

## VALUE ENGINEERING SIMPLIFIES SEISMIC EVALUATION OF BUILDINGS

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### ABSTRACT

The Earthquake Hazard Reduction Act of 1977 (as amended) initiated a long-term nationwide earthquake reduction program. As a part of the implementation of this act, the President issued Executive Order (EO) 12941, "*Seismic Safety of Existing for Federally Owned or Leased Buildings.*" The order requires all Federal Agencies to inventory, evaluate, and develop remediation cost estimates for all owned and leased buildings for earthquake safety. The Department of the Interior selected to use the Value Method to analyze the available resources, options, and alternatives for accomplishing this enormous and complex task. Interior executives used the results of the study to set the plans, budget, staff roles, and support needs to enact the Executive Order within Interior.

### BACKGROUND

When a moderate or severe earthquake strikes an urban area, a large number of buildings and infrastructures will be damaged. In recognition of the danger to life and safety, Congress passed the 1977 Act and has amended the Act as needed over the years. The act first directed that new buildings be constructed in conformance with appropriate earthquake design standards. Subsequently all

principal model building codes and standards have been amended to include seismic design and construction provisions and new buildings should now be relatively safe during earthquake events.

Numerous studies and recent experience have shown that the greatest current threat to life and safety arising from a large earthquake in the United States is posed by existing buildings that are not in conformance with current seismic code provisions. Buildings that are a risk to life and safety during an earthquake must be evaluated to determine the appropriate remedy and cost. Recent earthquakes and an increasing awareness of earthquake/seismic risks, have led to improved seismic standards for new construction, and increased policies addressing seismic safety. In December 1994, President Clinton signed EO 12941 "Seismic Safety of Existing for Federally Owned or Leased Buildings." This EO requires all Federal Agencies to: 1) complete an inventory of all buildings leased or owned, 2) identify all seismically high-risk buildings, and 3) evaluate the structural capacity and prepare mitigation cost estimates for all extremely high-risk buildings.

This seemingly simple task is a very large and costly undertaking for many Federal Agencies that have

extensive inventories of buildings. The sheer numbers and scale involved in the task is remarkable. The Department of the Interior presently owns approximately 40,000 buildings and structures. Agencies, such as the branches of the Department of Defense, i. e., Air Force, Army, and Navy; have building inventories many times greater than Interior. The identification and evaluation of building seismic risk is difficult because seismic risk is a complex outcome of seismic hazard (size and frequency of predicted the worse-case earthquake), vulnerability (amount of damage, building construction types, etc.), and occupancy or function of buildings. This complexity is further compounded by the resources and funds that are available to perform this difficult task, and the value and estimated cost of damages for a threatened structure.

#### INTERIOR SELECTS VALUE METHOD TO GUIDE DECISION

The Department of the Interior recognizes that the Value Method is a powerful decisionmaking and support tool. Accordingly, Interior directed that a Value Method value study be used to provide executive decisionmakers with the appropriate information and proposed compliance recommendations needed to make a quality decision. The Value Method was chosen in order to develop a value-based consensus on program requirements, incorporate strategic planning, provide reliable first cost estimates, and propose program implementation alternatives. Using the Value Method in early stages of program development provides improved participation of all interested parties and agreement on values to be assigned to a range of program parameters.

#### VALUE STUDY TEAM FORMATION

The value study team was formed to develop alternatives and recommendations for directors to use in determining a course of action and in allocating the funding levels necessary to implement a solution to comply with the requirements of EO 12941. The team consisted of engineers, geologists, facility managers and earthquake specialists. Although the team was weighted toward seismic safety expertise, it was balanced with multi-discipline professionals who had a variety of managerial, organizational, and other expertise in addition to their earthquake specialization. Further, so as to balance the differing organizational concerns involved, only one team member was selected from each Interior bureau and office that has significant numbers of buildings in its inventory.

#### INFORMATION PHASE AND CREATIVE PHASE ACTIVITIES

The value study occurred at a very early point in the EO activity. Although significant amounts of building inventory data were available from a wide variety of sources, it had not been centrally collected and evaluated. At the inception of the value study, not even the total number of buildings owned or leased by Interior was accurately known. Estimates of the total number of buildings varied by as much as 20-percent. This variation was not due to poor data, but rather to the differences of databases and their classifications, each separately developed and maintained by the different bureaus within Interior. Each building database had been developed for differing purposes by individual Interior bureaus and therefore were not comparable or interchangeable. In addition to the problems of combining individually unique building databases from different Interior bureaus, the existing databases did not include several data elements that were now required by the EO. Accordingly, the job plan phases were visited twice by the team. First to evaluate the overall capability of Interior to meet the intent and purposes of the EO. The second use of the job plan was for development of specific alternatives within each of the general value proposals developed in the first exercise of the study. The first use of the Value Method job plan utilized function analysis to generate multi-dimensional structure for a complex set of program requirements. It focused the study on three key functions, namely: gather appropriate data, classify risk, and determine options.

During the first information phase a FAST diagram (Figure 1) was generated for the EO activity intent and directives related to it. The FAST diagram connects and illustrates the "How" and "Why" bi-directional interrelationships of the higher order, basic and secondary functions. The study team used the resulting FAST to brainstorm and generate a large number of ideas and techniques that could be used to produce the data needed to allow people charged with implementing the EO requirements. Using the affinity technique, these ideas were collected into like areas. Then they were expanded and improved to generate a focused set of concepts for the value study team and top Interior officials to consider.

Once the potential data sources and concepts' analysis and developments were completed and placed in prominent places on the walls of the room (presented), the value study team revised the

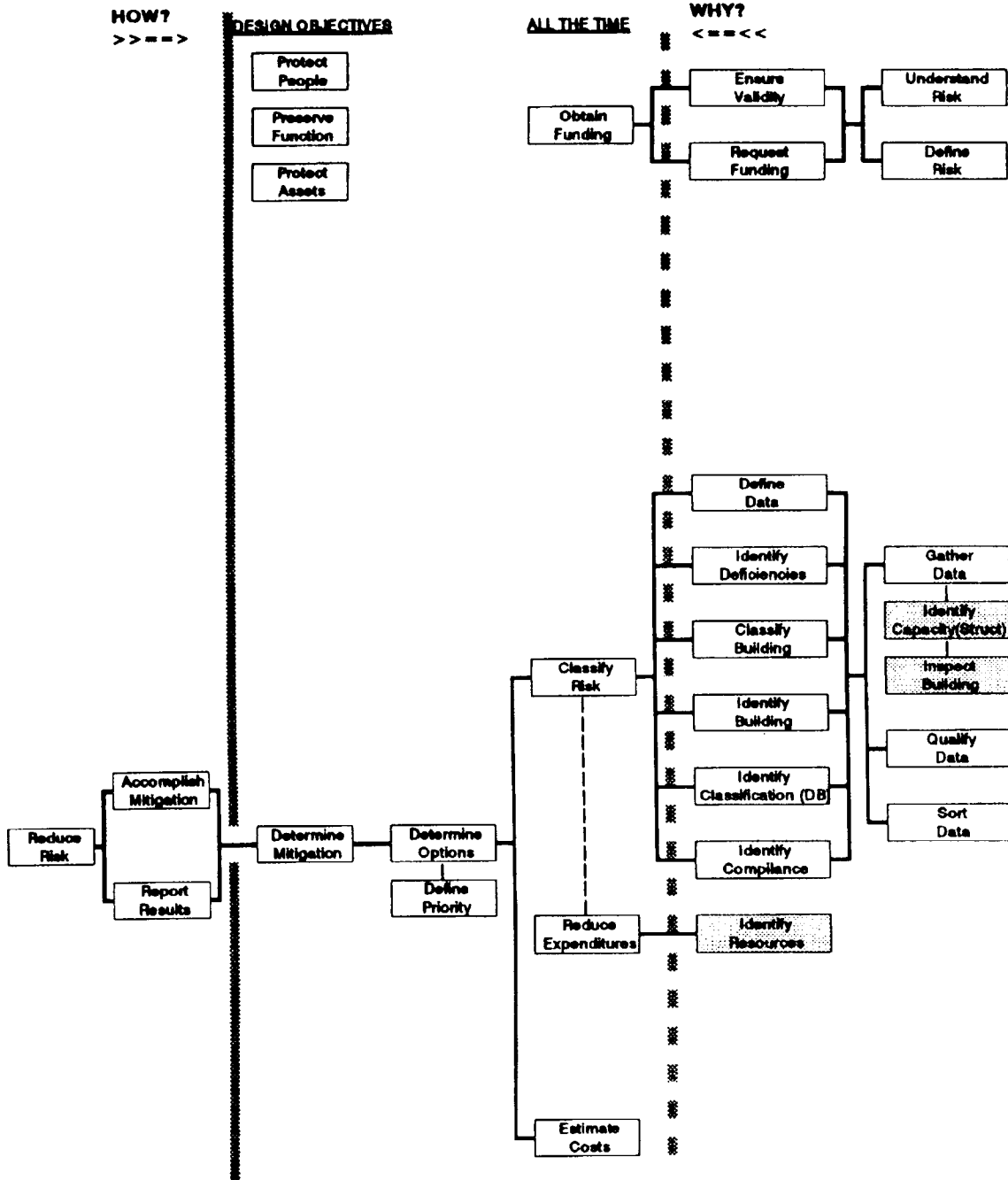


Figure 1. FAST diagram for implementing EO 12941 within the Department of the Interior.

information phase to complete understanding of the EO requirements and focus on Value Method analysis of the basic functions. The team determined that the Interior inventory involved was more than 40,000 buildings and structures. A conservative estimate of the number of buildings that would fall into each building definition category was generated. The team then used the previously developed concepts (implementation of previous value study job plan work) in a combination and affinity creativity session

to develop alternative methods to perform the actual inventory screening, building evaluations and seismic risk mitigation cost estimation work specified by the EO.

DECISIONMAKER CONCEPTS  
DEVELOPMENT

The value study determined that EO compliance requirements broke into three major areas or steps: (1.) inventory and database updating, (2.) screen data

and classifying risk, and (3.) evaluate high-risk buildings and estimate cost of mitigation. The first step was inventorying to determine the actual building number involved and probable status of the risk parameters for each building. Once the inventory was generated, resulting data would need to be screened, for probable risk and inclusion of special factors relating to a specific bureau or office that would affect decisions. Finally, the results would be used to perform costly onsite evaluations and other activities to confirm that the seismic hazard risk identified by the screening was real, and if real, the appropriate

course of action (refurbish, move and demolish, etcetera) would be determined and a cost estimate developed. Screening of the updated building inventories for exceptionally high-risk buildings is based on criteria customized for each Federal agency. Customizing of the database screen, in order to classify risk, includes designating certain building occupancy types as essential to mission accomplishment or critical for life safety considerations (Tables 1 and 2). Each step, for both decision and performance purposes, was dependent on the previous step.

Seismicity	Occupancy	Model Building Type	Age	Bureau Essential
High 1991 National Earthquake Hazard Reduction Program (NEHRP ) Zones 5,6,7	-Schools -Clinics - Fire Stations -Emergency Ops Center -Dormitory -Office w/ Day Care -Places of Assembly -Detention Center	Precast/Tilt-Up Concrete Walls  Precast Concrete Frames/Concrete Shear Walls  Reinforced Masonry Bearing Walls w/ Wood/Metal Deck Diaphragms  Reinforced Masonry Bearing Walls w/ Precast Concrete Diaphragms  Unreinforced Masonry Bearing Wall Buildings	> 7yr	Special Historic Communication Center Expensive Equipment Hazmat Storage
Model Building Types 11 through 15, as identified in Federal Emergency Management Agency (FEMA) 178.				

Table 1. Suggested definition of exceptionally high-risk buildings.

For each EO compliance requirement the team developed various alternative approaches. The added potential worth of performing additional work within a specific step was used to generate at least three possible alternatives within that required step. Within each step each potential alternative was placed in a matrix and ordered according to its estimated cost. The lowest cost option was placed on the bottom and the highest cost item on the top. The matrix was used to evaluate the incremental worth versus incremental cost within each step and the effect on subsequent steps.

The monetary cost of all alternatives for screening was determined to be very small, relative to inventory and evaluation activities. However, depending on which screening alternative is chosen, its effect on the last area, evaluation, was large in

both cost and accuracy. Further, screening was highly dependent on the quality of inventory data utilized. Incomplete or inaccurate data input would lead to a poor result regardless of the quality of screening. The summary of basic alternatives matrix is shown in Table 3.

VALUE STUDY TEAM SCENARIO ESTIMATES

The team then used their expertise and knowledge developed during the value study to evaluate the incremental worth and cost matrix in terms of two scenarios: (1.) highest estimated value and (2.) obtaining the best value if funding is limited (necessitating minimal actions involving cost). Using these scenarios, the team generated two combinations of alternatives for top management's consideration. For these two scenario combinations, the team further developed the various activity and funding timing

Seismicity	Occupancy	Model Building Type	Age	Bureau Essential
High 1991 NEHRP ZONES 5,6,7	-Schools -Dormitory -Fire Stations -Emergency Ops Center -Office w/ Day Care -Places of Assembly -Detention Centers -Clinics	Wood, Light Frame Wood, Commercial and Industrial Steel Moment Frame Steel Braced Frame Steel Light Frame Steel Frame w/ Concrete Shear Walls Steel Frame w/ Infill Shear Walls Concrete Moment Frame Concrete Shear Walls Concrete Frame w/ Infill Shear Walls Precast/Tilt-Up Concrete Walls Precast Concrete Frames/Concrete Shear Walls Reinforced Masonry Bearing Walls w/ Wood/Metal Deck Diaphragms Reinforced Masonry Bearing Walls w/ Precast Concrete Diaphragms Unreinforced Masonry Bearing Wall Buildings	> 7yr	Special Historic Communication Center Expensive Equip. Hazmat Storage
( Model Building Types 11 through 15, as identified in FEMA 178.)				

TABLE 2. SUGGESTED DEFINITION OF HIGH-RISK BUILDINGS

possibilities associated with those selections and the related worth and costs (monetary and non-monetary).

The team recommended that the highest cost alternatives also had the greatest worth, and the worth versus cost relationship was of sufficient value to recommend that approach to the directors and funding authorities. Staging of the steps with regard to funding would allow decisionmakers to change direction should the estimates change or actual value attained not meet expectations. This recommended scenario would provide an accurate Interior-wide building Inventory and a very comprehensive and

complete determination of where all the high-risk buildings are located and also provide detailed cost estimates for repair of building deficiencies.

The second scenario yielded a much lower cost requirement. However, it would not allow higher quality results and the potential risk of increased cost in later years was high. Essentially, this meant obtaining no additional data, minimal screening of inadequate data, conducting no building evaluations, and relying on internal occupant knowledge of the building. Further, if it was later determined that higher quality results were necessary, little of the work performed could be used. It would be necessary

Inventory	Screening	Evaluation
<p><u>Proposal No. 1A.</u> Fully implement the executive order relative to inventory and submit the inventory to FEMA. Cost to identify and report exempt buildings would be about \$2.41 per exempt building, non-exempt non-evaluated buildings would be about \$100.93 per building and non-exempt evaluated buildings would be \$104.21 per building. Comparative program cost would be about \$3,236,000.</p>	<p><u>Proposal No. 2A.</u> Screen database by fully utilizing Federal (ICSSC) Guidelines with some Interior customizing of sort criteria. Cost is about \$178,000 total.</p>	<p><u>Proposal No. 3A.</u> Use fully developed inventory and screening results and prioritize using ICSSC Guidance and special criteria. Cost is a maximum of about \$11,000 per building. Comparative program cost \$8,193,000. (Comparative cost is \$7,029,000 if Proposal No. 1A data is generated and available.)</p>
<p><u>Proposal No. 1B.</u> Use the existing data in existing databases - collect additional data for building occupancy only. Cost would be from about \$2.41 for exempt buildings to about \$8.49 for non-exempt evaluated buildings. Comparative program cost would be \$94,000.</p>	<p><u>Proposal No. 2B.</u> Screen by utilizing each bureau's existing database only. Cost is about \$115,000 total.</p>	<p><u>Proposal No. 3B.</u> Use inventory and Extremely High Risk (EHR) screening results and prioritize using building types. Cost is a maximum of about \$5,100 per building. Comparative program cost \$6,937,000.</p>
<p><u>Proposal No. 1C.</u> Use only the existing data in an existing database - collect no additional data. Cost ranges are from about \$2.41 per exempt building to a maximum of about \$7.73 per building. Comparative program cost \$69,000</p>	<p><u>Proposal No. 2C.</u> No formal screening. Cost is about \$18,000 total.</p>	<p><u>Proposal No. 3C.</u> Using the Rapid Visual Screening (RVS) and internal occupant knowledge of the building to perform an evaluation and prioritization. Cost is about \$550 per building. Comparative program cost \$1,163,000.</p>
<p><u>Proposal No. 1D.</u> Use internal criteria and utilize no database to identify or categorize buildings. Minimal cost of about \$0.24 per building. Comparative program cost \$10,000.</p>		<p><u>Proposal No. 3D.</u> Using bureau or office internal knowledge perform no formal evaluation and prioritization. Cost is about \$50 per building. Comparative program cost \$106,000.</p>

Confidence level and accuracy is highest at A

Notes:

- Cost per building figures have sufficient detail to be used in subsequent estimates.
- Total dollar amounts are based on cost per building and the assumed number of buildings involved. Total costs are for comparative purposes only and should not be used for program funding purposes. Further analysis by each bureau and office should produce results that would be sufficient for funding requests.
- Number of value study team estimated building categories used to generate total comparative numbers: 25 percent exempt, 5 percent non-exempt, evaluated, and the remaining 70 percent non-exempt, non-evaluated. About 10 percent of the non-exempt evaluated are assumed to be identified as Definitely Needs Repair (DNR).
- The total number of applicable buildings owned by Interior, as of 1995, was estimated to be about 42,000.
- Alternatives. 1A, 2A, and 3A constitute the team preferred alternative activity path recommended to be pursued by Interior that meets the highest value recognized by the team. Alternatives. 1B, 2B, and 3C make up a less preferred limited funding path chosen by the team that still generates reasonably fair value.

Table 3. Summary of basic alternatives matrix

to return to the inventory step and expend the funds at that time. This second scenario was provided to the decisionmakers because the lack of funding is always a very real possibility. The resulting determinations would not fully comply with the EO requirements, but Interior could still make a reasonable accounting of their most extremely hazardous buildings.

#### DECISIONMAKER PRESENTATION

The individual step alternatives within each of the major steps (inventory, screening, and evaluation), and two combination of alternatives scenarios were presented to the Interior Planning, Design and Construction Council directors.. The Council directors were extremely pleased with the value study team report and findings and instructed the team to present its findings to funding and other Interior management officials in Washington, D.C. Immediately after this presentation, a decision was made to implement the highest value scenario with minor modifications.

The use of Value Method procedures and reporting processes provided decisionmakers with a straightforward set of cost-based alternatives for accomplishing program requirements that initially appeared to be overwhelming. It proved to be a highly successful application for executive use of the Value Method as a management tool. It helped the customers (those in Interior buildings at the time of an earthquake risk event), the organization (those charged with the implementation of the EO), and management (executives needing to balance scarce resources with existing Interior program requirements and the new compliance requirements of EO).

#### SUMMARY

This case study is just one more example of how application of the Value Method generates high quality results that can be used by decisionmakers to produce supportable decisions that have high potential for benefitting everyone involved: customers, managers, and organizations. All phases of the Value Method job plan were visited twice. The Department of the Interior has found this to be an extremely valuable approach on activities and projects at an initial level of development. The value study results were used by managerial and funding authorities to

specify and support the direction selected for implementation. The results and supporting discussions, findings and observations contained in the value study continue to be used to guide and assist the people charged with performing the work.

The success of this study is the clarity, consensus building, and comparative risk assessments that resulted by using the Value Method to analyze the EO requirements. The Value Method confirmed program requirements definitions, established program and operational performance criteria, provided comparative risk assessments of alternatives, developed realistic cost estimates, and recommended the best program value for money proposals. The Value Method brought understanding and improved clarity of the program objectives, options and related consequences, for a better briefing to upper management. The decisionmakers were provided with a study that they could use to: (1.) Guide program and budget development, (2.) Establish project priorities within the program, (3.) Advance cost-effective, quality solutions at known risk, and (4.) Provide value based consensus recommendations.

#### REFERENCES

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