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A Structural Model Analysis of Public Opposition to a High-Level Radioactive Waste Facility

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The Nevada Agency for Nuclear Projects/Nuclear Waste Project Office (NWPO) was created by the Nevada Legislature to oversee federal high-level nuclear waste activities in the State. Since 1985, it has dealt largely with the U.S. Department of Energy's (DOE) siting of a high-level nuclear waste repository at Yucca Mountain in southern Nevada. As part of its oversight role, NWPO has contracted for studies designed to assess the transportation impacts of a repository.

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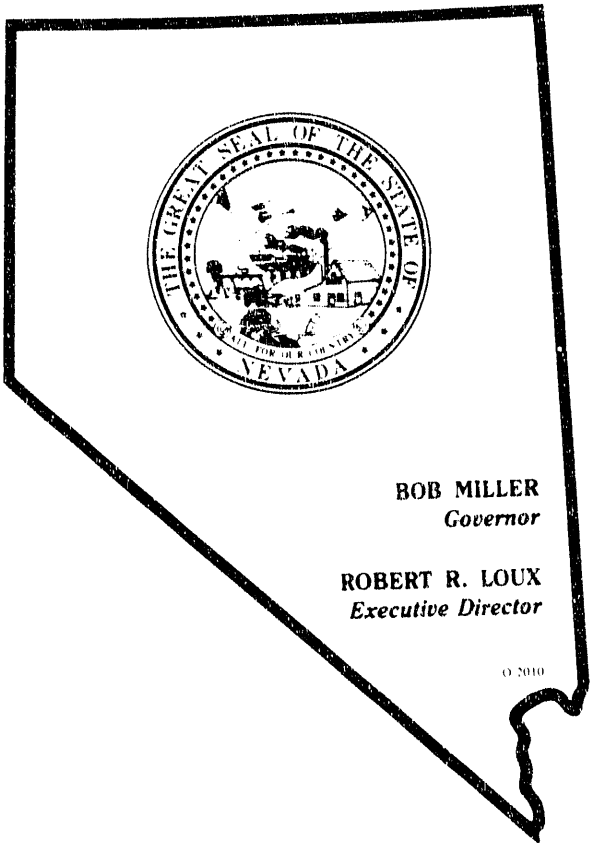

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ABSTRACT

Studies show that most Nevada residents and almost all state officials oppose the proposed high-level radioactive waste repository project at Yucca Mountain. Surveys of the public show that individual citizens view the Yucca Mountain repository as having high risk; nuclear experts, in contrast, believe the risks are very low. Policy analysts have suggested that public risk perceptions may be reduced by better program management, increased trust in the federal government, and increased economic benefits for accepting a repository. The model developed in this study is designed to examine the relationship between public perceptions of risk, trust in risk management, and potential economic impacts of the current repository program using a confirmatory multivariate method known as covariance structure analysis. The results indicate that perceptions of potential economic gains have little relationship to opposition to the repository. On the other hand, risk perceptions and the level of trust in repository management are closely related to each other and to opposition. The impacts of risk perception and trust in management on opposition to the repository result from a combination of their direct influences as well as their indirect influences operating through perceptions that the repository would have serious negative impacts on the state's economy due to stigmatization and reduced tourism.

Key Words: risk perception, trust, nuclear waste, structural modeling, economic impacts

I. INTRODUCTION

The importance of public opinion in defining policy for technological issues appears to be increasing. Over the past three decades, the public has become more concerned with the health and environmental effects of industrial facilities. At the same time there has been a steady decline in trust of technology and government.[1] Public concerns regarding technological and industrial hazards have tended to increase and to diverge markedly from expert opinion. The development of permitting and licensing procedures accessible to public and media review has provided, in many cases, a forum for confrontation and a point of focus for public debate and opposition. Not only has public opinion become more judgmental but effective means for its expression have expanded. Decisions that formerly were exercised by scientists, technology managers and public officials are now subject to extensive public debate and in many cases decisions are reversed because of public opposition.

Nowhere are projects more controversial than in the area of radioactive waste disposal where public concerns lead to strong state and local pressures on elected officials to oppose such facilities.[2] This public oversight of expert policy decisions is enhanced by the nearly instantaneous communication of public sentiments through the mass media, and by the ability

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[1] "The Age of Indifference: A Study of Young Americans and How They View The News," Times-Mirror Center for The People & The Press (1990). This report discusses survey findings from a number of sources for the 50 year period, 1941 to 1991. Also see, S. Lipset and W. Schneider, "The Decline in Confidence in American Institutions," *Political Science Quarterly*, 98, 1, (Fall, 1983).

[2] J. Tomain, *Nuclear Power Transformation*, Indiana University Press, Bloomington (1987); and, G. Jacob, *Site Unseen: The Politics of Siting a Nuclear Waste Repository*, University of Pittsburgh Press, Pittsburgh (1990).

of interest groups to identify public opinion through modern survey research methods and, in some cases, to define public responses through political action campaigns.[3]

The changing role of public opinion has generated a number of theories about the nature and origins of public attitudes and perceptions, and about the role that such opinion does, or should, play in specific policy issues. The purpose of this paper is to describe the design of a model that has been developed to empirically test components of current theory about public opinion as it applies to the high-level radioactive waste repository at Yucca Mountain, Nevada.[4] The model presented in this paper includes three major aspects of public opinion that have been proposed in the social science literature as important in forming the public attitudes toward nuclear facilities and programs: (1) trust in management and control; (2) the perceptions of the risk or hazard; and (3) perceptions of the costs and benefits resulting from the facility. Each of these points is discussed below as it applies to the Yucca Mountain project. We take a structural modeling approach with available survey data to examine the relative adequacy of these theoretical relationships in explaining public support or opposition to the repository program.

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[3] An article in the *Wall Street Journal* (October 3, 1989, p. A22) quoted a memo prepared by Fenton Communications on the stir resulting from media coverage of the chemical Alar on apples. The "campaign" was based on a report by the Natural Resources Defense Council, "Intolerable Risk: Pesticides in Our Children's Food," which was presented to the public and the media with actress Meryl Streep as the spokesperson. The memo credits the results with proving that there are "other ways to raise public awareness for the purposes of moving the Congress and policymakers" in addressing environmental issues.

[4] An earlier version of this model was presented in, Flynn, James, William Burns, Paul Slovic, and C.K. Mertz. "Development of a Structural Model to Analyze Public Opinion on a High-Level Radioactive Waste Facility." *Proceedings of the Second Annual International Conference on High Level Radioactive Waste Management*, Las Vegas, Nevada, April 28-May 3, 1991. pp. 773-779.

II. THEORETICAL CONSIDERATIONS FOR THE MODEL DESIGN

The purpose of this paper is to describe and test a covariance structure model that explicitly portrays the relationships among the following aspects: trust in the federal government's management of the proposed repository program, risk perceptions, evaluation of potential socioeconomic impacts, and public opposition and/or support of the Yucca Mountain repository program. Each of these aspects is designated as a "construct" in the model and the theoretical justification for its inclusion is the subject of this section. We also discuss how these perceptions and indicators of public opinion are to be measured.

Economic theory suggests that hazardous facilities, even those with technological risks, will be supported by the public so long as the benefits sufficiently outweigh the risks.[5] This appears to be the thinking behind some specific provisions of the Nuclear Waste Policy Act of 1982 such as the payments or grants in lieu of taxes.[6] The benefit/compensation theory is reiterated in the Amendments of 1987, wherein specific payments were authorized for states and local jurisdictions that would accept a repository or a Monitored Retrieval System (MRS), as well as in the establishment of the Office of Negotiator to bargain with states or Indian tribes regarding the economic and/or revenue benefits that might be added to encourage

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[5]A good summary presentation is contained in, E. J. Mishan, *Introduction to Normative Economics*, Oxford University Press, New York (1981).

[6]Nuclear Waste Policy Act of 1982, 96 Stat. 2201. The grants (payments) equal to taxes provisions are contained in Section 116(c)(3). For an overview of early Nevada response to these provisions see, A. Costandina Titus, "Bullfrog County: A Nevada Response to Federal Nuclear-Waste Disposal Policy," *Publius: The Journal of Federalism* 20 (Winter, 1990) 123-135.

acceptance of a repository or MRS.[7] These *Standard Effect* benefits could range from increased employment, purchases of goods and services from local, regional or in-state firms, tax revenues, population growth, and economic development, to extraordinary arrangements for cash payments, compensation, insurance or other benefits.

One question to be addressed with the proposed model is whether and to what extent perceptions of *Standard Effect* benefits by Nevada residents are related to their support or opposition for the Yucca Mountain repository program. A 1988 survey found that compensation payments did not increase the likelihood of acceptance or support for the repository program.[8] However, a survey in 1989 found that residents of Nye County, the *in situ* county, are more supportive of the Yucca Mountain project than other Nevada residents. This appears to be related to experience with existing nuclear facilities, the Nuclear Test Site and the Beatty low-level nuclear waste repository, and to the relatively large proportion of the county residents, as compared to the state population, who have either worked at these facilities or have personal relationships with those who do work there. Nye County residents are more likely than other state residents to say that increased employment and public revenues are likely consequences from a repository, and they rate the repository risks as smaller than do other residents of the state. In spite of this tendency, however, more people in

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[7] "Title V - Energy and Environment Programs, Subtitle A - Nuclear Waste Amendments" Pub. L. No 100-202, 101 Stat. 1330-227 (1987)

[8] H. Kunreuther, W. Desvousges, and P. Slovic, "Nevada's Predicament: Public Perceptions of Risks from the Proposed Nuclear Waste Repository," *Environment*, 30, 16 (1988).

Nye County oppose the Yucca Mountain project than support it.[9] Thus, there is support for the idea that standard effects, defined here as perceptions of increased employment and revenues from a repository, are associated with less opposition.

A second economic construct included in the model is *Special Effects*, which are perceived losses that might result from the potential stigmatization of Nevada and the possibility that this could decrease tourist visitation. These special effects could result from adverse psychological, cultural, and aesthetic responses on the part of potential visitors. The survey questions asked respondents how likely it was that such responses would take place if the repository were put into operation. Revisions to classical normative economic theory suggest that non-market and unpriced values must be taken into account in cases where social, cultural, and aesthetic values are involved.[10]

The hazards to human health and the environment from a high-level nuclear waste facility result from potential exposure to radioactivity. The *Perceived Risk* construct in the model applies to public perceptions of this potential hazard and is measured by several questions about the probability and potential consequences of various sorts of accidents. There is a major and important difference between professional or expert risk assessments and public risk assessments of nuclear facilities.[11] Members of the public see nuclear facilities as

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[9] J. Flynn, C. K. Mertz, and J. Toma, "Preliminary Findings: 1989 Nevada State Telephone Survey," NWPO-SE-025-89, State of Nevada, Nuclear Waste Project Office (Dec. 1989). Nye County respondents to a hypothetical referendum on Yucca Mountain voted against the repository 43 percent to 37 percent (with 8 percent who said they wouldn't vote and 12 percent who were unsure) as compared to state figures of 69 percent against, 14 percent for (with 17 percent who would not vote, were unsure, or did not answer).

[10] E.g., J. L. Knetsch, *Property Rights and Compensation*, Butterworth & Co. Ltd., Vancouver (1983).

[11] P. Slovic, S. Lichtenstein, and B. Fischhoff, "Facts and Fears: Understanding Perceived Risk,"

containing risks that are unknown and dreaded.[12] Public perceptions consistently show high levels of concern with all aspects of high-level radioactive waste management.[13] Repository risk perceptions have been found to be related to attitudes and opinions about risk management, perceived benefits from a repository, and support for the view that State of Nevada officials should strongly oppose the repository.[14]

Perceptions of *Trust in Repository Management* represent the confidence people have in the ability of social institutions and officials to control the hazards and minimize the risks. In the case of the Yucca Mountain project, the federal agency charged with management responsibility is the Office of Civilian Radioactive Waste Management, U.S. Department of Energy (DOE). A number of commentators have made recommendations or critiques of the DOE management program, based upon a theory that increased trust in the management

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Societal Risk Assessment: How Safe Is Safe Enough? p. 181. R. Schwing and W.A. Albers, Jr., Eds., Plenum, New York (1979); P. Slovic, "Perception of Risk," *Science*, 236, 280 (1987); and, P. Slovic, M. Layman, and J. Flynn, "Risk Perception, Trust, and Nuclear Waste: Lessons from Yucca Mountain," *Environment*, 33, 3 (April, 1991) 6ff.

[12]P. Slovic, "Perception of Risk from Radiation," *Proceedings of the Twenty-Fifth Annual Meeting of the National Council on Radiation Protection and Measurements*, No. 11, p. 73, W.K. Sinclair, Ed., National Council on Radiation Protection, Bethesda, Maryland (1990).

[13]See footnote 5; also: S. Papinchak and L. Wingard, "Poll Shows Strong Opposition to Dump," *Las Vegas Review-Journal* (October 21, 1990); J. Flynn, P. Slovic, C. K. Mertz, and J. Toms, "Evaluations of Yucca Mountain: Survey Findings about Attitudes, Opinions and Evaluations of Nuclear Waste Disposal and Yucca Mountain, Nevada," State of Nevada, Nevada Nuclear Waste Project Office (Sept. 1990); S. M. Nealy and J. A. Herbert, "Public Attitudes Toward Radioactive Wastes," *Too Hot to Handle: Social and Policy Issues in the Management of Radioactive Wastes*," p. 151, C. A. Walker, L. C. Gould, and E. J. Woodhouse, Eds., Yale University Press, New Haven, (1983); and, Mountain West Research, "An Interim Report on the State of Nevada Socioeconomic Studies," NWPO-SE-022-89, State of Nevada, Nuclear Waste Project Office, (June, 1989).

[14]M. Dantico, A. Mushkatel, K.D. Pijawka, and O. Ibitayo, "Political Trust and Risk Perceptions of the High-Level Nuclear Waste Repository," Paper presented at the Annual Conference of the American Association for the Advancement of Science (AAAS), Washington, D.C., February 16, 1991; also footnote 13: Flynn *et al.*, 1990.

agency will lead to lower levels of perceived risk for the repository program and increase public support for the repository program.[15] This position has the support of DOE officials. In discussing the Waste Isolation Pilot Project (WIPP) in New Mexico, DOE Secretary James Watkins said that he felt that a good performance in terms of the WIPP project would "significantly enhance the credibility of the department [DOE]" and improve public acceptance of DOE work at Yucca Mountain.[16] In addition, DOE has created an "Advisory Board Task Force on Civilian Radioactive Waste Management," charged with suggesting "approaches for establishing public trustworthiness."[17]

A major problem for society is to find a strategy that will effectively manage radioactive wastes. Quite different strategies would be needed to address public concerns and opposition depending upon how the people view benefits and compensation, management trust, or risk perception issues. The Yucca Mountain High-Level Nuclear Waste Repository may be the case in which technical risk assessment and evaluation is at the greatest odds with

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[15]L. Carter, *Nuclear Imperatives and Public Trust: Dealing with Radioactive Waste*, Resources for the Future, Washington, D.C. (1987); J. L. Campbell. *Collapse of an Industry: Nuclear Power and the Contradictions of U.S. Policy*, Cornell University Press, Ithaca (1988); J. G. Morone, and E. J. Woodhouse, *The Demise of Nuclear Energy?: Lessons for Democratic Control of Technology*, Yale University Press, New Haven (1989); J. Creighton, "Siting Means Safety First, *Forum for Applied Research and Public Policy*, 5, 97 (Summer 1990); National Research Council, "Rethinking High-Level Radioactive Waste Disposal: A Position Statement of the Board on Radioactive Waste Management," National Academy Press, Washington, D.C. (July 1990).

[16]S. Adams (Donrey Washington Bureau), "DOE looks to New Mexico for Credibility," *Las Vegas Review-Journal* (November, 12, 1990).

[17]*OCRWM Bulletin*, (DOE/RW-0309P) May/June 1991, pp. 4-5.

public risk perceptions and evaluations.[18] The proposed federal program to permanently dispose of these wastes has raised important concerns for people in Nevada.[19] In addition, the program has developed in such a way that it pits one level of government (the U.S. Department of Energy, a federal agency that has been designated to develop the Yucca Mountain site) against another (the State of Nevada who is actively opposing the current repository program).[20] Public support for the Yucca Mountain project is an important, perhaps pivotal, condition for the success of the repository effort. Existing public relations or public information campaigns tend to communicate expert opinions or arguments for the safety and trustworthiness of the repository program. However, by proceeding with inadequate information about the nature of public attitudes, such efforts are likely to be ineffective. The present analysis is intended to provide additional insight into how key aspects of public perceptions are related to each other and how these perceptions influence opposition to the proposed repository.

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[18]P. Slovic, M. Layman, N. N. Kraus, J. Chalmers, G. Gesell, and J. Flynn, "Perceived Risk, Stigma, and Potential Economic Impacts of a High-level Nuclear Waste Repository in Nevada," NWPO-SE-023-89, State of Nevada, Nuclear Waste Project Office (July 1989); P. Slovic, M. Layman, and J. H. Flynn, "Images of A Place and Vacation Preferences: Implications of the 1989 Surveys for Assessing the Economic Impacts of a Nuclear Waste Repository in Nevada," State of Nevada, Nuclear Waste Project Office (Nov. 1990), a revised version of this report will appear in the December issue of *Risk Analysis*; R. E. Kasperson, O. Renn, P. Slovic, H. S. Brown, J. Emel, R. Gobel, J. X. Kasperson, and S. Ratick, "The Social Amplification of Risk: A Conceptual Framework. *Risk Analysis*, 8, 177 (1988); and, W. Burns, R. Kasperson, J. Kasperson, O. Renn, S. Emani, and P. Slovic, "Social Amplification of Risk: An Empirical Study," State of Nevada, Nuclear Waste Project Office (Sept. 1990).

[19]See footnote 13, Flynn *et al.*, 1990.

[20]The response of Nevada state government and officials is summarized in, H.W. Swainston, "The Characterization of Yucca Mountain: Status of the Controversy," *Federal Facilities Environmental Journal*, (Summer, 1991), pp. 151-160.

III. MODEL DESCRIPTION AND RATIONALE

The modeling approach taken here, called covariance structure analysis, has important advantages over more traditional multivariate methods such as regression or factor analysis.[21] For example, covariance structure modeling is primarily theory driven and uses data to statistically test hypotheses of interest. This allows the proposed structural relationships between constructs to be evaluated by noting the size and sign of the model's path coefficients. Likewise, the direct and indirect effects of predictor variables can be scrutinized by observing the configuration of paths connecting model constructs. The use of multiple indicators for each construct also permits assessment of the reliability and validity of construct measures. Finally, this approach allows the analyst to incorporate latent or manifest variables, place them in dependent or independent positions, and calculate the path values.[22]

*** Figure 1 about here ***

The structural model shown in Figure 1 conceptualizes the relationships among the key factors that are discussed above. Each of the five theoretical constructs in this model represents a different aspect of the larger question of public opposition to the repository. The purpose of this study is to examine the ability of four of these constructs to explain the fifth,

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[21] C. Fornell, *A Second Generation of Multivariate Analysis: Methods*, Praeger, New York (1982).; C. Fornell, "A Second Generation of Multivariate Analysis: Classification of Methods and Implications for Marketing Research," *The Review of Marketing* 87, Sec. 6, p. 407, Michael J. Houston, Ed., American Marketing Association, Chicago (1987); and, P. M. Bentler, "Multivariate Analysis with Latent Variables: Causal Modeling," *Annual Review Psychology*, 31, 419 (1980).

[22] J. Loehlin, *Latent Variable Models*, Hillsdale, N.J.: Lawrence Erlbaum Associates, Publishers (1987). Chapters 2-4 deal with path and structural models.

Opposition to the Repository.[23] In the 1989 Nevada State telephone survey, this construct was measured by public response to a scale item questioning whether the state should attempt to stop the Yucca Mountain project and by three "yes/no" vote items which are combined to create an index indicating support for the State position on this issue.[24]

Special Effects depicts the potential for negative effects resulting from public perception of the "special" or risk-related nature of the Yucca Mountain project. This construct was measured by a question asking whether the respondent believes the repository will stigmatize the State of Nevada, and by a question asking whether the respondent believes the repository will cause a loss of tourism.[25] The *Special Effects* construct is hypothesized to have a positive influence on *Opposition to the Repository* (depicted in a covariance structure model as a single-headed arrow pointing from *Special Effects* to *Opposition to the Repository*).

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[23]The fact of massive opposition to the repository by Nevadans is not at issue. In addition to the 1989 survey (Flynn, *et al.*, note 9, above) similar levels of opposition have been recorded in subsequent polls. See the October 21, 1990 issue of the *Las Vegas Review-Journal* for results of a poll commissioned by the newspaper and conducted by Dr. Bruce Merrill of the Arizona State University Media Research Center; and, J. Flynn, C. Mertz, and P. Slovic, *The 1991 Nevada State Telephone Survey: Key Findings*, Nevada Nuclear Waste Project Office, Report NWPO-SE-036-91 (May, 1991).

[24]See Appendix A for frequency description of the survey questions and description of the index variables. A more extensive presentation of the survey findings with additional detail is provided in Flynn, *et al.*, 1990 (see note 13, above).

[25]The issue of stigmatization of Nevada and/or Las Vegas is one of great concern to residents. The perspective from potential visitors is addressed in Slovic, *et al.*, "Perceived Risk, Stigma, and Potential Economic Impacts. . . ", note 18, above; and in Mountain West Research, "An Interim Report. . .", note 13, above. A community view of stigmatization is presented in M. Edelstein, *Contaminated Communities: The Social and Psychological Impacts of Residential Toxic Exposure*, Boulder, Colorado: Westview Press, 1988. As the subtitle to Edelstein's book indicates, he is concerned with more than the potential economic impacts that result from stigmatization, and therefore provides a comprehensive perspective on social and psychological impacts.

Perceived Risk portrays public concern regarding the effects of an accident or incident resulting from the repository program. It was measured in two ways. The first was based upon a word association task in which people were asked to indicate the first thought or image that came to mind when they heard the words, "underground nuclear waste repository." These responses were then scored by the respondents on a five point scale between -2 (strongly negative) and +2 (strongly positive). These quantified responses make up the variable shown in Figure 1 as "image score."[26] The second variable, "Risk Index," sums the scale scores for six questions asking about the likelihood of serious accidents associated with construction and operation of the repository, including transportation and long-term storage of the radioactive wastes. The *Perceived Risk* construct is hypothesized to have a positive influence on both *Special Effects* and *Opposition to the Repository*.

Trust in Repository Management is defined by public perception of the Department of Energy's (DOE's) ability to manage the repository program. It is measured by questions that asked the respondents to rate their trust of DOE as the repository management agency, their confidence that DOE would conduct objective and scientific studies, and their belief that DOE would promptly and fully disclose problems with the repository program. This construct is hypothesized to have a negative influence upon *Perceived Risk*, *Special Effects*, and *Opposition to the Repository*. In addition, this construct is expected to be positively correlated with *Standard Effects* (a double-headed arrow indicates this relationship).

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[26]Distributions of these scores are shown in Appendix A; also see Slovic, *et al.*, "Risk Perception, Trust, and Nuclear Waste. . .", note 11, above, for full details.

Standard Effects pertains to perceptions of the positive economic benefits that might result from the large-scale development efforts planned for the repository. This construct was measured by items concerning the creation of new jobs and the generation of new public revenues. We hypothesize that this factor is positively correlated to *Trust in Repository Management* and will negatively influence *Opposition to the Repository*. Basically, these hypotheses state that people who think there will be significant economic benefits will be more likely to support the DOE repository program and to resist efforts by the State of Nevada in opposition.

Notice that the model in Figure 1 implies that *Perceived Risk, Trust in Repository Management*, *Special Effects*, and *Standard Effects* all directly influence *Opposition to the Repository*. In addition, *Perceived Risk* and *Trust in Repository Management* are hypothesized to operate on *Opposition to the Repository* indirectly through their influence on *Special Effects*.

IV. DATA AND ANALYSIS

The computer program used to structure the covariance structural models was EQS a computer program developed by Peter Bentler and his associates.[27]

The database used for the modeling runs was a subset from the 1989 Nevada State Telephone Survey. This data was collected by Standage Accureach, Inc. of Denver, Colorado. Survey respondents were selected by a random digit-generated sample provided by

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[27]P. Bentler. *EQS Structural Equations Program Manual.* (Version 3.0) Los Angeles, Ca., BMDP Statistical Software (1989).

Survey Sampling, Inc. of Fairfield, Connecticut. The samples included unlisted telephone numbers and were proportionate to the population of the areas designated for data collection. The Nevada State sample size was 677 of which 500 completed interviews were obtained for a response rate of 74 percent. Interviews were collected during the period September 25 to October 15, 1989.[28]

Covariance structure modeling requires a complete set of responses for each respondent. Missing data can either be reconstructed (for example by inserting mean values) or the modeling database can be limited to only those respondents who have complete data for each variable of interest. Complete data were obtained for 291 respondents. Because this is an adequately large database for these types of analysis, we decided to use only respondents with complete data. Descriptive statistics for each variable showed that the responses in the set of 291 records were within one to five percent of those in the original data set.

As reported earlier, Nevada residents take extreme positions on perceptions of risk, opposition to the repository program, trust of DOE, and support for state and local officials. Such one-sided opinion produces variables that are highly skewed. However, the EQS modeling program ideally requires variables to be more normally distributed. Therefore, where necessary, nonlinear transformations were performed in order to prepare these data for model estimation.

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[28] See Flynn, *et al.*, 1989, note 9, above.

V. RESULTS OF THE EQS COVARIANCE STRUCTURE MODELING PROCEDURES.

The estimates for the covariance structure model are displayed in Figure 2. The results shown in the figure include a set of model fit values. The chi-square goodness of fit statistic is 40.86 with 36 degrees of freedom and a probability value of .27.[29] The Bentler-Bonnett Normed Fit Index is .993.[30] This is the generalized least squares solution (elliptical distribution theory) linearized estimation. The baseline model for the Bentler-Bonnet Normed Fit Index is identified as a model of independent or uncorrelated variables. In this case, the independence model chi-square equals 5510.22 with 55 degrees of freedom.[31] In sum, the model shown in Figure 2 provides a good fit to the data.

*** FIGURE 2 ABOUT HERE ***

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[29]The chi-square statistic is a goodness of fit for the model that can be somewhat confusing at first glance. Bentler provides a clarification in the *EQS Manual*, pp. 92-93.

> "The given χ^2 statistic and tabled values of the $\chi^2_{(df)}$ distribution are used to determine the probability of obtaining a χ^2 value as large or larger than the value actually obtained, given that the model is correct. This is printed out as the probability value for the χ^2 statistic. When the null hypothesis is true, the model should fit the data well and this probability should exceed a standard cut-off in the χ^2 distribution (such as .05 or .01). Thus, in a very well fitting model, the probability will be large. In a poorly fitting model, the probability will be below the standard cut-off."

[30]Loehlin, *Latent Variable Models*, note 26, above, explains the Bentler-Bonnett normed fit index (pp. 68-69):

> "Bentler and Bonnett suggest that the goodness of fit of a particular model may be usefully assessed by placing it on a scale running from a perfect fit to the fit of some baseline "null model." Such a null model would be an arbitrary, highly restricted model – say, that all correlations are zero, or that all correlations are equal, or some such – which would represent a baseline level that any realistic model would be expected to exceed. The index would then represent the point at which the model being evaluated falls on a scale running from this null model to perfect fit. The normed fit index may be formally defined as:
>
> $$nfi = (\chi_o^2 - \chi_k^2)/\chi_o^2,$$
>
> where the subscripts k and o refer to the model in question and the null model respectively."

[31]See the *EQS Manual*, pp. 92-94 for a goodness of fit summary.

Coefficients associated with the direct paths linking *Perceived Risk* and *Special Effects* with *Opposition to the Repository* are both positive and statistically significant. Likewise, *Perceived Risk* has a direct influence on *Special Effects* so that risk perceptions are shown to have both a direct influence and an indirect influence, via the special effects, on *Opposition to the Repository*.

Somewhat surprising are the statistically non-significant coefficients associated with the paths linking *Trust in Repository Management* to *Special Effects* and *Opposition to the Repository*. However, the path coefficient between *Trust in Repository Management* and *Perceived Risk* was quite high (-.82), indicating a strong effect of the trust construct on opposition to the repository by means of the effect of trust on perceived risk.

The coefficient for the path linking *Standard Effects* with *Opposition to the Repository* was not statistically significant. As has been noted elsewhere, respondents to the Nevada survey were well aware that the Yucca Mountain project promised new jobs and public revenues.[32] However, perceptions regarding these benefits had very little influence upon attitudes toward the State of Nevada's opposition to the current repository program. The potential economic effects that were significant in explaining opposition to the repository program were those identified as *Special Effects*, which were measured by the potential loss of tourism and the perceived likelihood that Nevada will be stigmatized by location of the repository at Yucca Mountain. One apparently important difference between the *Standard Effects* and the *Special Effects* is that while the former offer the potential of modest economic

[32]See note 13, above, Flynn, *et al.*, 1990.

gain the latter pose the threat of significant loss to the most important segments of the state's economic base.

There might be two factors at work here. According to behavioral theories of decision making the potential for loss is more germane to a decision (in this case support or opposition for the Yucca Mountain project) than is the potential for gain of equivalent magnitude.[33] Moreover, the potential losses and gains are not really equivalent. The potential for loss is greater by many times than the potential for gain in terms of employment, spending, income, and public revenues. This is the result of the very large differences in the employment, spending, income, and revenue provided by the visitor economy of Las Vegas and Nevada when compared to the size of the repository program (at peak employment perhaps one half of one percent of the visitor economy).[34]

The *Special Effects* are influenced by *Perceived Risk*, but the questions that provide the definition for the two constructs are quite different. The variables that define *Special Effects* ask for an opinion about how other people will view the state with the repository in place, and how such perception by others will impact the economy and the reputation of the state. In the case of this model, the perceived potential for economic loss and stigmatization of Nevada, plays a key role in determining *Opposition* while the *Standard Effects* which offer

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[33]D. Kahneman and A. Tversky, "Prospect Theory: An Analysis of Decision Under Risk," *Econometrica*, 47, 263-291 (1979). Also see, W. Samuelson and R. Zeckhauser, "Status Quo Bias in Decision Making," *Journal of Risk and Uncertainty*, 1: 7-59 (1988).

[34]See note 13 above, the *Interim Report*, 1989, especially Chapter 4. The independent technical review committee appointed by the state in 1986 to oversee the socioeconomic studies reported that the repository has the potential "to result in significant negative impacts for the state's economic base . . . [and that] such impacts could more than offset any expected benefits...." See the *Interim Statement of the Technical Review Committee on the Yucca Mountain Socioeconomic Project*(January, 1990), p. 4.

employment and revenue benefits plays almost no role at all in predicting people's support or opposition to the repository at Yucca Mountain.

The model coefficients show that *Perceived Risk* and *Trust in Repository Management* are strongly and inversely related. As trust in DOE declines, perceived risk increases. This finding seems to substantiate the opinions of a number of expert observers who have concluded that trust in management of high-level radioactive wastes would directly influence public perceptions of risk.[35]

VI. CONCLUSIONS

What conclusions can be drawn from the results of this modeling process? The results provide strong evidence that Trust in Repository Management and Perceived Risk are the dominant constructs in determining public opposition to the proposed repository at Yucca Mountain. It has not always been clear to public officials and policy experts that this is the case, and that the role of trust in managing radioactive wastes may be a critical component in addressing the nation's need to find hazardous waste solutions. Understanding the dimensions of trust and their influence on risk perceptions may warrant much more attention in order to structure policy strategies that will gain public acceptance.

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[35] See note 14 above. Other articles of special interest in this context are two by D. Bella, C. Mosher, and S. Calvo in the January, 1988 *Journal of Professional Issues in Engineering* (Vol. 114, No.1): "Technology and Trust: Nuclear Waste Controversy," pp. 27-39; and "Establishing Trust: Nuclear Waste Disposal," pp. 40-50. R. Kemp discusses the trust issue in a broader context with consideration of the historical record of waste management, "Why Not in My Backyard: A Radical Interpretation of Public Opposition to the Deep Disposal of Radioactive Waste in the United Kingdom," *Environment and Planning A*, Vol. 22, 1239-1258 (1990).

Public concerns about risk from a repository are very much greater than concerns of experts. If policy strategies are ultimately dependent upon public assessments of the waste program risks, much more attention will need be directed to understanding public concerns and addressing their intuitive risk evaluations. While risk communication and public education programs based on expert views are the most commonly proposed solutions to the problem of public perceptions, these may not be enough.[36] Actually including the public, in some way, in the management process, and providing strategies, programs, and standards of performance that meet the public's desires, even when these go well beyond the expert judgments of necessity, may be important options to explore.

Perceptions of *Standard Effects* (possible benefits in terms of jobs and public revenues), as they were expressed in the survey data, offer little explanation for opposition to the repository program. This implies that benefit and compensation programs intended to make radioactive waste sites or nuclear facilities more acceptable will not substitute for trust in management and an acceptable minimum of risk from high-level radioactive wastes. These results strongly suggest that the public is not willing to trade essential health and community values for the potential economic benefits of a high-level radioactive waste repository.[37]

Perceived Special Effects (stigmatization of Nevada and the potential loss of tourism) are shown to be important in explaining the high levels of opposition to the repository.

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[36]S. Raynor and R. Cantor, "How Fair is Safe Enough: The Cultural Approach to Societal Technology Choice," *Risk Analysis*, 7, 1, (1987). This article argues that different "publics" have distinct and adversarial value systems, strategies, and desired outcomes that may not be addressed in the standard risk communication or public education and/or information programs.

[37]This point has been made in some detail by Kunreuther, *et al.*; see note 9, above.

Nevada residents who are largely dependent upon the tourist and visitor industries view these potential effects as serious threats to the state's established economic interests. The potential for behaviors that are harmful to the established economic base seems to make sense to the respondents in this survey, perhaps because they recognize the avoidance of a stigmatized place as reflecting their own responses to radioactive hazards. It very well may be that residents of other places, whose economies are less dependent upon visitors, tourists, convention attendees, and other outsiders, would give less weight to the role of *Special Effects*.

Overall, these findings show very strong aversion to the repository, grounded in the perception that a high-level radioactive waste repository would pose unacceptable risks, and that the current program management is not adequate to manage these risks.

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Figure Captions

Figure 1. Covariance structure model to examine public opposition to the Nevada repository: conceptual design.

Figure 2. Covariance structure model to examine public opposition to the Nevada repository: results with 1989 survey data.

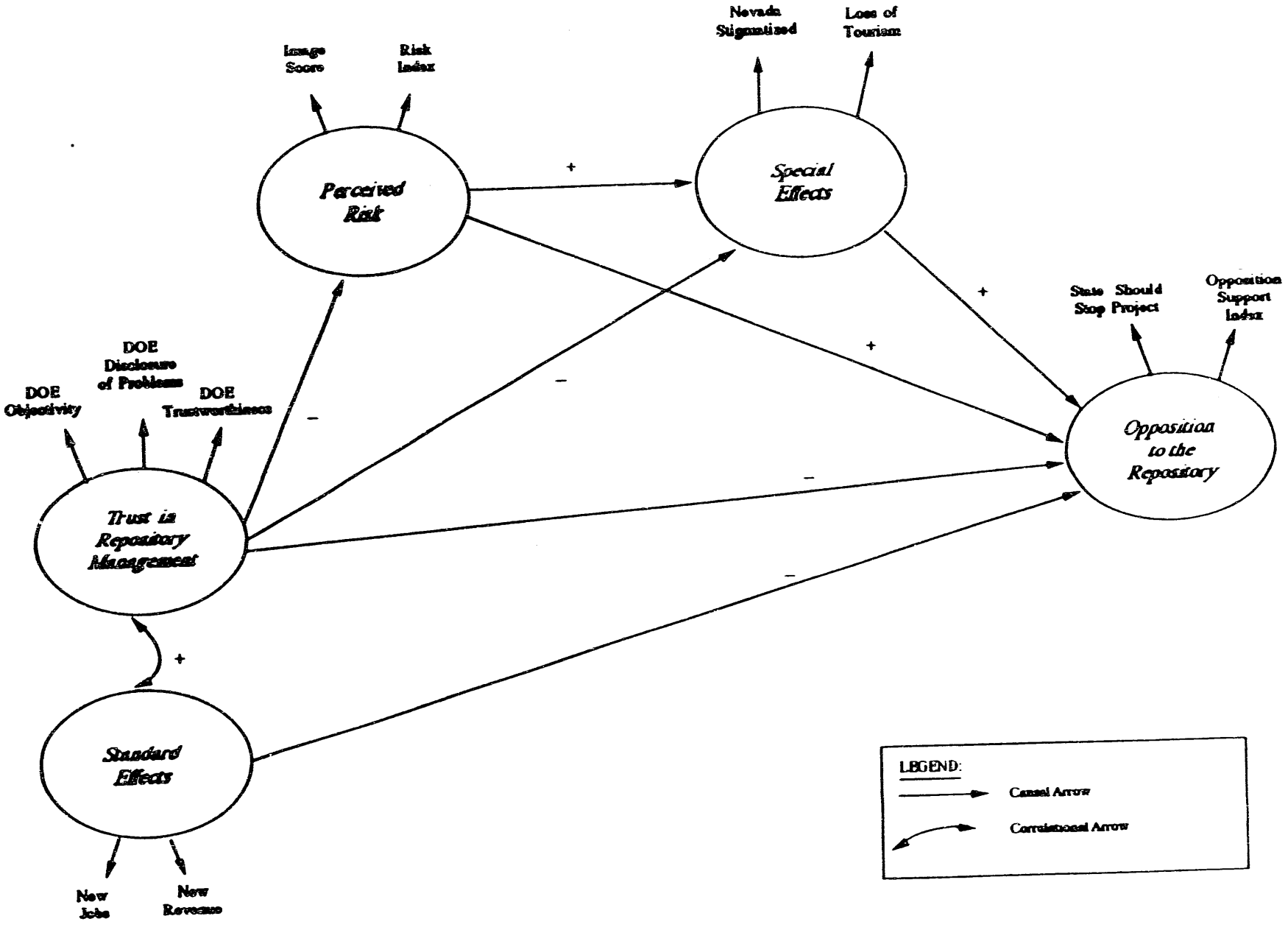

Figure 1. Covariance Structure Model To Examine Public Opposition To The Nevada Repository: Conceptual Design

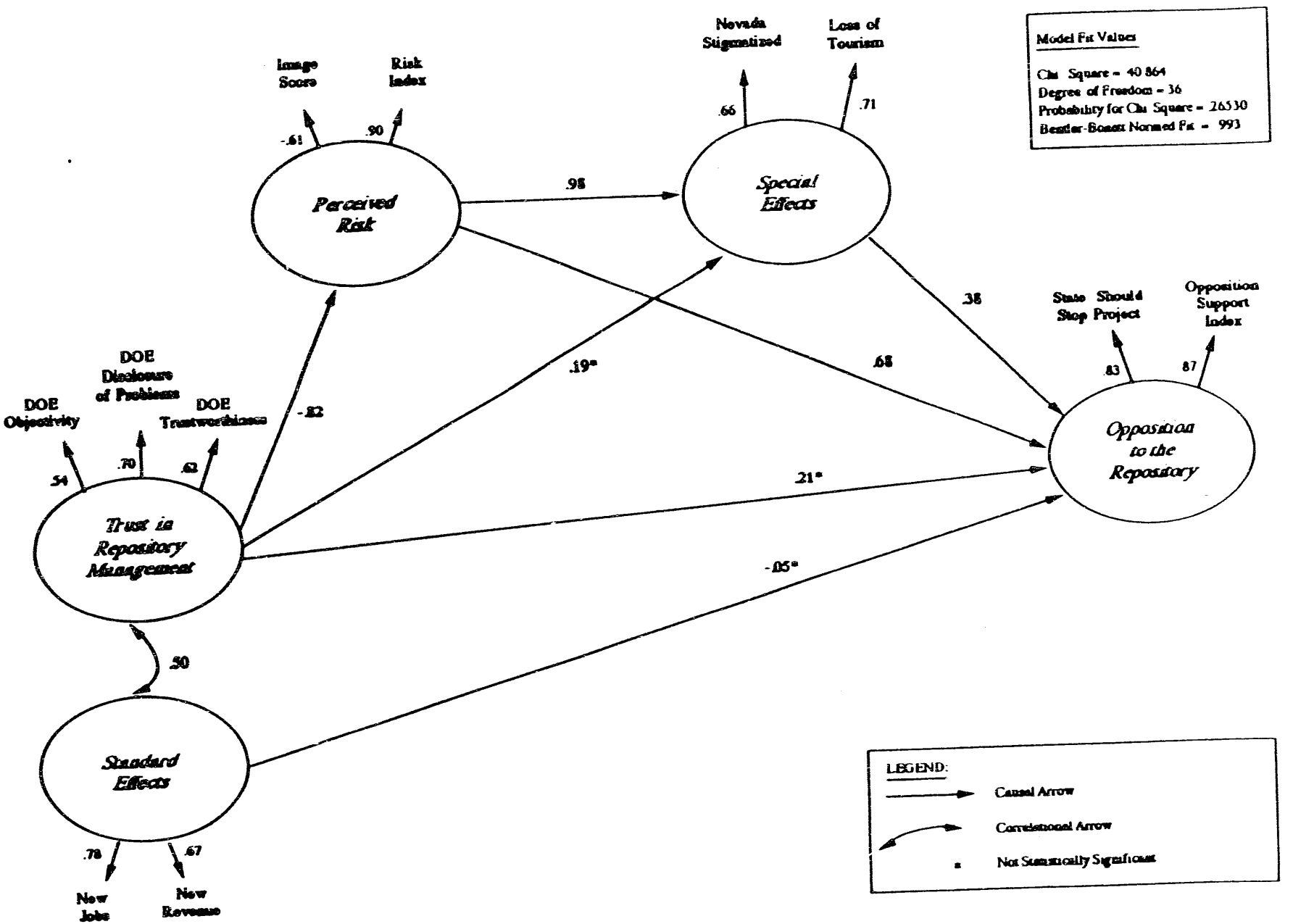

Figure 2. Covariance Structure Model To Examine Public Opposition To The Nevada Repository: Results with 1989 Survey Data

APPENDIX A

FREQUENCY DISTRIBUTION FOR RESPONSES TO QUESTIONS INCLUDED IN THE NEVADA PUBLIC OPPOSITION STRUCTURAL MODEL DATABASE

RESPONSES TO QUESTIONS INCLUDED IN CONSTRUCT:
TRUST IN REPOSITORY MANAGEMENT

Variable: DOE Disclosure of Problems

52. The Department of Energy is providing objective and scientifically sound studies for the Yucca Mountain program.

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	89	84	18	86	14	291
Percent	30.6	28.9	6.2	29.6	4.8	100.0

Variable: DOE Objectivity

49. The Department of Energy can be trusted to provide prompt and full disclosure of any accidents or serious problems with a repository program.

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	160	76	2	38	15	291
Percent	55.0	26.1	0.7	13.1	5.2	100.0

Variable: DOE Trustworthiness

Now I'm going to ask you how you feel about various government agencies and institutions. On a scale of 0 to 10 where 0 means you have NO TRUST AT ALL and 10 means you have COMPLETE TRUST, please tell me how much trust you have in each of these entities to do what is right with regard to a nuclear waste repository:

25. Department of Energy

Score	0	1	2	3	4	5	6	7	8	9	10	Total
Number	53	7	26	26	29	62	21	23	19	9	16	291
Percent	18.2	2.4	8.9	8.9	10.0	21.3	7.2	7.9	6.5	3.1	5.5	100.0

RESPONSES TO QUESTIONS INCLUDED IN CONSTRUCT: STANDARD EFFECTS

Having a high-level radioactive waste repository at Yucca Mountain could result in both benefits and problems. I am going to read you a list of possible benefits and problems. On a scale of 0 to 10, with 0 meaning NOT AT ALL LIKELY to occur and 10 meaning VERY LIKELY to occur, please tell me how likely you think each benefit or problem will be.

Variable: New Jobs

32. Create a significant number of new jobs in Southern Nevada

Score	0	1	2	3	4	5	6	7	8	9	10	Total
Number	16	2	13	25	21	43	17	22	50	14	68	291
Percent	5.5	0.7	4.5	8.6	7.2	14.8	5.8	7.6	17.2	4.8	23.4	100.0

Variable: New Revenue

34. Greatly increase revenues to state and local governments

Score	0	1	2	3	4	5	6	7	8	9	10	Total
Number	21	8	13	26	23	66	25	26	38	8	37	291
Percent	7.2	2.7	4.5	8.9	7.9	22.7	8.6	8.9	13.1	2.7	12.7	100.0

RESPONSES TO QUESTIONS INCLUDED IN CONSTRUCT: PERCEIVED RISK

Variable: Image Score

For this variable, the responses to Question 20 were used. Question 20 solicits a image score for an image of an underground high-level nuclear waste repository that was solicited in Question 19. In Question 19, the interviewers attempted to solicit six images from the respondent. After all the images were collected, the respondent was asked (as part of Question 20) to return to each image and provide an overall rating of that image. For the purposes of the EQS model, only the image score for the first image was utilized. The wording of both Questions 19 and 20 is provided below as well as the frequency distributions for Question 20.

19. My next question involves word association. For example, when I mention the word baseball, you might think of the World Series, Reggie Jackson, summertime, or even hotdogs. Today, I am interested in the first SIX thoughts or images that come to mind when you hear the words: an UNDERGROUND NUCLEAR WASTE REPOSITORY.

    Think about an UNDERGROUND HIGH-LEVEL NUCLEAR WASTE REPOSITORY for a minute. When you think about an UNDERGROUND HIGH-LEVEL NUCLEAR WASTE REPOSITORY, what is the first thought or image that comes to mind?

20. Next, I want to be sure I understand these words and images. When I say YOUR word, please tell me how it relates to your overall image of the REPOSITORY. Is it -- VERY NEGATIVE, SOMEWHAT NEGATIVE, NEUTRAL, SOMEWHAT POSITIVE, OR VERY POSITIVE? Let's begin with the first word: _____.

Score	Very Negative	Somewhat Negative	Neutral	Somewhat Positive	Very Positive	Total
Number	231	18	10	15	17	291
Percent	79.4	6.2	3.4	5.2	5.8	100.0

Variable: Risk Index

Two composite or index variables were created for use in the modeling processes. The first one, a risk perception index variable (Risk Index), was created from six questions asked in the original survey. These questions asked the respondents to rate statements of potential incidents on a scale of "Strongly Disagree" to "Strongly Agree" which were coded as one to five. The questions were alternated between accident and non-accident incidents. For example, one item stated: "Highway and rail accidents will occur in transporting the wastes to the repository site." This was followed by the statement: "The repository can be made safe so that future generations will not accidently dig into the site looking for resources." The responses to three of these statements (Questions 41, 43, and 45) were reversed so that all six statements were coded from 1 ("Strongly Disagree" meaning low potential risk) to 5 ("Strongly Agree" meaning high potential risk). The responses for each record were then summed to provide a score for the risk index variable. The numerical range for the value of this variable is from six to thirty with six being the lowest possible rating of risk potential and 30 being the highest possible rating.

40. Highway and rail accidents will occur in transporting the wastes to the repository site

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	16	32	11	109	123	291
Percent	5.5	11.0	3.8	37.5	42.3	100.0

41. The repository can be made safe so that future generations will not accidently dig into the site looking for resources

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	114	62	6	75	34	291
Percent	39.2	21.3	2.1	25.8	11.7	100.0

42. A future earthquake or volcanic activity may cause release of the nuclear wastes

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	15	25	6	67	178	291
Percent	5.2	8.6	2.1	23.0	61.2	100.0

43. The buried waste will be contained in the repository so that contamination of underground water supplies cannot occur

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	144	74	8	40	25	291
Percent	49.5	25.4	2.7	13.7	8.6	100.0

44. Accidents will occur in handling the materials during the burial operations and result in contamination of workers or radioactive releases into the air and ground

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	16	32	9	96	138	291
Percent	5.5	11.0	3.1	33.0	47.4	100.0

45. Shipments of nuclear wastes can be made safe from sabotage or attack by terrorists

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	146	58	6	55	26	291
Percent	50.2	19.9	2.1	18.9	8.9	100.0

Risk Index

Score	Number	Percent
6	1	0.3
9	1	0.3
10	1	0.3
11	3	1.0
12	4	1.4
13	6	2.1
14	3	1.0
15	7	2.4
16	9	3.1
17	9	3.1
18	15	5.2
19	11	3.8
20	7	2.4
21	15	5.2
22	16	5.5
23	16	5.5
24	21	7.2
25	20	6.9
26	23	7.9
27	20	6.9
28	12	4.1
29	23	7.9
30	48	16.5
Total	291	100.0

RESPONSES TO QUESTIONS INCLUDED IN CONSTRUCT: SPECIAL EFFECTS

Having a high-level radioactive waste repository at Yucca Mountain could result in both benefits and problems. I am going to read you a list of possible benefits and problems. On a scale of 0 to 10, with 0 meaning NOT AT ALL LIKELY to occur and 10 meaning VERY LIKELY to occur, please tell me how likely you think each benefit or problem will be.

Variable: Nevada Stigmatized

36. Result in Nevada being labelled as the "Nuclear Dump State"

Score	0	1	2	3	4	5	6	7	8	9	10	Total
Number	8	4	3	6	5	15	7	10	28	25	180	291
Percent	2.7	1.4	1.0	2.1	1.7	5.2	2.4	3.4	9.6	8.6	61.9	100.0

Variable: Loss of Tourism

37. Cause some tourists to avoid coming to Nevada

Score	0	1	2	3	4	5	6	7	8	9	10	Total
Number	20	6	20	19	14	31	15	28	36	11	91	291
Percent	6.9	2.1	6.9	6.5	4.8	10.7	5.2	9.6	12.4	3.8	31.3	100.0

RESPONSES TO QUESTIONS INCLUDED IN CONSTRUCT: OPPOSITION TO THE REPOSITORY

Variable: State Should Stop Project

46. The state of Nevada should do all that it can to stop the federal government from locating a high-level nuclear repository in the state.

Score	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree	Total
Number	23	17	7	23	221	291
Percent	7.9	5.8	2.4	7.9	75.9	100.0

Variable: Opposition Support Index

The second composite variable used in the modelling process is the Opposition-Support Index which was created from three questions that ask the respondents to select a position for or against the repository. The first question asked for a vote response on Yucca Mountain. "Suppose that the Department of Energy selected the Yucca Mountain Site for the nation's first high-level radioactive waste repository, but it wouldn't be located there unless state residents voted in favor of it". The second question asked the respondents if they favored or opposed the law passed by the 1989 Nevada State Legislature (Assembly Bill 222) which made it illegal to dispose of high-level nuclear waste within the state. A third question asked the respondents if the state should "continue opposition [to the repository] and turn down benefits" or if the state should "stop fighting [the repository] and make a deal" for benefits or compensation. The item on favoring or opposing Assembly Bill 222 was recoded so that a score of "1" equalled support for the repository (opposition to AB 222) and "2" meant support for AB 222 (opposition to the repository). This recoding made the three questions consistent in terms of their scoring; for each question, a score of "1" supported the repository and opposed the State of Nevada position while a score of "2" opposed the repository project and supported the State of Nevada position. The scores for the three questions were then summed to create a "Opposition/Support Index" with a potential range of values between 3 and 6. The higher the score, the greater the opposition to the repository and the greater the support for the State of Nevada position.

21. Suppose that the Department of Energy selected the Yucca Mountain site for the nation's first high-level radioactive waste repository, but it wouldn't be located there unless state residents voted in favor of it. If this were the case, would you vote for it, against it, or wouldn't you vote on this issue?

Score	Vote Yes	Vote No	Total
Number	42	249	291
Percent	14.4	85.6	100.0

60. Some people in the state think that Nevadans should stop fighting the repository and try, instead, to make a deal with the federal government in order to get benefits for the State. Other people believe that Yucca Mountain is a poor choice, and that State resistance should not be weakened or compromised by entering into deals for benefits. Do you believe the state should stop its opposition and make a deal, or do you think the State should continue to do all that it can to oppose the repository even if that means turning down benefits that may be offered by the federal government?

Score	Make a Deal	Oppose & No Benefits	Total
Number	43	248	291
Percent	14.8	85.2	100.0

The final question in the Opposition Support Index is Question 56, which asks the respondent if he/she favors a law (AB222) passed by the Nevada Legislature making high-level nuclear waste disposal in Nevada illegal. Question 55 asked respondents: "Are you aware that the last session of the Nevada Legislature passed a law making high-level nuclear waste disposal in Nevada illegal?" Question 56 then asked:

56. Do you favor such a law?

Score	Favor	Oppose	Total
Number	248	43	291
Percent	85.2	14.8	100.0

Opposition Support Index

Score	3	4	5	6	Total
Number	19	19	33	220	291
Percent	6.5	6.5	11.3	75.6	100.0

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