by Walter W. Hays and Badaoui M. Rouhban

Technology Transfer

Fundamental knowledge on the nature and extent of the physical and societal impacts of earthquakes and ways to mitigate and prepare for them has advanced significantly during the 1990's. However, transfer of technology (that is, the transfer of fundamental knowledge and know-how for use by society to achieve a practical purpose such as earthquake risk reduction) lags behind research because people and organizations are: (a) paralyzed by apathy, (b) neutralized by narrow mindness, and (c) rendered powerless by ineffective actions. Solutions to these constraints have begun to emerge and are expected to improve during the 1990's as existing national and regional programs in the US, such as those composing the National Earthquake Hazards Reduction Program, are expanded and cooperative international programs, such as a seismic zonation study in Algeria and those of the International Decade for Natural Disaster Reduction, are initiated by individual nations throughout the world.

Introduction

This paper reviews the concept of transfer of technology, an important and essential element of national and international scientific programs. Two experiences are cited, a regional earthquake hazards reduction program in Utah in the United States, a part of the National Earthquake Hazards Reduction Program (NEHRP), and the Algerian seismic zonation study following the 1980 El Asnam earthquake.

Technology transfer is defined as the transfer of knowledge and know-how by society to achieve a practical purpose such as reduction of risk from natural hazards such as earthquakes, floods, severe wind storms, or volcanic eruptions. Technology transfer is more than information transfer; it also involves transfer of know-how. Risk reduction measures, which are adopted and enforced by local governments, typically include:

- Response and recovery plans—planning to guide an efficient and economical short-term emergency response and long-term recovery from the societal and economical impacts of a natural hazard.
- Building and land-use regulations—regulations to control the design and construction of buildings and the use of land in a community in order to minimize loss of life and property damage from the physical phenomena generated by a future event.
- Prediction and warning systems—procedures for warning the populace of imminent hazardous events and providing guidance, so that they can protect their lives and property from the anticipated physical effects.

U.S. National Earthquake Hazards Reduction Program

The Earthquake Hazards Reduction Act (Public Law 95-124) established the NEHRP in 1977. The goal was to reduce the risk to life and property from future earthquakes in the United States through the establishment and maintenance of an effective research and development program. Technology transfer was an important component of the NEHRP because of the need to bridge the gap between researchers and practitioners so that the research would be applied by State and local governments.

In the NEHRP, researchers conduct studies to increase fundamental knowledge on the nature, frequency, and spatial and temporal extent of the physical and societal impacts of earthquakes and the most effective ways to mitigate them. Practitioners apply the results in accordance with the political decisionmaking process in State and local governments.

Four Federal agencies have programs in NEHRP. Their programmatic objectives are described below:

1. The Federal Emergency Management Agency (FEMA).—FEMA, the lead agency, which had an annual budget for this activity in fiscal year 1990 of about US\$5 million, has a program that, over the past 12 years, has emphasized: (a) design practices and manuals for new buildings, (b) guidelines on the abatement of seismic risk posed by existing buildings, (c) seismic safety planning for lifeline systems, (d) support for a study of a national earthquake-engineering experimental facility, (e) earthquake-hazard mitigation strategies, (f) Federal response planning, (g) State and local preparedness planning, (h) earthquake education and information transfer, and (i) postdisaster mitigation. FEMA implements its program through solicited competitive contracts and planning assistance grants to State and local government agencies.
2. The National Institute of Standards and Technology (NIST) (formerly National Bureau of Standards).—NIST had an annual budget for this activity in fiscal year 1990 of about US\$0.5 million. NIST's program during the past 12 years has emphasized: (a) improved seismic design and construction practices, (b) prediction of the behavior of masonry walls and bridge columns, (c) the feasibility and need for a national earthquake engineering experimental facility, and (d) the U.S./Japan Panel on Wind and Seismic Effects. NIST staff performs its program.
3. The National Science Foundation (NSF).—NSF has programs in the Earth Science Division (fiscal year 1990 budget for this activity of about US\$10 million) and the Division of Fundamental Research in Critical Engineering Systems (fiscal year 1990 budget of about US\$18 million). NSF's objectives in the Earth Science Division are: (a) basic understanding of earthquake processes; (b) international activities; and (c) workshops, symposia, and conferences. The objectives in the Critical Engineering Systems program are research on: (a) fundamental engineering issues related to earthquake ground shaking; (b) earthquake responses of soil and geologic structures; (c) tsunamis; (d) seismic zonation; (e) steel, masonry, reinforced concrete, and wood structures; (f) lifeline systems and offshore structures, and (g) postearthquake investigations. NSF implements its programs through unsolicited grants.

4. The U.S. Geological Survey (USGS).—USGS had an annual budget for this activity in fiscal year 1990 of about US\$35 million. The ongoing USGS program has emphasized: (a) regional monitoring and earthquake-potential studies, (b) earthquake prediction research, (c) regional earthquake hazards and risk assessments, (d) earthquake data and information services, (e) engineering seismology, and (f) technology transfer. The program is implemented through internal projects conducted by staff and external grants funded and awarded through an annual program solicitation.

Significant progress in the NEHRP has been made in both research and technology transfer (Hanks, 1985 and Hays, 1988). The process for creating a body of fundamental knowledge to meet the Nation's needs and for disseminating results through professional meetings and publications was already well advanced when the NEHRP was created in 1977, so expansion was relatively easy. In contrast, however, the process for fostering transfer of technology and applications was not well advanced, and new innovative approaches were needed to bring researchers and practitioners together and to stimulate the decisionmaking process to achieve risk reduction. The next section describes such efforts in the Wasatch Front, Utah, a region of moderate seismicity in the Intermountain seismic belt.

Research and Technology Transfer in Utah

In 1983, the USGS initiated a 5-year cooperative program of research and technology transfer along the Wasatch Front, Utah area (fig. 1). Simultaneously, FEMA focused its emergency management program in the region. Together, these programs established a public/private partnership, involving Federal, State, and local governments; universities; and the private sector, to assess the earthquake hazards and risk in the Salt Lake City-Ogden-Provo urban corridor. This corridor contains about 80 percent of Utah's 2 million people and faces a potential loss of \$3 billion in future M 7.5 earthquakes (Algermissen and others, 1988). The program had two primary goals:

- To accelerate and expand ongoing research, to produce a comprehensive knowledge base on the ground shaking and ground failure hazards, and to assess the risk in a 10 county region containing Salt Lake City and other urban centers.
- To transfer technology from Federal and State researchers to local and State practitioners, so that State and local government decisionmakers could adopt and enforce scientifically sound public policies to reduce their earthquake risk.

Leadership for marshalling State and local government resources and efforts was provided by the Utah Geological and Mineral Survey (UGMS) and the Utah Division of Comprehensive Emergency Management. University researchers were led mainly by the University of Utah, Utah State University, and Brigham Young University. Activities of the private sector and professional organizations were led by Reaveley Engineers and Associates and several individual consultants.

The USGS's Wasatch Front program was completed in 1988. It demonstrated the importance of five interrelated elements (fig. 2) for advancing transfer of technology. They are:

1. A comprehensive body of geologic, seismological, geotechnical, engineering, and planning data from credible sources. As such information became available from USGS and Utah researchers, practitioners in Utah demonstrated willingness to use it for loss-reduction measures.

Figure 1.—Map of Utah showing the Wasatch fault zone, an active, 370-km-long normal fault system capable of generating magnitude 7 or larger earthquakes.

Knowledge Utilization Pyramid

Figure 2.—Illustration of the key elements of technology transfer. Communities throughout the Nation gamble when they do little or nothing to foster the transfer of existing technology from researchers to practitioners and to implement risk-reduction measures before a damaging earthquake strikes.

2. People who are trained, concerned, and committed to technology transfer. Once the communications gap between researchers and practitioners in Utah was recognized, steps were taken to correct it. USGS scientists trained UGMS geologists in paleoseismicity (that is, trenching and age dating to define earthquake recurrence intervals). Three trained geologists of the UGMS were assigned to urban planning departments of five of the largest counties to facilitate transfer of technology from researchers to practitioners. The benefit was almost "real time" because each county was able to use the results for making short-term decisions about important urban development programs.
3. Programs that are focused, integrated, and coordinated and have clear short- and long-term goals. Each year, workshops were designed to bring researchers and practitioners together to report on their accomplishments, to set new goals, to develop plans for future research, and to identify targets for transfer of technology.
4. Experience with natural hazards. Flooding and landslides in Utah in 1983 and a damaging earthquake in Mexico in 1985 provided a realistic indication of the risk to urban centers of the urban corridor and to the State. These experiences helped to marshal political support for adoption and enforcement of risk-reduction measures.
5. Practical and proven techniques for reducing potential losses. Experienced professionals from California were participants in the annual workshops and in other consensus building meetings. They demonstrated that effective measures for loss reduction exist and that they can be applied in a cost-effective manner by existing Utah institutions.

Research and Technology Transfer in Other Parts of the United States

The Wasatch front program has been adopted as a model for use in two other earthquake-prone regions of the Nation, the Pacific Northwest (Hays, 1989) and the Central Mississippi Valley region (USGS, 1990). Both regions, like Utah, have moderate seismicity. Also, both regions have experienced damaging earthquakes in the past, and a future recurrence would be potentially devastating to some of the buildings and lifeline systems exposed to ground shaking and ground failure. Fortunately, the recurrence intervals for moderate- to large-magnitude earthquakes range, respectively, in these regions from several decades to a century or more, leaving adequate time to develop the knowledge base and to foster transfer of technology to practitioners and the adoption and enforcement of loss-reduction measures by State and local governments.

Seismic zonation in Algeria

The seismic zonation study in Algeria following the magnitude 7.2 El Asnam earthquake on October 10, 1980, is an excellent example of technology transfer. This earthquake accelerated transfer of technology in Algeria more than any other past Algerian earthquake, even though other recent earthquakes, such as the 1954 Orleansville event, were also devastating. The El Asnam earthquake (fig. 3) killed 2,700 people, injured several thousand, left 300,000 homeless, de-

Figure 3.—Map of Algeria showing the location of past damaging earthquakes. The polygon shows the region where seismic zonation studies were performed after the 1980 earthquake.

stroyed buildings and lifeline systems valued at several billion dollars, and slowed economic development in a rapidly growing region for 10 years. Recognizing the long-term risk from future earthquakes, Algerian authorities froze construction in the stricken area and took specific steps after the El Asnam earthquake to change their national and local building and land use regulations as a part of the long-term recovery and reconstruction program. With the assistance of UNESCO (Hays, 1985), an international tender was prepared to obtain a skilled consultant to produce the required technical products (for example, seismic zonation maps) and to develop a process to transfer the technology on seismic zonation to Algerian scientists, engineers, and urban planners. A contract having these requirements was awarded to Woodward Clyde Consultants in 1983. Immediately thereafter, Controle Technique de la Construction (CTC), the Algerian organization empowered to lead the program, took additional steps to ensure transfer of technology by asking UNESCO to create a Control Board to act as their technical advisor, to monitor the study by Woodward Clyde Consultants, and to facilitate technology transfer. A Control Board, consisting of a chairman from the United States and 15 international experts having knowledge and experience in all aspects of seismic zonation, was established in 1983. It performed three tasks on behalf of CTC and UNESCO:

1. Identified technical issues associated with the seismic zonation study of the stricken area and 10 rapidly growing urban centers in the region.
2. Evaluated the quality and usefulness of the final products (that is, the regional- and urban-scale seismic zonation maps) and process used to transfer technology to the Algerians, and
3. Created additional technology transfer activities to compliment those of the contractors.

Technology transfer was accomplished by the Control Board in part by convening five multidisciplinary training workshops on topical problems in seismic zonation. Each one was convened 1 or 2 days before each of the scheduled project meetings between Woodward Clyde Consultants, CTC, and their Algerian partners. The training workshops were designed to introduce Algerian professionals (for example, scientists, engineers, urban planners, and code officials) to the wide variety of issues inherent in seismic zonation and to help them gain self-confidence as well as know-how. Algerian scientists learned how to conduct paleoseismicity studies, for example. Technical aids such as maps and exercises to illustrate professional judgment and a glossary of technical terms (both in French and English) were provided to each of the approximately 50 Algerian participants who attended each workshop. Algerian professionals were also assigned roles in each workshop; they lectured, coached Algerian colleagues in the exercises, and helped to evaluate and plan the workshops. Awards signed by the lecturers were given to all participants who completed each training workshop.

A decade after the earthquake, all indications are that the transfer of technology on seismic zonation to Algerian professionals was successful. Algeria now has a modern building code and updated, realistic urban master plans that incorporate the earthquake hazard in the planning phase. Algerian scientists have applied their new know-how to excavate new trenches and to perform a seismic zonation study of Ouled Fares, a small urban area near El Asnam, and recently they started work on Algiers, the capital, which was destroyed by a large earthquake on February 3, 1716. They convened an international conference on Seismic Zonation in 1984 to share the new knowledge on seismic zonation with professionals from neighboring countries. A new institution, the Institute of Earthquake Engineering and Applied Seismology, was established in 1984 with about 10 professionals. It now has 46 professionals. Two hundred strong-motion accelerographs have been purchased since 1980, and they are deployed throughout Algeria to complement the modern seismicity network installed earlier. At present, Algerian professionals are

contributing to SEISMED, a cooperative regional project involving 18 nations to reduce earthquake risk in the Mediterranean region (Hays, van Essche, and Maranzana, 1991).

Factors that constrain technology transfer

The Utah and Algerian programs and other national and international programs have shown that technology transfer is difficult for three primary reasons. They are: apathy (Der Heide, 1989); differences in perspectives of scientists and engineers (that is, researchers) and decisionmakers (that is, practitioners) (Szanton, 1981); and persistent use of ineffective techniques for technology transfer (Hays, 1988).

Apathy is a universal problem (fig. 4). It causes knowledge to be unknown, unused, or ignored, and it is manifest in many different ways, such as: (1) lack of awareness of the potential threat and indifference about the consequences, (2) inaction by State and local officials, (3) underestimation of the risk to the community, business, or individual, and (4) overreliance on technology, luck, or personal ability to cope with a "hypothetical" problem.

The "law of apathy" can be stated as follows: The status quo about earthquake-risk reduction will be maintained until external forces compel change.

Technology transfer is difficult also because of narrow mindedness (fig. 5). Scientists, engineers, practitioners, and decisionmakers often fail to see the total picture. Consequently, they can have very different perspectives on research and technology transfer, which impede the process needed for risk reduction, namely:

- The ultimate objective of scientists and engineers (that is, researchers) is the respect of their peers; whereas, it is the approval of the appointing or contracting official or the stockholders for practitioners and decisionmakers.
- The time horizon of scientists and engineers is long; whereas, it is short for practitioners and decisionmakers.
- The most valued outcome for scientists and engineers is original insight; whereas, practitioners and decisionmakers want a reliable solution.
- The role of expression is obtuse and highly qualified for scientists and engineers; whereas, practitioners and decisionmakers want a simple and absolute statement.

TECHNOLOGY TRANSFER LAW OF APATHY

Figure 4. — Schematic illustration of apathy. The status quo about earthquake risk reduction will be maintained until external forces compel change.

TECHNOLOGY TRANSFER

LAW OF NARROW MINDEDNESS

Figure 5.—Schematic illustration of the reason for narrow mindness. Scientists and engineers need is to see the total picture; that is, from the perspective of the decisionmaker or practitioner as well as their own viewpoint.

TECHNOLOGY TRANSFER

LAW OF INEFFECTIVE ACTIONS

Figure 6.—Schematic illustration of ineffective actions. Transfer of technology will fail when scientists, engineers, practitioners, and decisionmakers act on the basis of incorrect assumptions about human behavior.

- The preferred form of conclusion of scientists and engineers is multiple possibilities with emphasis on the uncertainties; whereas, practitioners and decisionmakers usually want the “best” solution with the uncertainties submerged.

The “law of narrow mindness” can be stated as follows: individuals, scientists, engineers, practitioners, and decisionmakers will

often view the goals of research and technology transfer differently until external forces compel them to work together as partners to solve a problem such as risk reduction in their community.

Technology transfer will lag when the actions of scientists, engineers, practitioners, or decisionmakers are ineffective (fig. 6). Technology-transfer techniques work best when they are tailored to the community and are based on correct assumptions about human behavior. For example, technology transfer will usually fail (Hays, 1988) when scientists, engineers, practitioners, or decisionmakers assume that:

- There is a general public.
- Mailing a technical report is sufficient for communication, understanding, and transfer of know-how.
- The end of a research project is the best time to involve a practitioner or decisionmaker in technology transfer.
- Practitioners and decisionmakers cannot process complex technical information.
- Practitioners and decisionmakers will not use scientific results and technology unless a consensus has been reached.
- Practitioners and decisionmakers only want and need the “worst case” scenario.

The “law of ineffective actions” can be stated as follows: Technology-transfer techniques based on false assumptions about human behavior will be ineffective and fail until external forces compel realistic modification of the transfer techniques.

External Forces

Experience in national and international natural hazards programs has shown that the key to improving technology transfer is to find external forces that will transform: apathy into commitment, self-centered, narrowminded individuals or organizations into partners who see the total picture and work on the total problem, and ineffective unrealistic technology transfer techniques into effective realistic technology transfer techniques.

In Utah and Algeria, the most effective external forces that forced change were:

- A damaging earthquake or other natural disaster such as floods or landslides.
- Empowerment of individuals or organizations to bridge the gap between researchers and practitioners (for example, the Utah county geologists program and the Control Board).
- Training (figs. 7 and 8) designed to give individuals specific know-how and to transform them into local experts having a stake in their future (for example, the annual workshops in Utah and the training workshops in Algeria).
- Legislation that sets and enforces deadlines for compliance (for example, freezing construction in Algeria).

International Decade for Natural Disaster Reduction (IDNDR)

Technology transfer is a critical element of the IDNDR (National Research Council, 1987; United Nations, 1989). This international program has the challenging goal of reducing loss of life and socioeconomic impacts from natural hazards throughout the world. The two key strategies are: (1) deepening knowledge through research on natural hazards and postdisaster investigations and (2) transferring technology from researchers to practitioners for use in risk-reduction measures for the natural hazards: earthquakes, severe windstorms,

PROFESSIONAL SKILL ENHANCEMENT

INCREASING THE SKILLS OF PROFESSIONALS
TO ADDRESS THEIR PROBLEMS

Figure 7.—Professional skill enhancement is effective when it is based on a process that leads to increased know-how and a personal commitment for action.

floods, landslides, wildfires, volcanic eruptions, and drought. Risk-reduction measures encompass five broad categories: preparation, prediction and warning, intervention, emergency response, and recovery.

All nations expect to experience many natural hazards during the 1990's. Technology transfer must be accelerated because many of the world's 5 billion people are living and working in communities located: along the water's edge, on flood plains, in regions susceptible to drought, in earthquake-prone regions, on unstable slopes susceptible to landsliding, in zones susceptible to volcanic eruptions, or at urban/wilderness interfaces susceptible to wildfires.

The potential for large economic losses and casualties at such locations is increasing because dwellings, structures, lifeline systems, and facilities in each community are not always sited,

Figure 8.—Relative influence of various technology transfer techniques. The influence of on-the-job training and workshops is very high; whereas, that of mailing a publication is very low (from Thiel, 1988).

Figure 9.—Illustration of effective and ineffective technology transfer on natural hazards knowledge.

designed, and constructed with adequate consideration of the physical phenomena expected to occur during their useful life.

Conclusions

Reduction of risk for natural hazards is the goal of the world in the 1990's. An integrated program of research and technology transfer is the key to success (fig. 9). Although much has been learned from past international experiences, innovative ways are still needed to overcome apathy, narrow mindness, and ineffectiveness of researchers, practitioners, and decisionmakers throughout the world.

References

- Algermissen, S.T., Arnold, E.P., Steinbrugge, K.V., Hopper, M.G., and Powers, P.S., 1988, "Earthquake Losses in Central Utah," in Gori, P.L., and Hays, W.W., eds., Assessment of Regional Earthquake Hazards and Risk in the Wasatch Front Area, Utah: U.S. Geological Survey Open-File Report 88-680, p. X-1-62.
- Der Heide, Erik A., 1989, Disaster Response—Principles of Preparation and Coordination: C.V. Mosby Co., St. Louis, 363 p.
- Hanks, T.C., 1985, The National Earthquake Hazards Reduction Program—Scientific Status: U.S. Geological Survey Bulletin 1659, 39 p.

- Hays, W.W., van Essche, L., and Maranzana, F., 1991, SEISMED and the IDNDR—Opportunities to Reduce the Risk from Earthquakes and Other Natural Hazards: Episodes, v. 14, no. 1, p. 13.
- Hays, W.W., ed., 1989, Earthquake Hazards in the Puget Sound, Portland Area, Proceedings of the Conference 48: U.S. Geological Survey Open-File Report 89-465, 261 p.
- , 1988, Applications of Knowledge Produced in the National Earthquake Hazards Reduction Program—1977–1987: U.S. Geological Survey Open-File Report 88-13-B, 100 p.
- , 1985, The Realization of Seismic Microzonation in the Chlef Region of Algeria Following the 1980 El Asnam Earthquake, in Kusler, J.A., ed., Post Disaster Response and Mitigation of Future Losses: Proceedings, American Bar Association, pp. 51–60.
- National Research Council, 1987, Confronting Natural Disasters—An International Decade for Natural Hazard Reduction: National Academy of Sciences, Washington, DC, 60 p.
- Szanton, Peter, 1981, Not Well Advised: Russell Sage Foundation and Ford Foundation, 81 p.
- Thiel, Charles, C., 1988, Enhancing Utilization, in Hays, W.W., ed., 1988, Applications of Knowledge Produced in the National Earthquake Hazards Reduction Program—1977–1987, U.S. Geological Survey Open-File Report 88-13-A, p. 203–210.
- United Nations, 1989, Resolution of the 44th General Assembly International Decade for Natural Disaster Reduction: United Nations, New York, 6 p.
- U.S. Geological Survey, 1990, A Reader on Earthquake Hazard Reduction in the Central United States: U.S. Geological Survey Open-File 90-94, 325 p. □

Dr. Walter W. Hays is Deputy Chief for Research Applications in the U.S. Geological Survey's Office of Earthquakes, Volcanoes, and Engineering. Since 1977, and after 16 years as an educator and a research engineering seismologist, he has been responsible for fostering research applications and loss reduction throughout the United States. On behalf of Unesco and UNDRO, he participated in earthquake engineering programs in Algeria and Jordan and in the Mediterranean region. Through USGS's international activities, he contributed to scientific programs in Spain, Italy, Japan, China, Argentina, Switzerland, Australia, and the Soviet Union. He participated in the formative phases of the International Decade for Natural Disaster Reduction. He is also a former director of the Earthquake Engineering Research Institute. Dr. Hays has published more than 100 papers, books, and reports.

Dr. Badaoui M. Rouhban is a specialist in the Division of Earth Sciences of Unesco based in Paris, where he has been working in the Natural Hazards Program over the last 9 years. He is involved in the Organization's contribution to the International Decade for Natural Disaster Reduction. He holds a doctorate in engineering from the Pierre and Marie Curie University, Paris.