science syntheses because “there is so much research going on—agencies simply can’t keep up with what they need to know.” One participant described the challenge of “identifying and getting access to data and science that is already out there.” Another said, “I wish I knew what is already out there, I don’t know what is already known.” A specific suggestion was the creation of positions and cultivation of staff “whose job it is to know [the scientific landscape]. That doesn’t happen accidentally.”

Also mentioned was the lack of integrated, cross-disciplinary analysis necessary for decision relevance. In contrast, several successful science-decision interactions were explained by their ability to integrate diverse forms of analysis, including climate science, engineering, hydrology, and ecology. Other participants called out the importance of integrated natural and social science analysis. “It’s the ecology and economics bundled together that can really move decisions,” said one.

In general, success stories tended to feature the use of “existing science” or existing local capacity to do needed science. The challenge, given mismatches in timing and the need to develop science analysis over longer time frames, is that for most of the success stories, the “existing science” was initiated for more purely intellectual reasons years before there was an applied demand. One manager described policy decisions as reflecting “accumulated scientific intuitions” developed over years, both internally and externally.

Several described the need to encourage the right amount of ongoing “risky” and “experimental” science, which, while potentially irrelevant, could be the foundation for policy needs in years to come. According to one participant, the balance between relevance and the need for long-term investment in fundamental research requires “prescience” on the part of science and policy managers. Another participant from an agency research program described the challenge this way: “When people say we need to be responsive to program offices, that’s wrong. The right relationship is a long-term relationship. Is this relevant to you today? No. Next year? No. It’s the long-term strategic vision that needs to be better. People who can have that long-term vision on the client and provider side are rare. And the incentives don’t support it. On the program side, the capacity to do something right now is what people get rewarded for. But the capacity to respond today reflects decisions made 10 and 20 years ago.”

A program office participant related this problem to budget allocation and authority issues: “Should I run my programs or do new research? It’s very tough to make the argument to do more basic research even if it’s directly tied to a regulation. Also people say, isn’t that the science program’s job?” On the other hand, the same participant described her policy office’s commitment to long-run science despite the disincentives. She detailed efforts to invest in analysis that will be “tweaked and improved” over time so that “at some point in the future they can come back to the rulemaking and the science will be much better established.” “Career folks” were “totally getting this model” of science-decision coordination, even though the model was hampered by a lack of dedicated long-term funding.

8. Summary and Recommendations

Study participants were able to identify successful science-decision interactions and help us identify factors common to these successes. Agencies and their nonfederal partners can build on these examples and lessons to make successful science-decision interactions more common.

Our survey of experiences suggests that interactions will not be successful absent deliberate attention to the challenges of communication and coordination between scientists and decisionmakers. Deliberate attention involves the creation of administrative processes, budget authority, and professional positions dedicated to interaction. This kind of institutional approach remains rare within agencies. A lack of institutionalized mechanisms regularly leads to both poor design of science input and problems with the budgeting, planning, and implementation of science initiatives. The balkanization of policy program and science offices into their own separate administrative and budgetary spheres exacerbates the difficulty.

The institutionalization of science-decision mechanisms requires that high-level policy leaders lend their authority to the budget and personnel allocations necessary to deliberate mechanisms for interaction. Such executive leadership goes beyond redirecting resources. It also energizes scientific input by underscoring its potential decision relevance and helping overcome mid-level resistance to science input due to risk aversion and bureaucratic inertia.

We also highlight the important role of science-decision stewards with the personality and expertise to foster collaboration. These leaders are able to motivate and manage science-decision interactions within agencies. Most of the success stories identified featured a single individual who acted as a catalyst, liaison, and knowledge manager. In general, successful stewards exhibited deep institutional knowledge and the ability to creatively navigate their agencies’ complex bureaucratic and institutional settings. More specifically, stewards were described as successfully providing three key functions: identification of pertinent science capacity and personnel, science-policy translation, and management of an effective collaboration process. In performing these functions, stewards develop the building blocks of success: relationships and trust, the synthesis and communication of scientific input, and the matching of science capability to decision needs.

In our view, administrative reforms designed to broaden or institutionalize science-decision mechanisms should focus on these science-decision stewards. First, they should identify, develop, and reward such managers. Second, they should provide stewards with an administrative framework that acknowledges the importance of a deliberate, rather than ad hoc, approach with sufficient authority and budgets to meet the challenge of managing science-decision interactions. Such a framework should, for example, treat science-decision interactions as having distinct managerial aspects. To be effective, science-decision stewards must be able to call on and manage dedicated budgetary resources and be invested with authority adequate to motivate collaboration on the part of both policy and scientific professionals within the agency. We also conclude, however, that a deliberate administrative framework should not be equated with a rigid framework that stifles creativity and flexibility. The likelihood of success is greatly enhanced by a deliberate framework that also gives good managers the license to build new networks, adapt, and innovate.

Is the appetite strong enough for such administrative reforms? Our conversations revealed to us a broadly held craving for improvement and a sense that passive approaches to science input (in general, the status quo) are not effective. Also, nearly all participants conveyed the sense that science-decision collaborations are difficult and require specific attention. Clearly, however, any administrative reform faces budgetary and administrative headwinds. Reforms will require both the involvement of high-level policy executives who see the need for improved science input and insight from managers who have already successfully shepherded such activities. Luckily, a pool of such leaders was revealed in this activity.

Agencies could take additional steps to hire staff with the traits and skills important to science-decision collaborations and management. Job descriptions and position announcements could easily emphasize the importance of network building, natural and social scientific training, interdisciplinary thinking, and communication skills. Equally important is the way staff members are evaluated and rewarded. Performance plans and criteria could include network-building efforts, scientific and stakeholder outreach, and demonstration of science impact on decisionmaking. Leadership training programs could be developed to build relevant skills.

Greater "colocation" of scientists, stakeholders, and decisionmakers (physically and administratively) should be considered. Many of our success stories emerged from contexts where colocation already occurs: around place-based natural resource policy collaboration, for example. It includes creating opportunities for scientists to work directly with decisionmakers outside of the beltway, as well as nonagency scientists. Inside the beltway, decisionmakers also benefit from interactions with regional and local scientists and stakeholders. To be clear, this goes beyond putting agency scientists on university campuses (a practice that may in fact encourage scientists to become more academic in orientation and thus less in touch with decision needs).

A number of participants also highlighted the important role already played by various "boundary organizations." These are distinct from federal program offices or science programs. Participants identified examples from state government and the NGO, philanthropic, and academic sectors. Boundary organizations tend to be multidisciplinary in their approach to environmental issues, value independence over advocacy, and regularly engage in facilitation and synthesis. The key characteristic, however, is a focused—deliberate—mission to improve linkages between science and policy. While relatively uncommon, participants noted that such organizations already exist and could be drawn upon more extensively by federal agencies.

Alternatively, similar institutions could be created within agencies to perform a similar function. One participant suggested agencies "establish a separate, disinterested decision analytic group [with expertise in both science and public policy] that would operate independently of the science research community" to provide synthetic policy analysis for decisionmakers.

Quick turnaround of scientific input on national-scale decisions poses the greatest challenge to effective science-decision interaction. These contexts generate the greatest contrast between decision needs and science's ability to deliver, given that science is deliberative (and thus relatively slow) and tends to collect and apply site-specific, local, or regional data, not national-scale data. In these contexts, having the "right science, right now" requires existing capacity in terms of data, models, and science synthesis. Having that capacity requires prognostication on the part of science program managers and the ability to align science program investments and personnel around issues likely to be policy-relevant in 5, 10, or 15 years' time. That is a heavy lift for any institution. But the desire for ready-to-deploy national-scale assessment capabilities was often articulated. Our sense is that greater attention to this need and mechanisms to coordinate longer-range planning by specific program and science offices would be beneficial.

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