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# Reversing Nuclear Opposition: Evolving Public Acceptance of a Permanent Nuclear Waste Disposal Facility

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Nuclear facilities have long been seen as the top of the list of locally unwanted land uses (LULUs), with nuclear waste repositories generating the greatest opposition. Focusing on the case of the Waste Isolation Pilot Plant (WIPP) in southern New Mexico, we test competing hypotheses concerning the sources of opposition and support for siting the facility, including demographics, proximity, political ideology, and partisanship, and the unfolding policy process over time. This study tracks the changes of risk perception and acceptance of WIPP over a decade, using measures taken from 35 statewide surveys of New Mexico citizens spanning an 11-year period from fall 1990 to summer 2001. This time span includes periods before and after WIPP became operational. We find that acceptance of WIPP is greater among those whose residences are closest to the WIPP facility. Surprisingly, and contrary to expectations drawn from the broader literature, acceptance is also greater among those who live closest to the nuclear waste transportation route. We also find that ideology, partisanship, government approval, and broader environmental concerns influence support for WIPP acceptance. Finally, the sequence of procedural steps taken toward formal approval of WIPP by government agencies proved to be important to gaining public acceptance, the most significant being the opening of the WIPP facility itself.

**KEY WORDS:** LULU; nuclear waste; risk perceptions

## 1. INTRODUCTION

On March 26, 1999 the first truckload of radioactive waste was delivered to the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico. The opening of the WIPP, the first licensed deep-geologic radioactive waste disposal facility, occurred after 25 years of often-strident scientific, legal, and political controversy. Much of this controversy appears to have been firmly grounded in perceptions of the WIPP as a health and safety risk to those proximate to the facility. This article analyzes the evolution of public perceptions of WIPP, based on data from a series of 35 statewide public opinion surveys conducted in New Mexico over the decade leading up to the opening of WIPP. The primary question we address is whether perceptions of the localized risks posed by WIPP played a central role, and whether these perceptions were attenuated by the extended policy debate. The implications of this case are substantial, as developed countries struggle with the dilemma posed by the need for siting hazardous facilities (of which nuclear waste repositories are only one example) in the face of deep apprehension and strong opposition.[1]

Locally unwanted land use (LULU) concerns are generally understood to reflect resistance to potentially hazardous facilities that are perceived to pose risks to local residents. Proximity to such facilities has been shown to generate opposition,[2] and in

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some cases to reduce property values near the site of the potential hazard.[3] Nuclear waste facilities are among those most likely to raise concerns by nearby residents.[4,5] Among some observers, self-interest is thought to be the primary motive for LULU opposition, wherein residents reject a facility because their expectations of localized losses outweigh prospects for some larger public good.[6] Opposition to potentially hazardous facilities has also been attributed to distrust, concerns about broader environmental threats,[7] and even to the dynamics associated with quantitative analysis and communication of risk.[8] However, taken as a whole, previous research indicates that LULU concerns provide the primary explanation for nearby residents' responses to potentially hazardous facilities.

What role did LULU concerns play in the case of the WIPP? Over the course of the policy controversy, a vocal coalition of the local officials and residents of Carlsbad (the town closest to WIPP) were consistently in favor of the project. Qualitative accounts of the debate suggest that the most strident public opposition was based well away from the site in the Santa Fe and Albuquerque areas.[9] What was the relationship between proximity to the facility and perceived risk or opposition? And how did that relationship change over time? Was proximity to the facility the primary driver of perceived risk and opposition, or did other factors play a larger role?

### 1.1 The Waste Isolation Pilot Plant

When a proposed waste site near Lyons, Kansas was abandoned in the early 1970s due to objections from Kansas state officials,[10] Carlsbad leaders saw an opportunity for economic development and invited officials from the U.S. Atomic Energy Commission (AEC) to examine the underground rock salt in and around Carlsbad.[1] Scientists from the AEC agreed that the deep layers of salt had the potential to be suitable for permanent storage of radioactive waste, and exploratory work began in 1974.[10]

Initially, New Mexico state-level officials were largely supportive of WIPP; however, that support eroded in the late 1970s following the nuclear power plant accident at Three Mile Island and efforts in the U.S. Congress to include highly radioactive spent nuclear fuel from commercial reactors in the waste that would be shipped to WIPP.[10,11] While state officials objected to emplacement of high-level waste at WIPP, they were more receptive to receipt of defense-related waste largely because the defense wastes were perceived to be less dangerous than the high-level commercial waste.[2] [10,11] As a result of procedural concerns and in an effort to resist being forced to accept high-level commercial waste, the state of New Mexico filed suit against the U.S. Department of Energy (DOE) in 1981.[9] As part of a "consultation and cooperation" agreement signed by the U.S. Secretary of Energy and the Governor of New Mexico shortly before the case was scheduled to reach court, the state of New Mexico received assurance of a formal role in the siting process.[3]

As the dispute with state officials was being resolved, environmental interest (and other) groups within New Mexico became increasingly engaged in opposing WIPP. Most prominent among them were "Citizens for Alternatives to Radioactive Dumping" (CARD, formed in 1978) and the Southwest Research and Information Center (formed in 1971).[12] According to McCutcheon,[9] many of the activists protesting WIPP were doing so on the basis of broad opposition to nuclear energy and nuclear weapons development, and distrust of government.

These developments constituted the opening salvos in what became an extended political battle over WIPP. Broadly speaking, environmental groups and some state elected officials formed an opposing coalition, and local Carlsbad officials along with representatives of the national laboratories (Los Alamos and Sandia) and the DOE lined up in favor of the facility. State officials were cautious about the developing program, but tended to defer to the federal government on defense-related programs and therefore avoided outright opposition to the program.[4]

[1] A timeline of events leading up to the opening of WIPP is in Appendix B (available online).

[2] The waste intended for WIPP did include some highly radioactive material, but the bulk of it is low- and medium-level waste. The technical term for the waste is "transuranic"—meaning that it consists of waste contaminated with radioactive elements that have an atomic weight greater than that of uranium (such as plutonium). One characteristic of such wastes is a very long half-life (the period over which half of the radioactive material will decay); for plutonium-239 it is about 24,000 years.

[3] New Mexico agreed to drop the lawsuit in return for agreements by the U.S. Department of Energy to provide periodic state review of WIPP studies, with provision for the state to return to court in the event that it was unsatisfied with the results of those reviews. It also provided assurance that DOE would address concerns about state roads and a number of other monitoring, health, and safety issues related to WIPP.

[4] To address state concerns, the DOE provided funding to New Mexico for a technical oversight group, called the Environmental

In the early phases of the policy debate, WIPP was not popular with the New Mexico public. As early as 1976, over a hundred people gathered at a local meeting organized by WIPP opponents.[5] [12] Furthermore, in 1978 and 1980 opinion polls in the press indicated that New Mexico residents opposed WIPP by a ratio of nearly 2:1.[9]

During the 1980s and 1990s the battle over WIPP appeared to take on an increasingly partisan tone. Senator Pete Domenici (R-NM) and Representatives Manuel Lujan Jr. (R-NM) and Joe Skeen (R-NM, whose congressional district included Carlsbad) were outspoken in support of WIPP. Democratic Representative Bill Richardson, elected in 1980, was stridently opposed to WIPP.[6] Senator Jeff Bingaman (D-NM) was "less enthusiastic" about WIPP than his Republican colleagues, but "willing to let it proceed as long as it could independently be shown to be safe."[9] Outside of New Mexico, Democrats in Congress pushed for oversight of WIPP by the Environmental Protection Agency (EPA), rather than allowing the DOE to handle both operations and oversight.[13] Over time the partisan character of the debate over WIPP came to coincide with ideological cleavages, with Democrats and environmental groups such as the Environmental Defense Fund and the National Resources Defense Council in opposition and Republicans and conservatives in Congress generally in favor.[12]

In October 1992 President George H. W. Bush signed WIPP legislation that included making the EPA the regulator of WIPP.[9] As required by that legislation, the DOE submitted a scientific and technical assessment of the WIPP site and facilities (consisting of a 21-volume technical report) to the EPA in October 1996,[9] detailing how the repository would meet with the regulatory standards specified by the EPA. The EPA formally accepted the DOE findings (after several iterations of queries and responses between the agencies), and approved the opening of the WIPP site in 1998. Finally, after a quarter century of controversy, wrangling over regulatory process, and extensive scientific evaluation of the site, WIPP began accepting shipments of waste in March 1999.

The WIPP case provides a nearly ideal test of the determinants of public support and opposition for that most dreaded of facilities—a nuclear waste repository.[5,6,14] Were perceived risks posed by the transport and storage of the waste, and the related LULU concerns, paramount? To what extent did partisanship and political ideology enter into the citizens' assessments of the risks of the facility? What role did broader environmental beliefs play? Did the unfolding of the process itself—in the form of regulatory approval and licensing of the facility by the EPA—have a discernable effect on perceived risks and public acceptance? And what were the effects of the onset of the shipments of nuclear waste for public opinion and preferences?[7]

The next section briefly reviews the literature on public responses to hazardous facility siting, and delineates a number of contending hypotheses concerning public opposition and support for such facilities. Then, using data from a series of 35 statewide telephone surveys of residents of New Mexico collected by the University of New Mexico between 1990 and 2001, we test those hypotheses using a set of time-series models. We draw implications both for public opinion theory and for the practical issue of hazardous facility siting.

## 2. LULU ATTITUDES AND OTHER EXPLANATIONS FOR FACILITY SITING OPPOSITION

LULU sentiments are often expressed by residents close to a potentially hazardous site, and are related to concerns about health, safety, and environmental welfare.[2,16–25] Among the most important factors related to LULU sentiments are the perceptions of the affected residents concerning the risks posed by the site, trust for the groups involved, and acceptance of the process of site selection.[2,14,16,26–28]

A range of types of facilities are prone to raise concerns about localized risks, including prisons, mental health facilities, landfills, incinerators, and

Evaluation Group (EEG). The EEG consistently reviewed and criticized the technical analyses of the safety of the facility and nuclear waste transport plans, but tended more toward "constructive engagement" over the analyses, rather than arguing for abandonment of the program.

[5] Opposition to WIPP by some local residents was evident (and made it to the pages of the *New York Times*), but was overshadowed by broad support by local leaders and a substantial majority of the area residents.[9]

[6] Later, as Secretary of Energy for the Clinton Administration, Bill Richardson supported opening the WIPP facility.

[7] Recent research[15] has suggested that public acceptance of *new* nuclear facilities near WIPP is less than that nationwide or elsewhere. Perceptions of WIPP itself have not been systematically measured for nearly a decade.

nuclear facilities.[4,17] Nuclear facilities (including reactors, waste disposal facilities, and the routes that connect them) tend to be perceived as the most risky.[4,5,29] The general understanding of opposition resulting from LULUs assumes that proximity is a central driving factor; proximity places the nearby residents at largest risk, resulting in greater concerns and opposition by those residents. Recent research has found that preexisting nuclear facilities may lead to greater support for new nuclear siting by nearby residents,[15] though the area surrounding WIPP had no significant nuclear activities prior to WIPP itself. Public perceptions of the risk posed by environmental hazards are also related to a number of individual-level characteristics, such as gender, education level, race, and income.[25,30–32]

Perceived risks may also stem from the perception that government officials cannot be trusted to competently manage the risks of hazardous facilities.[19] Slovic[1] argues that the American style of participatory democracy, when applied to potentially hazardous technologies, may amplify and polarize conflicting views about risks, and erode trust in the risk management capabilities of government. Indeed, conflicts over nuclear facilities like WIPP are expected to be the exemplar for the erosive conflict over risk assessment and management.[5] The general expectation is that lower confidence in government will increase perceived risks, and reduce support, for hazardous facilities.

Research on public responses to facility siting has added a number of wrinkles to the proximity-based understanding of LULU attitudes. Proximity can be positively related to acceptance of potentially hazardous facilities when local residents believe the facility provides offsetting localized or societal benefits.[4,27,29] Offsetting localized benefits might include employment, increased local tax revenues, and infrastructure enhancements (such as roads and schools). More generally, support is related to the perceived societal need for the facility.[4] Local residents may also be more inclined to favor a facility when employees of the facility are in their social network.[33] Familiarity with the activities and technology related to the facility also appears to decrease risk perceptions.[34–37]

While the provision of localized benefits might serve to mitigate opposition, the case is more problematic when localized benefits are absent or ill defined. Prior research has found that residents along hazardous materials transportation routes perceive themselves to be exposed to risk without compensating benefits.[32,38] Moreover, opportunities for development of familiarity that might be expected to reduce opposition near a fixed facility are (presumably) absent. Previous research has also found that people living along hazardous material transportation routes had increased perceptions of the risks posed by such materials,[39] and that property values along the route can be affected due to real and perceived risk.[3] Localized benefits on the transport route might, however, take the form of improved roads or expenditures on emergency response capabilities for communities along the route. In the case of WIPP, substantial investments were made to upgrade the state roads that make up the WIPP transport route. These included a major bypass route around Santa Fe, the site of some of the most fervent opposition to WIPP. In addition, the WIPP program included a substantial investment in emergency response capacities (including training and equipment for police, fire, and medical officials) in communities along the route. These efforts can be seen, in part, as providing localized benefits and greater program familiarity to officials and residents along the WIPP route. Based on the findings in the broader literature, however, we would presume that the intermittent nature of the transport passage and diffuse opportunities for economic development benefits would militate in favor of greater perceived risks and opposition to the WIPP program along hazardous materials transport routes.

Of course, LULU-based attitudes need not be the only explanation for siting opposition. In other cases broader environmental attitudes have been shown to influence acceptance and support.[6,8,37,40,41] General political attitudes can also shape support or opposition to potentially risky technologies.[42] This may be of particular importance in the case of WIPP, in which partisan divisions colored much of the policy debate.[9,12]

Public perceptions of risk and policy preferences may also respond to events and policy developments at specific points in time. Overall support in the United States for nuclear energy declined following the Three Mile Island nuclear power plant accident in 1979, and dropped again after the Chernobyl nuclear reactor disaster in 1986.[43,44] The general opposition to nuclear energy appeared to spill over to WIPP, apparently leading to broad public opposition to the repository in the late 1970s and 1980s.[9–11] What is interesting for this analysis is the manner in which steps in the subsequent process of policy adoption and implementation of the WIPP may have

incrementally moderated the initially low approval for the facility. Over the course of the decade before WIPP opened, several highly publicized legal and regulatory hurdles were cleared, and these events may have influenced both perceptions of risk and acceptance of WIPP among residents of New Mexico. Some of the important events that took place during the early to mid-1990s include (a) the resolution of the regulatory debates over testing and land use, (b) formal designation of the transportation route, and (c) the designation of the EPA as the WIPP regulator. This allowed DOE to submit the WIPP license application to the EPA, and it was the provision of that license by the EPA that some believe may have had the largest impact on public perceptions.[8] And finally the formal opening of WIPP, and the receipt of waste without mishap, may have also affected public acceptance of WIPP.[9]

In sum, the literature provides a set of quite reasonable yet distinct explanations for public opposition (or support) for hazardous facility siting. Some of these are conflicting, and others can be seen as theoretically complementary. We distill them into seven broad categories:

1 Demographic attributes, including gender and minority status, should contribute to perceived risks and facility opposition.[30,31,34]
2 Proximity to the facility and the transport route should be positively related to perceived risk, and to opposition to the facility.[2,19]
3 Support for the facility should be positively related to perceived benefits and familiarity; such perceived benefits would be less likely along a transportation route than near a fixed facility.[3,27,38]
4 Positive perceptions of government—in particular, greater approval for governmental performance—should reduce perceived risks and, therefore, opposition to the facility. For purposes of this analysis, an overall measure of the performance of state government is used rather than a measure of trust.[47–50]
5 Political ideology and partisanship should be related to policy support for WIPP. In particular, we expect Democrats and liberals to express greater opposition than Republicans and conservatives.[16,42]
6 General environmental beliefs will influence both the perceived risks posed by WIPP, and policy support. Those who are more concerned about the general state of the environment will perceive greater risk from, and express greater opposition to, WIPP.[8]
7 Policy support will be influenced by developments in the policy process, as (a) formal regulatory assessments conclude that the facility can safely contain the waste, (b) as regulators complete the licensing process, and (c) as the facility opens for the receipt of waste, public support should increase.

## 3. DATA AND METHODS

This article draws on a unique series of 35 statewide surveys of the New Mexico public collected by the University of New Mexico's Institute for Public Policy (IPP) over the period of 1988–2001. The survey series is described, along with full question wording, in Appendix A (available online). To standardize the time periods for the series, we combined the quarterly surveys, resulting in a data set for spring and fall in each year. Survey response rates for the most recent surveys (fall 2000 and spring 2001) were 59% and 63%, respectively.[51]

The first question, asked from 1990 through 2001, considered whether the site was perceived to be safe enough to open. The data were coded so that responses were given a value of 1 (WIPP is safe enough to open as is or needs only minor changes to make it safe) and 0 (the WIPP is unsafe and should never open, or could be only be made safe after major changes). Responses to this question, referred to hereafter as WIPP Support, provide 25,543 observations across 22 six-month time periods. The mean values for this series are shown in Fig. 1.

In the fall of 1992 a second question was added to the WIPP series concerning the perceived risk of transporting radioactive waste to the WIPP facility. Responses were coded from 1 ("no risk") to 5 ("extreme risk"). Responses to this question, hereafter referred to as WIPP Transport Risk, provided 17,958

[8] Bill Richardson, Secretary of Energy when WIPP opened, opined in 1999 that: "As an issue, WIPP faded after the EPA [certification], and I am convinced it's not a very important political issue or environmental issue in New Mexico."[9:187]

[9] One can conjecture a kind of nuclear facility siting "bow wave effect" in which opposition intensifies as the date at which the facility becomes operational nears because, absent experience, claims of imminent radioactive disasters that raise dire nuclear imagery seem plausible.[15,46] Once the facility opens and operations appear to be benign, worst-case images decline and claims of imminent disaster become less plausible. Opposition, therefore, might be expected to decline with the onset of normal operations.

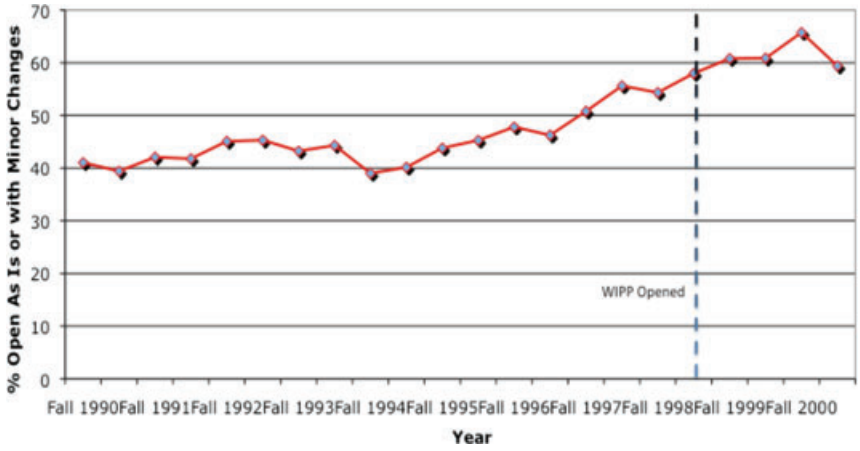


**Fig. 1.** Changing support for WIPP.

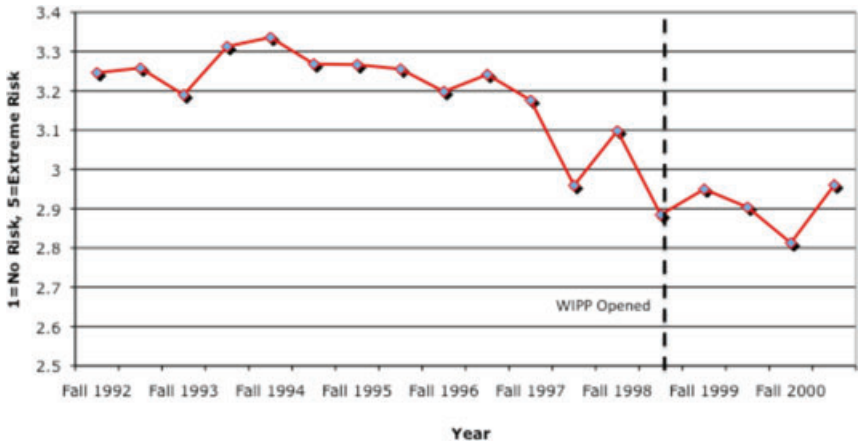


**Fig. 2.** Perceived risk for WIPP transport.

observations across 18 six-month time periods. The average values of the responses to WIPP Transport Risk in each time period are shown in Fig. 2.

And finally, in the fall of 1995, a vote referendum question was added to the WIPP series, coded 1 (a vote to open the facility) and 0 (a vote against opening the facility). Responses to this question (hereafter called WIPP Vote) provided 11,071 observations over 12 six-month time periods. The percentage of votes in favor of WIPP over time are shown in Fig. 3.

The surveys included measures of an array of respondent demographics, including age, gender, race and ethnicity, education level, and income. For purposes of this analysis, race and ethnicity were recoded into a "minority" category, with African-American, American-Indian, and Hispanic respondents coded as minority. A measure of household income was included, with categories ranging from less than $10K to over $50K in the prior calendar year. Education level was represented in a six-point scale, ranging from less than high school through terminal graduate degrees.

As discussed above, prior analysis on risk perception and LULU attitudes leads us to hypothesize that respondents who are male, nonminorities, more highly educated, and with higher incomes will express greater support for WIPP, and will perceive the transport of wastes to WIPP to pose a smaller risk than is the case for female, minority, poorer respondents with less education. We have no prior expectations about the effect of age.

Proximity to the WIPP facility is expected to have conflicting effects; *ceteris paribus*, closer proximity should result in greater perceived risks and less support for WIPP. At the same time, proximity to the facility may also bring a sense of familiarity with the facility and the prospects for economic benefits, both of which should result in less perceived risk and greater support for WIPP. To capture proximity to the facility, we used the respondents' residential zip codes to geo-code the linear distance (in miles) from

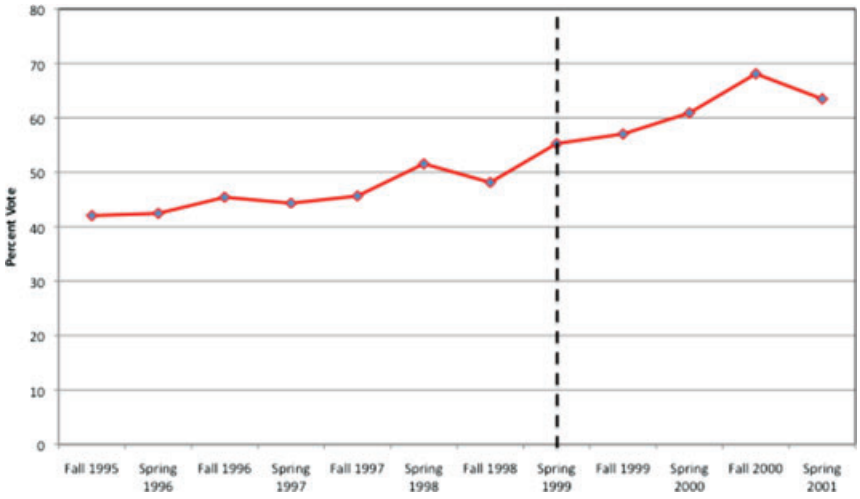


**Fig. 3.** Percent vote to open WIPP.

the centroid of their zip code area to the site of the WIPP facility. We hypothesize that those closest to the facility will perceive smaller risks from, and express greater support for, opening WIPP.

Based on the literature concerning the perceived risks of hazardous transport, we expected that proximity to the WIPP transportation route would provide little tangible benefit to most nearby residents, and afford less opportunity for becoming familiar with the WIPP facility and program. To capture proximity to the route, we geo-coded the linear distance from the centroid of each respondent's zip code to the nearest point on the WIPP transport route. Our hypothesis is that, all else being equal, the closer the respondents' residential zip codes to the route, the greater the perceived risk of transport of waste to WIPP, and the less support for opening WIPP.

As noted above, confidence in the government to perform well in program operations and oversight may influence both perceived risks and support for siting potentially hazardous facilities. To test for such a relationship, we include a measure of respondents' assessments of the performance of New Mexico state government, composed of the average performance approval scores ("excellent," "good," "fair," or "poor") for the governor, the state legislature, and public employees. We hypothesize that greater performance approval will decrease perceived risks and increase support for WIPP.

Both facility siting scholars and WIPP historians have implicated broader political beliefs as potential determinants of attitudes toward potentially hazardous facilities. To capture these beliefs, we use measures of both partisanship and political ideology. Partisanship is operationalized using two dummy variables, one for respondents who identify with the Republican Party, and a second for those who identify with the Green Party, Reform Party, other party, and no party. The implicit comparison will be with respondents who identify with the Democratic Party. For political ideology we use a seven-point scale, on which respondents self-identify as strong liberals to strong conservatives.

Press attention is expected to influence public perceptions.[52,53] In the case of nuclear facilities, Flynn *et al.*[54] argue that widely held negative connotations attached to nuclear images[45] mean that *any* attention generates more concern and, therefore, more opposition. Unfortunately, continuous data for New Mexico media attention are not available for the time period of our analysis; the *Albuquerque Journal* (the largest circulation newspaper in New Mexico) provides access to online content from 1995, five years after our series begins. However, over the 1995–2001 time period the frequency of national WIPP coverage in the *New York Times* is highly correlated with that in the *Albuquerque Journal*.[10] Therefore, for our longer time series, we have employed the count of *New York Times* articles that referred to WIPP as a proxy for New Mexico media attention to WIPP.[11] For the 1995–2001 period, we were able to employ the number of

[10] The correlation between frequency of WIPP-related articles in the *NYT* and *Albuquerque Journal* is 0.65, indicating that the *NYT* index is a reasonable proxy for the New Mexico press.

[11] We also coded counts of references to the various agencies and interest groups that were involved in the WIPP policy debate, but found no statistically significant relationship between variation in the year-to-year counts of these references and WIPP perceived risk or support.

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Age | 0.014*** | 0.014*** | 0.015*** | 0.015*** |
| Gender (male = 1) | 0.802*** | 0.817*** | 0.842*** | 0.842*** |
| Minority | −0.532*** | −0.486*** | −0.445*** | −0.449*** |
| Education | −0.031* | −0.006 | 0.031* | 0.031* |
| Income | 0.157*** | 0.156*** | 0.132*** | 0.131*** |
| WIPP distance | | −0.010*** | −0.009*** | −0.009*** |
| WIPP distance$^2$ | | 0.00002*** | 0.00002*** | 0.00002*** |
| Route distance | | −0.006*** | −0.006*** | −0.006*** |
| Route distance$^2$ | | 0.00003*** | 0.00003*** | 0.00003*** |
| Ideology | | | 0.113*** | 0.113*** |
| Republican | | | 0.434*** | 0.432*** |
| Other party | | | −0.037 | −0.044 |
| Environmental concern | | | −0.746*** | −0.751*** |
| NM government performance | | | 0.247*** | 0.244*** |
| *NYT* articles | | | | −0.031* |
| WIPP open | | | | 0.402*** |
| DOE application | | | | 0.176* |
| EPA approval | | | | 0.206* |
| Constant | 1.352*** | −0.212 | −1.445*** | −1.634*** |
| Rho | 0.0318954*** | 0.024113*** | 0.0344846*** | 0.0017026* |
| Log likelihood | −118590.039 | −11727.367 | −9586.7646 | −9560.8447 |
| Additive chi$^2$ | | 149.57*** | 451.11*** | 131.37*** |

Statistical significance: *= <0.05; **= <0.01; ***= <0.001.

**Table I.** Modeling Support for Opening the WIPP Facility: Random Effects Logistic Regression Estimation

references to WIPP in the *Albuquerque Journal*. Thus we can employ state measures of attention to WIPP for the WIPP Vote variable, but for the longer series (WIPP Support and WIPP Transport Risk) we rely on media data characterizing the national (*New York Times*) press attention as a proxy for local press attention.

As the regulatory process concerning WIPP evolved, a number of events might be given credit for increasing or undermining support for opening the facility. We single out three such events as likely candidates. The first, in October 1996, was the date of the Department of Energy's submission of the formal application to the Environmental Protection Agency, seeking to demonstrate that the WIPP was in compliance with the EPA's regulatory standards for operating the WIPP facility. The second event was the EPA's formal approval of DOE's compliance application, which took place in May 1998. The third was the arrival of the first containers of transuranic waste—to much fanfare—at the WIPP site in March 1999. A dummy variable, with a value of 0 prior to the occurrence, and 1 at the occurrence and afterward, represents each of these events.

### 3.1 Results

We first model the effects of the independent variables on the WIPP Support series, as depicted in Fig. 1. We employed a random-effects logit regression, running as panels each six-month data period. Four sets of independent variables were added sequentially, including individual-level demographic characteristics (model 1), the distance measures (model 2), ideology, partisanship, and perceived competence of government (model 3), and the policy variables (model 4). The addition of the independent variables as grouped hypotheses demonstrates the stability of the estimated coefficients, which (with the exception of education) remain highly consistent. Each addition contributed significantly to explained variance, as shown by the additive chi$^2$ test. The results are shown in Table I.

Given the stability of the estimated coefficients, we concentrate on evaluation of the complete model (model 4), shown in the 5th column of Table I. Among the demographic variables, all are significantly related to support for WIPP and in the expected directions. Men (gender, men = 1) are more supportive than women, and minorities less than whites. Education and income[12] both increase support. As age increases, so does support. Proximity to WIPP was also significantly related to support. For those closest to the WIPP site (WIPP distance), support is greater. The square of distance (WIPP distance$^2$) is negative, indicating that support for the

[12] Education has a weak positive effect ($p = 0.05$) in Model 4. Absent the inclusion of the ideology, partisanship, and trust variables, it has a slightly negative effect on support.

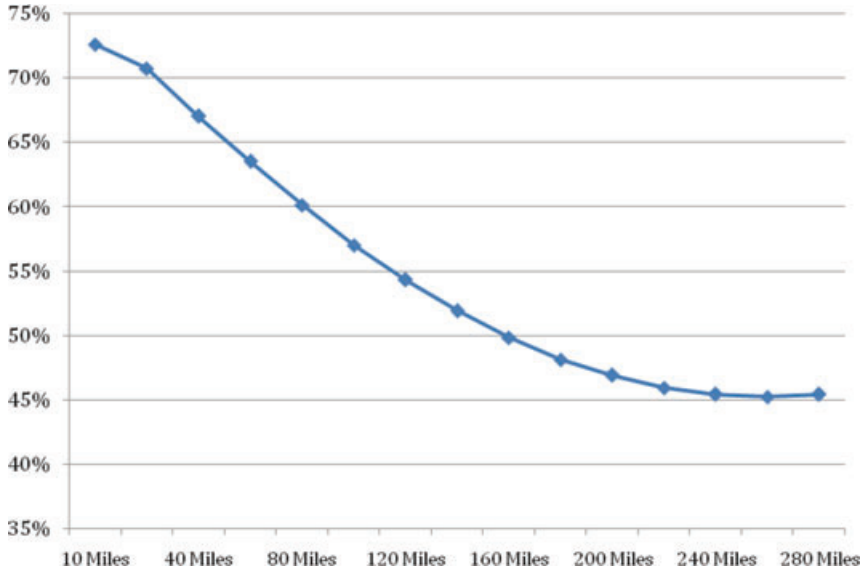


**Fig. 4.** Predicted percent support by distance from WIPP facility.

facility drops off at a declining rate of distance from the facility. The nonlinear effect of distance is illustrated in Fig. 4, which shows the estimated effect of distance from the facility (in miles) on support, while holding all other variables at their mean value. The effect is substantial, with support dropping from 73% (at 10 miles distance) to 45% (at 240 miles distant).

Proximity to the transportation route (route distance) was inconsistent with our hypothesis: rather than increasing opposition, closer proximity to the route significantly increased support for opening the WIPP facility. Again, the effect declined with greater distance, as shown by the significant (and positive) effect of the square of the distance from the route (route distance$^2$). This effect was less pronounced than that of proximity to the facility; at one mile support is estimated to be 53% on average, declining to 44% at 120 miles distance.

The effect of overall approval of government performance (NM govt. performance) is as expected: greater approval is associated with greater support for WIPP. General political beliefs also operate as expected: conservatives and Republicans are more supportive than Democrats and liberals; those who identify with other political parties are indistinguishable from Democrats. Finally, those who see environmental issues as the most pressing problems express greater opposition to WIPP.

The effects of the policy process variables proved to be mixed. Greater exposure of WIPP in the press (as indicated by the effect of the *NYT* index) appears to have depressed support slightly. The program milestones, including the application submission by the DOE (DOE application), EPA approval (EPA approval), and opening WIPP (WIPP open), all served to increase support for WIPP.[13] Thus it appears that members of the public were attentive to the unfolding of the policy process, and acceptance of the facility grew with each successive step toward making WIPP operational. Note also that, with the introduction of the time-specific policy variables, the magnitude of rho (the estimation of first-order autocorrelation in the series of surveys) declines markedly, though it remains significant at the 0.05 level. Thus what initially appeared to an underlying trend of greater support may be attributable to the sequence of policy process milestones accomplished through the 1990s.

The second set of analyses employ random-effects likelihood regressions, corrected for first-order autocorrelation, to predict the perceived risk of transportation of waste to the WIPP facility. Recall that this dependent variable is a five-point Likert-type scale.[14] The pattern over time for the dependent variable series was shown in Fig. 2. As with the previous analysis, we introduce the independent variables in stages. Again the results are quite stable, permitting us to concentrate attention on the model

[13] The effects of articles in the *New York Times* and the approval by the EPA were statistically significant in one-tailed (directional) hypothesis tests.

[14] The full model was also run as an ordinal logit model, with consistent results. We focus on the linear MLE results because they are more readily interpretable.

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Age | −0.007*** | −0.008*** | −0.008*** | −0.008*** |
| Gender (male = 1) | −0.602*** | −0.605*** | −0.604*** | −0.604*** |
| Minority | 0.450*** | 0.416*** | 0.377*** | 0.377*** |
| Education | −0.012 | −0.021** | −0.038*** | −0.038*** |
| Income | −0.100*** | −0.104*** | −0.086*** | −0.084*** |
| WIPP distance | | 0.004*** | 0.003*** | 0.003*** |
| WIPP distance$^2$ | | −0.00000*** | −0.00000*** | −0.00000*** |
| Route distance | | 0.003*** | 0.003*** | 0.003*** |
| Route distance$^2$ | | −0.00001*** | −0.00002*** | −0.00002*** |
| Ideology | | | −0.061*** | −0.60*** |
| Republican | | | −0.255*** | −0.254*** |
| Other party | | | 0.056 | 0.058 |
| Environmental concern | | | 0.430*** | 0.438*** |
| NM government performance | | | −0.139*** | −0.137*** |
| *NYT* articles | | | | −0.015 |
| WIPP open | | | | −0.161** |
| DOE application | | | | −0.051 |
| EPA approval | | | | −0.122* |
| Constant | 4.01170*** | 3.513819*** | 4.20937*** | 4.321971*** |
| Rho | 0.0119369*** | 0.0125864*** | 0.0155111*** | 0.0007614 |
| Log likelihood | −25586.266 | −25208.651 | −21319.97 | −21301.973 |
| Additive chi$^2$ | | 73.32*** | 209.74*** | 35.99*** |

Statistical significance: *= <0.05; **= <0.01; ***= <0.001.

**Table II.** Modeling Risk Perception of Transportation to the WIPP Facility: Random-Effects Maximum Likelihood Regression Estimation

including all hypothesized relationships (model 4). The results are shown in Table II.

As with support for WIPP, the demographic and proximity variables are all significantly related to perceived risk of transportation. Respondents who are older, male, white, more highly educated, and higher income perceive less risk than do younger, female, minority, less educated, and lower income respondents. Those who live closer to WIPP perceive less risk (at a declining rate) than do those who live closer to the transport route.

Greater approval for the performance of New Mexico government officials is associated with less perceived risk, as expected. Republicans and conservatives perceived less risk than did liberals and Democrats or members of other parties. And, again as expected, those who rated environmental issues as the greatest problem confronting New Mexico citizens (environmental concern) perceived greater risks from WIPP transportation.

The effects of the policy process were more muted for perceived transport risks than they were for support for opening the WIPP. Coverage in the national press had no noticeable effect, nor did the DOE's application for the license to open WIPP. However, both the EPA approval of the WIPP license application and the initiation of receipt of waste at WIPP were associated with decreases in perceived risks of transportation. The addition of the policy variables substantially reduces the estimation of series autocorrelation; indeed, rho becomes statistically insignificant once the major policy events are accounted for in model 4.

Our third model, with a time series over the 1995–2001 periods, predicts a hypothetical referendum vote to open WIPP (see Fig. 3). While analogous to the measure WIPP Support analyzed in Table I, this measure captures the added behavioral element of a referendum vote. In addition, the series for this variable coincides with measurement of the perceived risk of WIPP Transport Risk, permitting us to evaluate the role of perceived risk in shaping support for a referendum on WIPP. Again we applied a random-effects logit regression, running as panels each six-month data period. The results are shown in Table III.

The sequential addition of independent variables again illustrates the stability of the estimated coefficients as the model is made more inclusive. Nevertheless, some changes are evident. The effect of education is diminished once ideology and partisanship are included as independent variables. And once the perceived risk of WIPP transportation (WIPP Risk) is included (model 5) the estimated effects of

**Table III.** Modeling Referendum Vote for Opening the WIPP Facility: Random-Effects Logistic Regression Estimation

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| Age | 0.013*** | 0.014*** | 0.013*** | 0.013*** | 0.006** |
| Gender (male = 1) | 0.879*** | 0.883*** | 0.915*** | 0.914*** | 0.465*** |
| Minority | −0.737*** | −0.686*** | −0.564*** | −0.570*** | −0.265*** |
| Education | −0.054** | −0.031 | 0.025 | 0.024 | −0.009 |
| Income | 0.172*** | 0.174*** | 0.146*** | 0.143*** | 0.086*** |
| WIPP distance | | −0.010*** | −0.009*** | −0.009*** | −0.009*** |
| WIPP distance$^2$ | | 0.00002*** | 0.00002*** | 0.00002*** | 0.00002*** |
| Route distance | | −0.003 | −0.006*** | −0.006*** | −0.004 |
| Route distance$^2$ | | 0.00001 | 0.00003** | 0.00003** | 0.00002 |
| Ideology | | | 0.112*** | 0.112*** | 0.079*** |
| Republican | | | 0.455*** | 0.460*** | 0.313*** |
| Other party | | | −0.015 | −0.007 | 0.014 |
| Environmental concern | | | −0.633*** | −0.639*** | −0.327 |
| NM government performance | | | 0.299*** | 0.280*** | 0.0181** |
| *AJ* articles | | | | −0.006 | −0.010*** |
| WIPP open | | | | 0.537*** | 0.476*** |
| DOE application | | | | 0.276** | 0.356** |
| EPA approval | | | | 0.241 | 0.265 |
| WIPP risk | | | | | −1.233*** |
| Constant | −1.080*** | −0.072 | −1.524*** | −1.750*** | 3.202*** |
| Rho | 0.0239742*** | 0.0263386*** | 0.0757822*** | 0.0021682* | 0.0006799 |
| Log likelihood | −5622.8125 | −5542.0674 | −4746.6592 | −4729.9126 | −3401.0444 |
| Additive chi$^2$ | | 35.90*** | 322.19*** | 67.25*** | 1084.56*** |

Statistical significance: *= <0.05; **= <0.01; ***= <0.001.

gender, minority status, ideology, partisanship, and environmental concern (all of which are strong predictors of perceived risk) diminish in magnitude.[15] Nevertheless, with the exception of the measure of environmental concern (which becomes statistically insignificant), all of these variables retain both their directional effect and statistical significance.

As with the prior analyses, the demographic variables are significantly related to the referendum question except education. Respondents who are older, male, white, and wealthier are more likely to say they would vote in favor of WIPP; younger, female, nonwhite, and less wealthy respondents were more likely to say they would vote to oppose WIPP. Respondents who lived closer to WIPP were significantly more likely to opt to vote to open WIPP, with the same nonlinear relationship to distance observed when predicting WIPP Support and WIPP Transport Risk. Once the perceived risk of WIPP transport is included in the model, the effect of distance from the WIPP route ceased to be significantly related to the WIPP referendum vote.

Approval of government performance remained significant, contributing to a greater likelihood of voting in favor of WIPP. Conservatives and Republicans were more likely to vote in favor of opening the WIPP facility, and Democrats and liberals more likely to vote against.

The policy process variables (with the exception of the EPA approval) were significant, and in the expected directions. When WIPP was the focus of greater press attention (*AJ* articles, referring to counts of WIPP references in the *Albuquerque Journal*[16]), support declined. When the DOE filed the license application, support increased. Support for the referendum increased significantly ($p < 0.000$) when the facility was opened.

As expected, perceptions of the risk of transporting wastes to WIPP were strongly associated with responses to the WIPP referendum question. Those who perceive greater risks are significantly less likely

[15] This is of course precisely what we would expect, as the partial coefficients for these variables are estimated after their covariance with perceived risk (and the other independent variables) is removed.

[16] The effect of national (*New York Times*) coverage was negative, but not statistically significant. The covariation of the *NYT* and *Albuquerque Journal* coverage precluded inclusion of both variables simultaneously in the model.

to vote for opening WIPP. Note that the addition of the perceived risk variable improved model fit significantly, as shown by the additive chi$^2$ test.

## 4. DISCUSSION AND CONCLUSIONS

Standard LULU models tend to presume that individuals are rather narrowly self-interested and resistant to facilities that are perceived as risky, regardless of the overall community or societal benefit that these facilities can offer. Early research on LULU (and NIMBY) attitudes focused on proximity as the leading cause of resistance to hazardous facilities.[2,28] Later research showed that perceptions of localized benefits can outweigh perceived risks.[4,29] Apart from benefits, research has also indicated that familiarity with the people and technology involved with the facility can also reduce perceived risk and increase acceptance.[33,34,37] These later insights enrich the standard LULU model, suggesting that proximity will conditionally affect opposition to potentially hazardous facilities.

This conditional model of proximity receives strong empirical support from our analysis of the WIPP case. In particular, the effect of proximity is evident with respect both to distance from the facility and distance from the WIPP transportation route, where residents can expect few benefits and the intermittent nature of the shipments limits the accretion of familiarity. In both cases, closer proximity is associated with significantly greater support. In addition, these effects are nonlinear, with the change in support diminishing and perceived risk increasing as distance from the facility and route increase. The localized effect of the facility on increased support appears to extend farther (up to 180 miles) than it does for the transport route (up to 80 miles). This result clearly demonstrates that LULU-type resistance based on proximity can be overwhelmed and reversed by the localized benefits and familiarity with the people and technology involved with the facility. The remarkable implication here is that this effect, in the case of WIPP, applies to proximity to the transport route as well. These findings provide strong support for the conjecture that the extensive investment in upgraded (and new) highways, and training and equipment for local emergency responders along the transportation route, had a significant positive effect on support for WIPP in New Mexico.

Standard LULU models tend to oversimplify the effects of the broader political beliefs and values that infuse considerations of risk and facility siting. Within the assumptions of the standard model, citizens in close proximity are brought together to resist a facility and in the process put aside their differences in beliefs and values in the cause of resisting a potentially risky facility. This view has been challenged by findings that broader environmental views are predictive of resistance.[8] While this insight implicates political belief systems as possible contributors to resistance, to date little research has systematically explored the impacts of ideology or partisanship on LULU attitudes (for an exception, see Ref.16). Political ideology and partisanship are likely to be important considerations because the siting of hazardous facilities, while informed by science, is ultimately a *political* process. Our analysis confirms the importance of broader political beliefs in the siting of hazardous facilities. Both political ideology and partisanship were significantly related to WIPP risk perceptions and support, and in the expected directions. Risk perception in particular was strongly related to political ideology, with conservatives perceiving less risk than liberals. The persistence of these effects over more than a decade of the WIPP policy process is suggestive of their generality in the facility siting process, though evidence from a broader range of cases will be necessary to confirm the more general role of political belief systems in shaping the contours of facility siting controversies.[17]

Policy and siting decisions are made, regulated, and enforced by political actors. For that reason, we expect that citizens' views on facility siting will be affected by their perceptions of the competence and performance of government in general. Other research has indicated that confidence in government positively impacts acceptance of facility siting.[17] Our interest has been in whether perceived governmental *performance* plays a similar role.[18] Using measures of citizens' approval of government performance, our models indicate that, *ceteris paribus,* individuals with a higher level of approval of governmental performance consistently had a lower level

[17] We suspect that siting debates that occur over extended periods of time will be the most likely to become aligned with ideological beliefs and partisan preferences, and suspect that political institutions (single member district elections) and campaigns play a substantial role in that process. See Anthony Downs's[55] characterization of the process by which the iteration of political campaigns over time may integrate new issues into partisan (and ideological) dimensions of dispute.

[18] Trust in government is, of course, strongly related to approval of elected and other government officials.[48,49,50]

of perceived risk and a higher level of acceptance of WIPP.

A controversial scientific, legal, and political process that spanned two decades preceded the opening of the WIPP facility. The process was covered by both national and local New Mexico news organizations. Flynn *et al.*[54] argued that increased press attention leads to increased risk perceptions and facility opposition. Consistent with this argument, our findings indicate that media attention to WIPP—whether in the local or national media—decreased acceptance of WIPP. This may be because media mentions of WIPP often included discussion of the controversy and comments by those in opposition to WIPP as a proxy for "journalistic balance."[19]

Apart from the media coverage, we expect the workings of the policy process to influence risk perceptions and acceptance. Several prominent events leading to the opening of WIPP occurred during the data collection period. The most notable was the compliance application submitted by DOE (in 1996), the certification of WIPP by the EPA (in 1998), and the opening of WIPP facility to the receipt of radioactive waste (in 1999). While acceptance of the process itself has been understood to diminish LULU sentiments,[17] little research has tracked changing risk perceptions and levels of acceptance over time as affected by key events that take place within that process. Our analysis demonstrates that acceptance is influenced by the temporal nature of the process and the policy events in ways not previously considered. In particular, the onset of actual shipments to the WIPP facility was consistently related to increased support (or decreased perceived risk) in our models. This may be an indication of a more general feature of siting controversies; once a facility demonstrates (over time and in the policy/regulatory process) that it can operate safely, perceived risks will erode and support will increase. Whether this kind of "bow wave effect" can be generalized to the operation of other hazardous facilities is a critical question for future research.

Our analysis also speaks to the relative importance of the different ingredients of hazardous facility opposition and support. Table IV shows the magnitudes of the effects, sorted in descending order, of the primary independent variables on WIPP Support and perceived risk of the transport of WIPP materials. The cell entries are the estimated change in the absolute value of the dependent variable (with appropriate logit reversals for WIPP Support) when the independent variable moves from one standard deviation below its sample mean to one standard deviation above the mean for the continuous variables, and when the binary independent variables move from 0 to 1. For each of the estimated effects, all other independent variables are held at their mean values.

**Table IV.** Estimated Effects of Independent Variables on Support for Opening WIPP and Perceived Risk of WIPP Transport*

| | **WIPP Support Range: 0–1** | | **WIPP Risk Range: 1–5** |
|---|---|---|---|
| WIPP Distance | 0.257 | Ideology | 1.886 |
| Gender (Male)* | 0.207 | WIPP Distance | 0.653 |
| Environmental Concern* | 0.180 | Gender (Male)* | 0.604 |
| Age | 0.169 | Environmental Concern* | 0.438 |
| Minority* | 0.111 | Minority* | 0.377 |
| Republican* | 0.108 | Age | 0.266 |
| WIPP Open* | 0.101 | Republican* | 0.255 |
| Ideology | 0.088 | WIPP Open* | 0.161 |
| Route Distance | 0.085 | NM Govt Performance | 0.151 |
| Education | 0.071 | Route Distance | 0.137 |
| NM Govt Performance | 0.066 | Income | 0.137 |
| DOE Application* | 0.048 | EPA Approval* | 0.122 |
| EPA Approval* | 0.046 | Education | 0.116 |
| Income | 0.040 | Other Party* | 0.057 |
| *NYT* Articles | 0.016 | DOE Application* | 0.052 |
| Other Party* | 0.011 | *NYT* Articles | 0.041 |

*Effects of ±1 standard deviation change in continuous independent variables, and a 0–1 change in the dichotomous (dummy) variables (*).

In most cases the rankings of the variables in the two lists are consistent. The notable exception is political ideology, which ranks as most influential in shaping risk perception (± one standard deviation from the mean leads to a change of 1.89 units on the 1 to 5 perceived risk scale) but is only ranked near the middle (where ± one standard deviation from the mean leads to a shift in the percentage support of 8.8%) as a predictor of WIPP Support. This is consistent with the broader literature on risk perceptions, which finds strong influences of

[19] A striking feature of the press coverage on WIPP was the frequent reference to the facility by reporters as a "nuclear waste dump." The imagery of a "dump" for radioactive waste might reasonably lead to increases in perceived risk and facility opposition. See Rothman and Lichter[42] for a more general account of media reporters' tendency to perceive nuclear technologies as risky.

ideological and world-view orientations on perceptions of risk.[31,56,57] Our analysis indicates that the role of ideology and values is somewhat less influential in the formulation of siting preferences. Otherwise, the most influential explanatory variables include distance from the facility, gender, the importance of environmental problems, and minority status. A more moderately influential group of variables includes age, political party identification, the opening of the facility, approval of the performance of the government, and distance from the transportation route. The policy process variables, including the completion of the facility license application, regulatory approval, and attention by the press, were more predictive (in aggregate) of the acceptance of the WIPP facility than they were of perceived risks.

The theoretical implications of the WIPP case for understanding controversies concerning facility siting are substantial. Our analysis suggests that public responses to siting debates are embedded in the more general structure and content of public opinion. Partisanship, environmental attitudes, beliefs about governmental performance, and ideology all play a significant and persistent role in shaping responses to potentially hazardous facility siting. Attempts to understand opposition and support absent attention to the structure and content of public opinion will therefore be underspecified, resulting in misleading characterizations of siting disputes as chiefly driven by proximity-based reactions to the facility.

In addition, analysis of the quarter-century-long process that led to the licensing and operation of the WIPP nuclear waste repository has important practical implications for future efforts for nuclear repository siting. Initially subject to opposition by a large majority of the public, and dogged by persistent charges of secrecy and reckless imposition of dire risks on the public, support for WIPP nevertheless grew gradually but substantially over time. By the time the facility opened, a majority of New Mexicans supported its continued operation. Proximity to the nuclear waste transport route—widely expected to be the Achilles Heel of nuclear waste disposal[32]—came to be a positive factor in assuaging concerns and garnering support. Attention to the lengthy and often contentious regulatory process involved in licensing the facility served to increase public confidence and acceptance, despite the generally negative influence of press coverage. The opening and successful operation of the facility without significant mishap, at least in the early period measured here, also appeared to lessen concerns and increase support. Perhaps most broadly, the WIPP experience demonstrates that it is indeed possible for the most dreaded of LULU facilities—a permanent deep geologic nuclear waste repository—to gain public acceptance.

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## SUPPORTING INFORMATION

The following supporting information is among that available for this article, but is not a complete list.

**Appendix A:** WIPP Surveys and Question Wording

**Appendix B:** Timeline of the Waste Isolation Pilot Plant

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