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Ground-Penetrating Radar: A Review for Resource Managers

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INTRODUCTION

Ground-penetrating radar (GPR) systems permit us to "look" into the earth and see what lies beyond the limits of our normal vision. GPR is, as its name suggests, a radar-based system that transmits a signal or beam into the earth. This beam is reflected by subsurface interfaces. The reflected signals can be analyzed to identify these features, which we can neither see nor touch. GPR also is called "subsurface interface radar," "ground profiling radar," or "electromagnetic subsurface profiling." The technology has been available since about 1970.

WHAT GPR IS

This technology is based on impulse radar systems. This type of radar system repeatedly radiates very short electromagnetic pulses into the earth. The pulses are radiated from an antenna that is set close to the ground.

The system operates similar to acoustic profiling systems. The pulses (each lasting only a few billionths of a second) are reflected from the ground surface and from subsurface interfaces. The reflected signals are detected, interpreted, and displayed on a continuous-strip chart recorder. Depending upon the electromagnetic characteristics of the geologic material, the depth to reflecting discontinuities can be calculated accurately to within a few inches.

WHERE GPR STARTED

Like many remote sensing systems, GPR probably owes its beginning to research conducted by the military. They have been interested in developing the ability to detect land mines and enemy tunnel works (4). For many years now, this technology has been used to profile ice thickness (1).

Researchers in the field of mine safety also have worked to develop techniques that permit the routine use of GPR to see clay veins and voids from 200 to 400 feet into otherwise solid limestone (6).

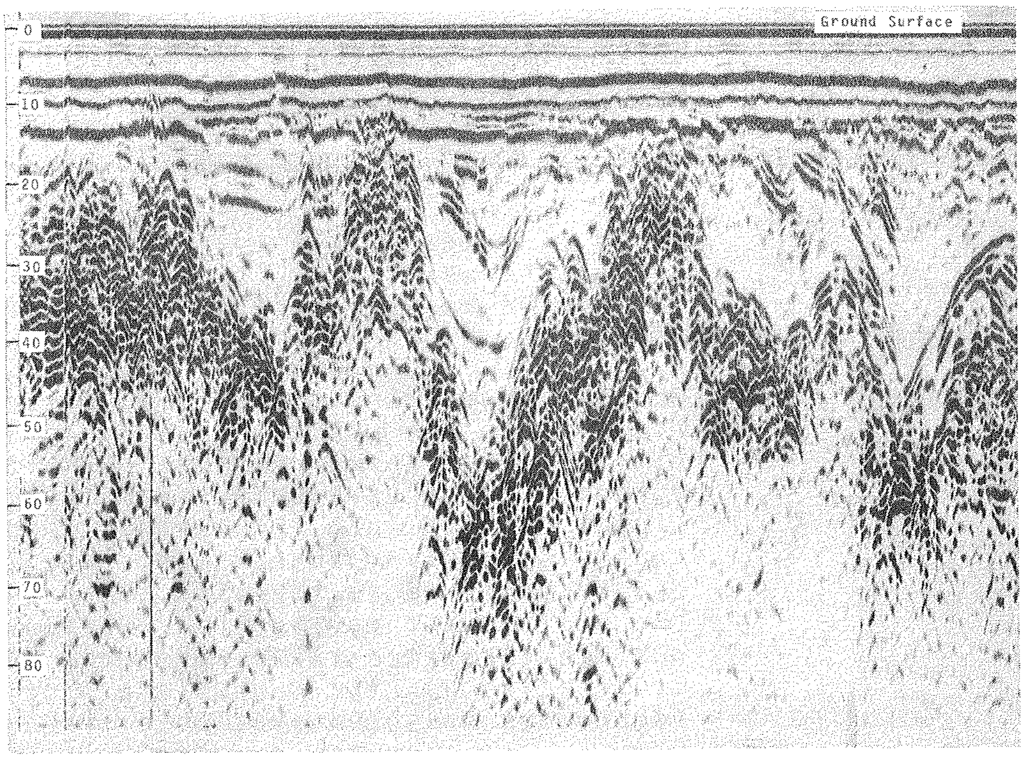

Figure 1.--The relationship of bedrock to the ground surface can be mapped using GPR. This profile from near Salem, New Hampshire, reveals a very undulating bedrock surface. The darkest part of the scan is the bedrock. The depth of penetration here exceeded 80 feet.

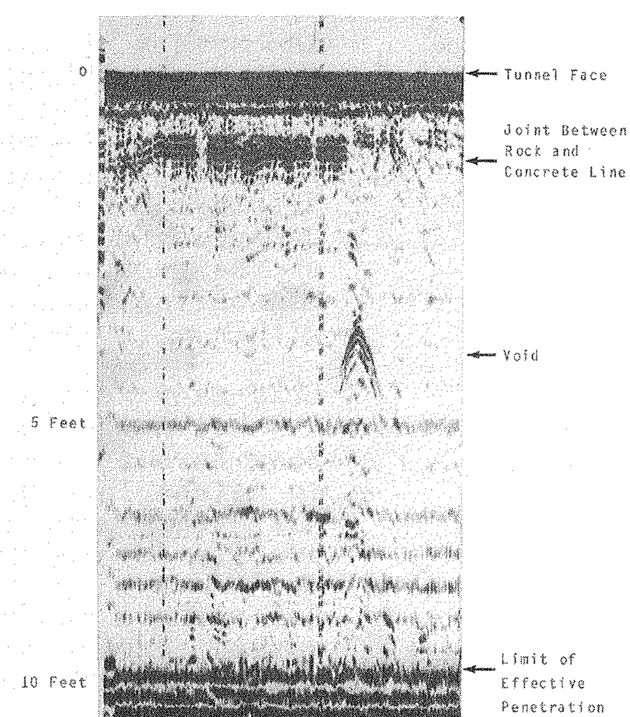

Figure 2.--Ground-penetrating radar can be used to inspect critical cement structures such as dam facings, railroad and auto tunnel walls, and aquaducts. In this example, GPR was used to examine the concrete walls of a railroad tunnel in France. The boat-wake pattern is a void within the solid rock behind the tunnel facing (at the top of this figure. This void is about 5 feet back into the rock.

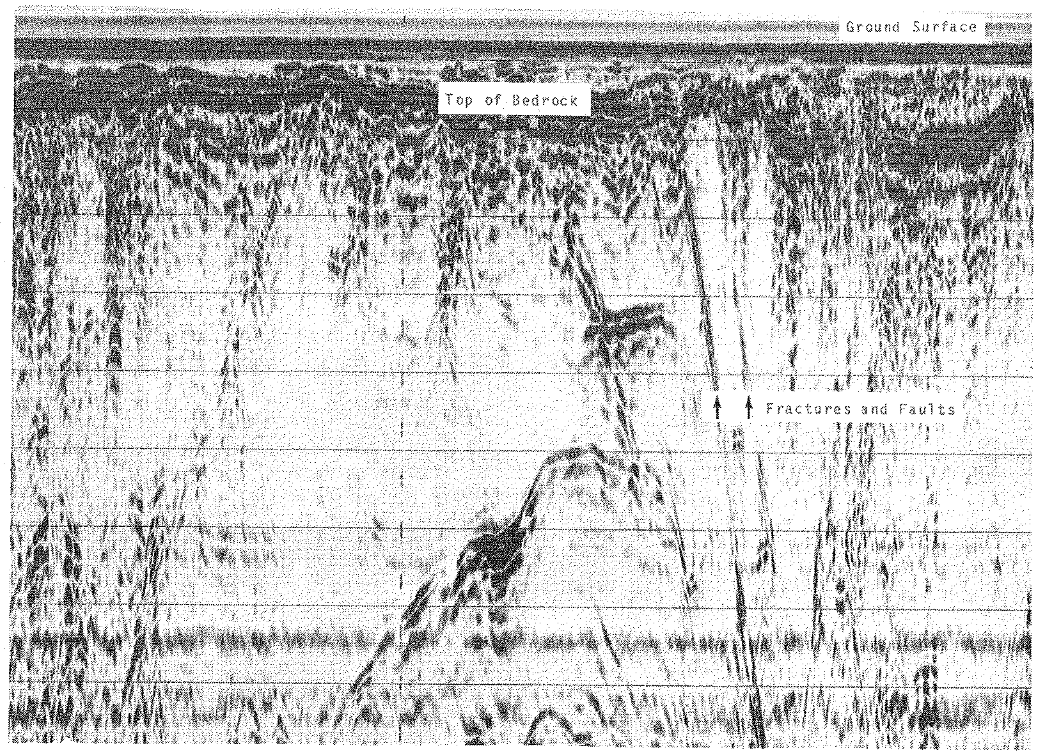

Figure 3.--In advance of construction, subsurface features of the earth can be examined to locate potential problem areas or hazards. In this printout of the recorded GPR data, a series of nearly vertical, parallel fractures stand out. Designs can be modified to accommodate such features or another site may be selected.

WHAT GPR CAN DO

GPR has many routine applications and researchers continue to find and develop new ones. Compared to standard radar systems, where distances involved can be extremely long (the first maps of Venus were made using Earth-based radar systems), the distances involved in GPR are relatively short. Depths of 10 meters are common. Research indicates that impulse radar systems could penetrate to 10 kilometers in certain kinds of rock or mineral (2,4).

The penetration depth of a system is a function of the effective conductivity of the geologic materials being evaluated. The conductivity is primarily determined by the water content of the material and by the quantity of salts in solution. Other factors that limit the depth of penetration are the temperature and density of the geologic material and the frequency of the transmitted electromagnetic waves.

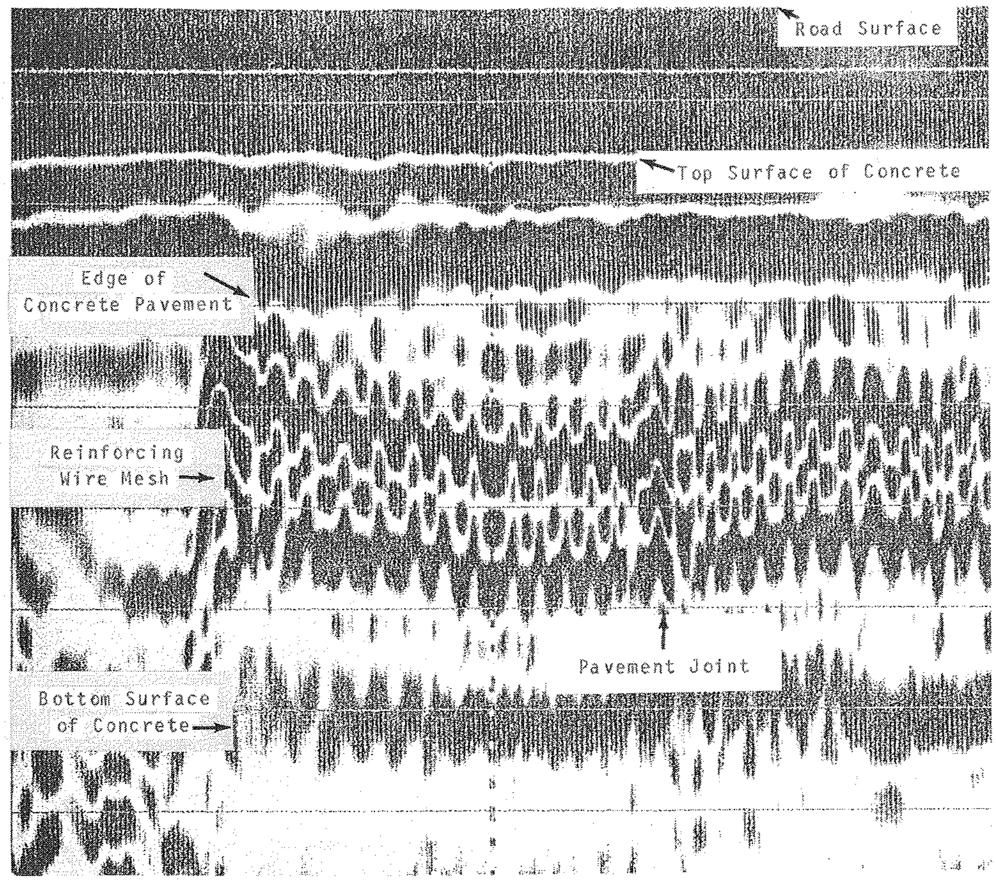

Figure 4.--Nondestructive inspections of highway pavements can be made at any time during the life of the roadway. This figure shows a radar scan made from near a pavement edge across the centerline to the opposite edge. The reinforcing wire mesh forms a prominent pattern across the middle of the image. The pavement joint is at the center of the highway.

Because the electromagnetic characteristics of geologic materials vary widely, the potential depth of penetration cannot be predicted with any accuracy. Work done with electromagnetic subsurface profiling systems indicate that a depth of 75 feet was reached in a Massachusetts glacial delta composed of water-saturated sands. The depth of an Antarctic ice shelf measured 230 feet. On the other end of the scale, a depth of only 5 feet was reached in wet clay and less than a foot could be reached in open sea water. When rocks have electrical characteristics like that of dry sand, depths of 100 feet or more could be expected (3).

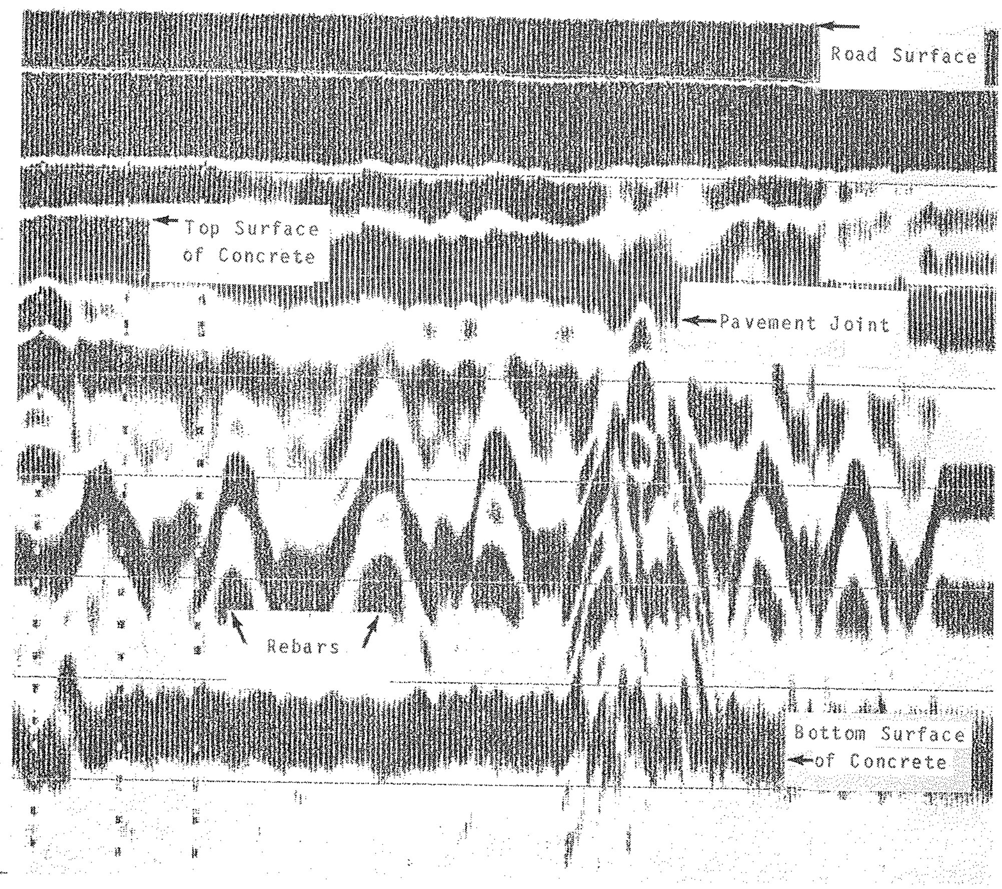

Figure 5.--In this radar scan printout, notice the way the rebars stand out in this concrete highway. This scan was made by towing the radar unit along the centerline of the highway. A transverse joint in the concrete also is easy to see.

USES for GPR

During NASA's Apollo program, an impulse radar system was used to probe the subsurface features of the moon (5). For the Forest Service, uses will be closer to home, and the technology has already been applied to many problems. For several applications, GPR seems to be the most effective and most efficient way to gather data about specific subsurface features. Table 1 contains a list of many current applications.

Ground-penetrating radar is a potentially useful tool for resource managers. Some potential uses of GPR are listed in table 2. Readers of this article probably could add new ones to the list.

Table 1.--A partial list of some current applications.

Geological strata profiling for highway and other excavation projects.
Bedrock mapping for subway tunnel excavations.
Rock fracture mapping for safety and other purposes.
Void detection for air bases, New Brunswick, Navy Base (rapid evaluation of airfield pavements).
Fault mapping for San Andreas fault.
Crevasse detection on glaciers.
Mapping and profiling salt domes.
Borehole profiling for mine safety and other operations.
Detecting lost oil well or water well casings.
River and lake bottom profiling.
Ice thickness profiling for sea and river ice.
Airborne ice and snow depth measurements.
Permafrost profiling.
Locating large masses of ground ice.
Iceberg draft profiling.
Sinkhole prediction in Florida and other States.
Peat profiling in Europe and the United States.
Measuring coal beds and rock strata.
Buried pipe and cable mapping (plastic or metal).
Tunnel detection military activities.
Pavement thickness and voids under pavement.
Perimeter security surveillance for tunnels, mines, and cables.
Reinforcing bar locating at nuclear plants and other construction sites.
Submarine pipe and cable location.
Mine detection (metal and nonmetal).
Hazardous waste mapping at Love Canal and Michigan.
Contamination intrusion mapping.
Archaeological surveying, mapping subsurface features.
Locating hidden chambers in the great pyramids of Egypt.
Detecting water-filled voids in coal mines.
Treasure hunting.
Railroad bed profiling.
Pipe leak detection.
Oil under ice detection.
Buried body detection in England.
Explosive mine detection by British Navy in Falkland Islands.
Detection of nondetonated mortar shells and other armaments in San Diego.

Table 2.--Some potential uses for GPR in resource management.

Evaluate visitor safety in caves open to guided tours.
Evaluate hazards to the public in abandoned mines.
Evaluate hardrock tunnels on Forest roads and highways.
Locate unknown, potentially hazardous mine tunnels in areas frequented by people.
Locate and map caves for management information.
Locate new rooms, tunnels, and features in caves being managed.
Locate lava tubes in volcanic areas.
Locate perched water tables.
Evaluate potential water production for horizontal drilling projects.
Plan tile drain systems.
Locate potential land slip areas.
Evaluate foot and horse trail stability.
Inspect timber haul roads for compliance with standards.
Inspect special use rights-of-way and easements.
Evaluate geologic conditions of proposed foundations of electric line, antenna, and other towers.
Make better cost estimates for trenching projects prior to letting contracts.
Inspect electronic site antenna foundations for the proper use of reinforcing steel.
Evaluate proposed stock water tank sites to detect potential trouble or leak spots.

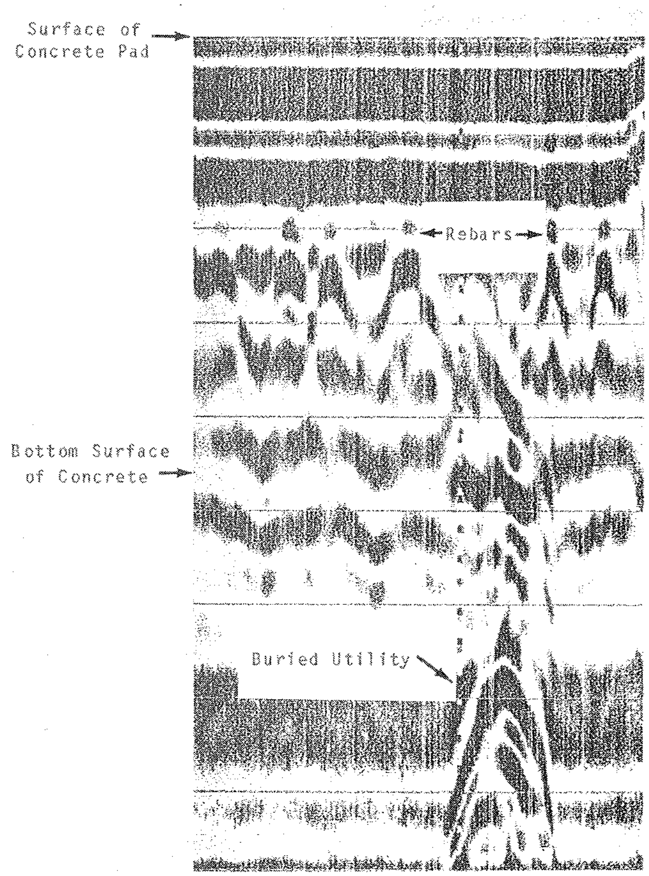

Figure 6.--Ground-penetrating radar is used to locate utilities buried beneath streets or concrete pads. This figure shows how buried utilities can be accurately located even when they are beneath heavily reinforced concrete.

AVAILABILITY

Equipment and training currently are available from private businesses. Geophysical surveys routinely use GPR at relatively shallow levels--to about 15 or 20 feet. Simple systems cost approximately $15,000. More powerful systems with more potential application can cost as much as $43,000. The services may be contracted.

SUMMARY

Ground-penetrating radar is an available technology with many current and potential applications. Research is continuing to improve the depth of penetration. The systems available present an alternative method of gathering data about subsurface features.

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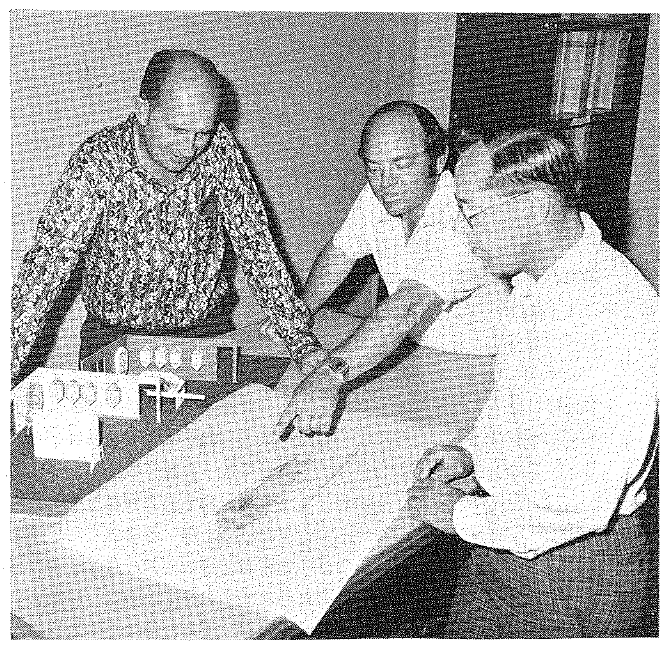
Lost River Ranger Station—Breaking New Ground

Wilden W. Moffett
Architect
Region 4

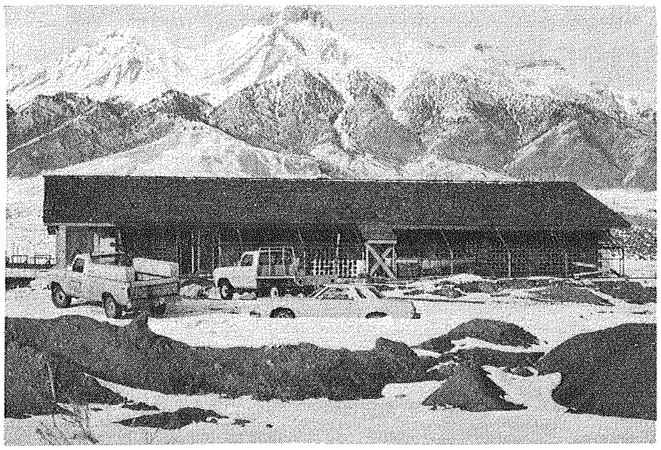
INTRODUCTION

In the fall of 1982, when the first shovel of earth was turned for the new Lost River Ranger Station on the Challis National Forest at Mackay, Idaho, new ground was broken on more than the construction of a building.

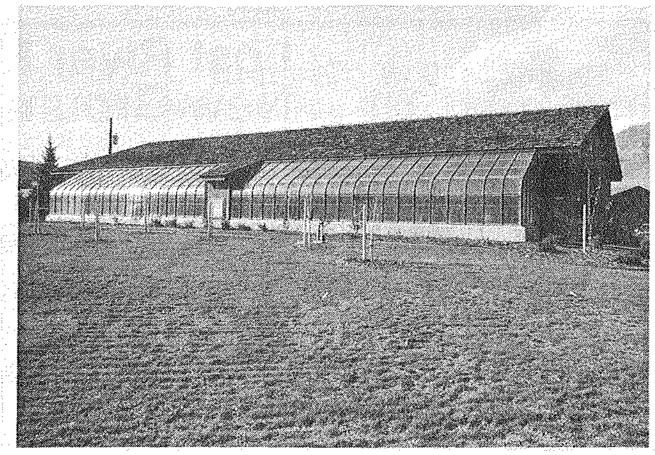
Lost River is the first office in Region 4 to depend largely on solar energy for heat. Designed as a passive system, the entire south wall of the office is enclosed in a greenhouse. Energy from the sun, traveling through the greenhouse, is absorbed into a special collector wall constructed of concrete blocks



An early review of the building and its exhibits. From left to right: Exhibits Designer Mel Alexander, Forest Engineer Dale Armstrong, and Regional Architect Wilden Moffett.



A view of the special collector wall and greenhouse during construction.



The Lost River District Ranger Office, viewed from the southeast. The greenhouse helps to provide solar heat--the primary source of heat for this building.

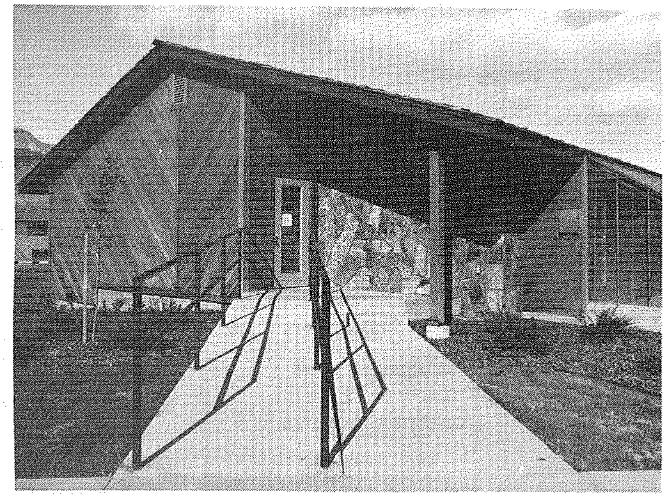
laid on their sides. Blinds inside the greenhouse help control the amount of energy collected in the daytime and lost at night.

PASSIVE SOLAR HEATING SYSTEM

The system is passive except for the three-quarter-horsepower blower, which is about the same size blower in a home furnace. The air within the system is forced to flow, serpentine fashion, through the collector wall so that it passes over all of the solar-heated surfaces. The heat from the sun that has been absorbed into the concrete block is transferred to the air, which then is channeled down into a floor duct in the basement.

From the duct, the air flows around the perimeter of the building at the base of the basement walls. Special furring on the exterior walls allows the solar-heated air to wash the entire interior surface of the exterior walls, thus transferring the heat back into the solid masonry storage walls. These storage walls are heavily insulated on the outside to reduce heat loss from the building and to retain the stored heat. The heavy mass walls at the building's perimeter, storing the solar heat, are radiant walls and become the heating source for the building.

This solar system carries the trademark "Xen-Wall." The design concept was developed by Xenarcx, Inc., Sparks, Nevada, and incorporated into the building design by the Regional Architect.



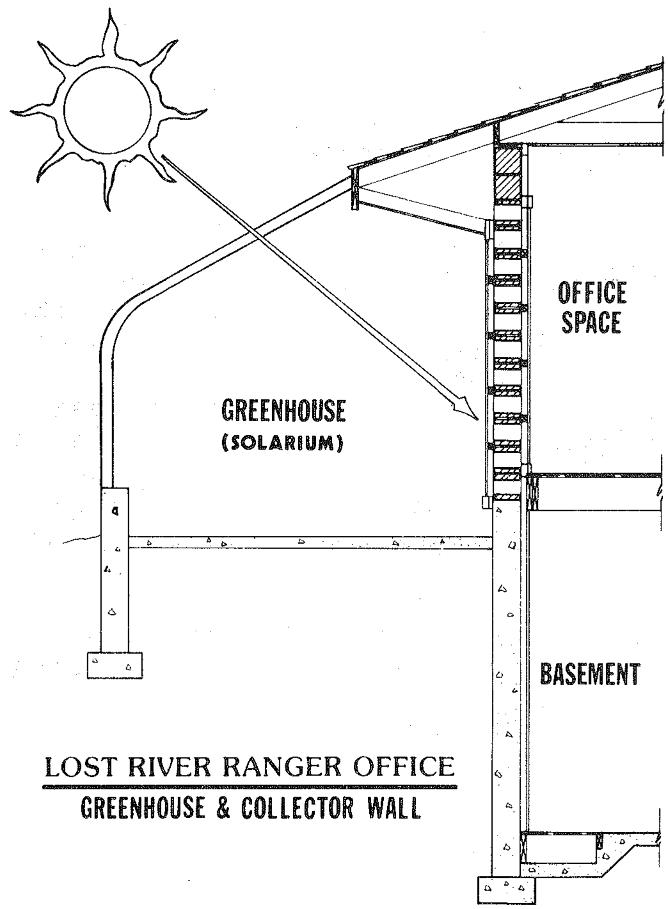
A view of the entrance. A small portion of the greenhouse, a dynamic part of the building's solar system, shows at right.

BACKUP ELECTRIC HEATER

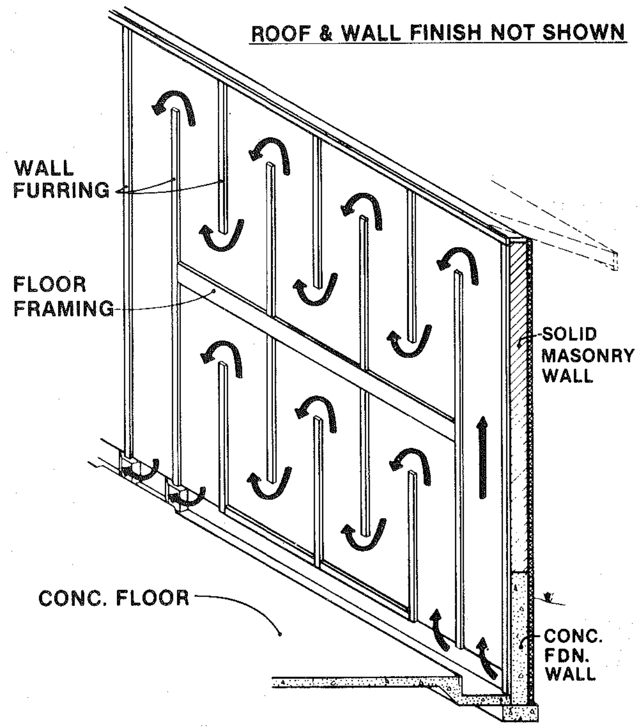
The backup heating system is a small (15-kilowatt) electric heater mounted in the duct system. When the solar system cannot provide all the needed heat for the building, the heater turns on and generates supplemental heat for the mass storage walls. This differs from most solar systems. The backup is not an independent heating system but a very-low-cost extension of the solar heating system.

Another departure from tradition in Region 4 involves the design of the reception area and exhibits. Former Interpretive Service Graphics Designer Mel Alexander, in cooperation with Regional Architect Wilden Moffett and Forest personnel, coordinated the design and decor. These areas were included during building construction, rather than added at a later time. Colors, wood trim, and materials in the counter and exhibits were planned to provide a warm, attractive atmosphere for visitors and employees. The exhibits include a backlighted map and other panels to introduce visitors to the District and to its resources. These exhibits were designed to fit in with finishes and the unique wall construction of this building--a difficult task if planning had been left to a later time.

Ranger Jim McKibben feels that the coordinated planning for the entire building has improved service to the visitors. In addition, the new building stood undamaged through the Challis/Mackay earthquake while other masonry buildings in town suffered heavy damage.



A section through the collector wall and greenhouse at the south side of the building.



TYPICAL STORAGE WALL

Arrows indicate path of the solar-heated air as it gives up its heat energy to the masonry storage walls on the north, east, and west sides of the building.

WINTER PERFORMANCE

Mackay is located in a very frigid winter setting. It is common, during the winter, for nighttime temperatures to drop below -30 °F. On many winter days, temperatures do not rise above 0 °F. The heating degree days at this site vary from 9,500 to 9,900 (for comparative purposes, the winter heating degree days in Ogden, Utah, average about 6,000).

The records, after two full seasons of operation, show that the solar system is contributing about 60 percent of the heat for the building:

Total heating load (2 seasons)	123,400 kWh
Energy consumed by backup unit	48,900 kWh
Total equivalent energy contributed by solar system	74,500 kWh

The building is alive and well. Because of some problems encountered the first winter, all employees did not keep as warm as expected. After these problems were identified and corrected, performance the second winter was very acceptable.

UTILITY SAVINGS

The initial cost of the building, including the solar system, was approximately $30,000 more than a similar building with conventional construction and heating. A conventionally constructed office of the same size would have a heating load of approximately 154,000 kWh. Using current electrical rates of $0.04 per kWh, we project that the additional cost of construction will be offset by utility savings in about 14 years (discounted payback). This payback time would be significantly reduced in a milder climate and in an area where power rates are comparable to those found in the Rocky Mountain area.

FOR MORE INFORMATION

If you have questions or desire more information about this project or about "Xen-Wall" solar heating systems, contact Wilden Moffett in the Region 4 Regional Office. EFN

The Technology of Technology Transfer—A Blueprint for Success

Connie Connolly
Technical Information Specialist
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INTRODUCTION

The Engineering Road Technology Improvement Program and the related final action plan, which were sent to Regional Foresters on April 18, 1986, by Deputy Chief Cargill, focused on technology transfer (TT) as a solution to many of our problems. For most of us, however, TT is still a nebulous term--an intangible goal. For Engineering, it must become a reality.

The major reason we need to make TT a reality is that we are now expected to be more productive--in an era of rapid change and dwindling resources. Look around. Budgets are shrinking; personnel and resources are being spread thin. Most of us find ourselves being asked to take on new activities--often without the resources necessary to do the job! To meet this challenge--not just today, but in the next decade and next century--we have to adapt to changing circumstances.

Technology transfer is a tool--not just a floating concept--that can help us meet challenges. It can help us reduce costs and it can lead to more efficient management of personnel, budgets, materials, and natural resources. It can allow us to pool our knowledge and eliminate duplicated efforts.

The Forest Service has been attempting to transfer technology for years--and with some success, but until now we have been concentrating our efforts on getting Research results applied by our cooperators, the public, and field units.

We now need to expand our efforts and make technology transfer a tool that Engineering managers and technical specialists can understand and use. If we are to achieve efficiency and provide more services, we _must_ look for, accept, and share not only new or innovative ideas, but existing, tangible methods or tools that will help us be more productive.

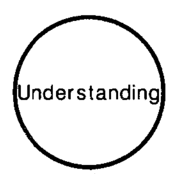
Most of us are, or have been, involved in some form of a TT project. We've all had ideas or seen a tool demonstrated that we just know would make others' work easier if we could just get them to try it. Or, we've had a problem that we knew there had to be a solution to--we just couldn't find someone else who had faced a similar problem. Some of us even have TT as a performance element, and we've all tried to convince a group or an individual to support a concept; even that was a technology transfer effort.

This article is meant to help you take the giant leap from knowing TT simply as a concept to understanding TT as a tangible tool that you can then use to improve your or your unit's efficiency.

Let's see if we can build a blueprint that will help us understand the technology of technology transfer, and how we can make it work, so that we can attain the benefits of reduced costs and more efficient management.

UNDERSTANDING

The first thing we need is a common understanding of important terms.

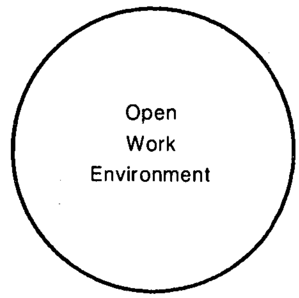


Many times we think that we are transferring technology when we are merely transferring information.

> INFORMATION is KNOWLEDGE, and INFORMATION TRANSFER is simply MAKING THAT KNOWLEDGE AVAILABLE TO OTHERS. On the other hand, TECHNOLOGY is APPLIED KNOWLEDGE, and TECHNOLOGY TRANSFER IS THE ART OF NOT ONLY MAKING PEOPLE AWARE OF TECHNOLOGY, BUT GETTING THEM TO USE IT. When they accept and apply the technology, technology transfer has taken place.

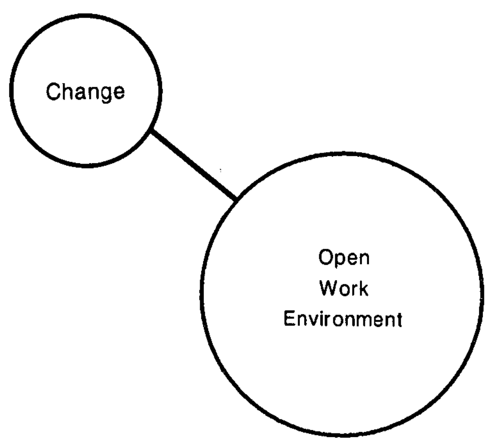
OPEN WORK ENVIRONMENT

The next thing we need is to create an open work environment that will allow technology transfer to take place. There are several points we need to consider here.



Change

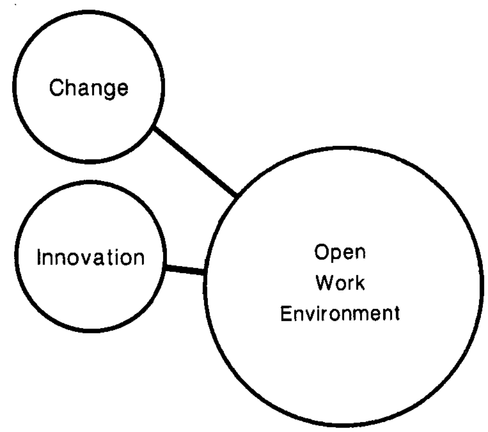
The first is change. We mentioned earlier that we are being forced to do a better job in an era of rapid change and dwindling resources. We have to be able to manage that change; in fact, we need to cultivate it if it will help us do a better job. We can't afford to waste a dollar or a minute doing any work that is not necessary or doing work in any way that doesn't allow us to maximize our resources. To make change work for us instead of against us, we have to change our outlook--the way we view ourselves and our work environment. Once we do, we'll be able to make the real changes--the sharing of better ways of doing things that technology transfer can bring about.



If we want others to change their way of doing something, we have to change first, and that's not always easy. We all react differently to change. Some of us actively seek out better ways to get our work done. Most of us don't seek better ways, but we will change if we can see the benefits of doing so. And then there are a few who resist change. But we all have to try. We have to create a work environment that welcomes change.

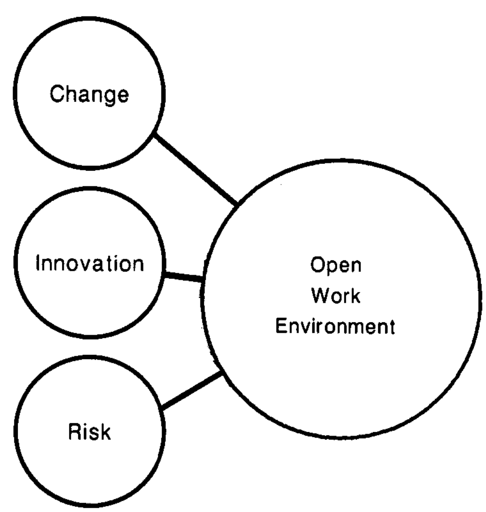
Innovation

Innovation is the second thing we need. We can foster innovation by being innovative ourselves and by encouraging others to be innovative and share information. The best way to do this is not to over-manage the flow of information or ideas. Restricting the flow of information not only stifles creativity, but increases the likelihood that information will be held until it's obsolete.



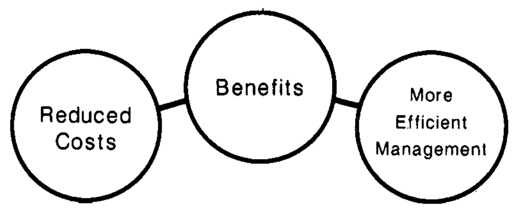
Risk

This brings us to the third element--risk. When we foster a more open work environment, we risk some loss of power and control. Staff who are better informed will become more independent and will rely on us less. But this is really more a perceived than an actual risk. The greatest risk--to individuals, or to an organization--comes from stifling the flow of ideas and information, the risk that the information or technology we should be using now to operate more efficiently will be missed, and needed change will not take place in a timely way. That's the risk that's not worth taking. As for the risk of carrying out an actual technology transfer, there is practically none if we're operating in an open work environment, and if the transfer is well planned.



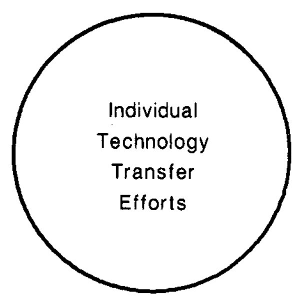
BENEFITS

We can sell the concept of the open work environment to ourselves and others by enumerating the benefits. We mentioned the two most important ones earlier--reduced costs and more efficient management of resources. Well, there are also four less tangible, but still very significant benefits--a better informed and motivated staff; a more cohesive organization; recognition for successful technology transfer efforts; and the challenge of discovering and putting into practice ways to do our work more efficiently.



INDIVIDUAL TECHNOLOGY TRANSFER EFFORTS

What we have done so far is set the stage for an open work environment that will encourage a free flow of information, technology transfer, and the adoption of new ideas. The next thing we need to discuss is how to succeed in specific technology transfer efforts.



There are three important areas we need to consider:

(1) How to plan a technology transfer.

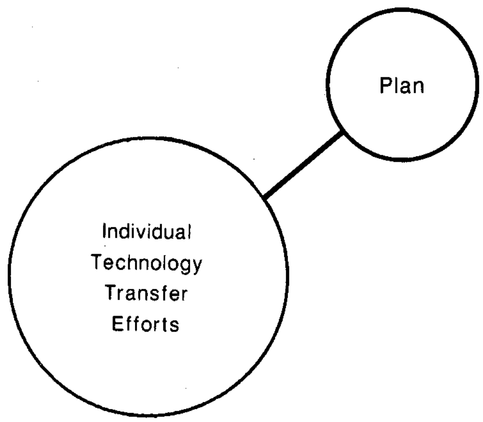
(2) How and where to find useful technology.

(3) How to choose the most effective technology transfer media.

Plan

If technology transfer is going to happen, it has to be planned. We could argue that if we have that open work environment we've been talking about, wouldn't technology transfer just take place on its own--through free exchange of information and ideas?

Occasionally this will happen. For example, when someone started using stick-on notes, someone else saw them and started using them and now most of us wouldn't be without them. But most technology transfer efforts involve a technology that is not as easy to sell as stick-on notes.



So we need to put together a technology transfer plan, an outline of how we intend to carry out a specific transfer, and what we expect it to accomplish. It doesn't need to be long or elaborate--just functional. It should address the following areas:

Define the Problem. If we state the problem clearly, it will be easier to choose an effective technology to solve it. On the other hand, if we already know about a technology that could be useful to others, we need to define the problem so that others will know why they should adopt that technology.

Identify the Technology To Be Transferred. Technology is a broad term, and the technology we are trying to transfer may be something as specific and easy to describe as a piece of equipment or something a little more involved like a process or method of working.

Identify the Intended Users. If we don't know, or have only a fuzzy idea of who our users are, we won't know how to get them interested. To win them over, we have to know them--that is, we have to know their interests and needs. We have to view our technology transfer effort from their perspective.

Establish the Objectives. We need to establish specific objectives to design a plan that will meet them and to evaluate the results of our efforts.

Select Appropriate Transfer Media. Selecting media is crucial to technology transfer because it is through media that we sell our ideas. Because media are such an important, and little understood, part of a successful technology transfer, they will be discussed in more detail later.

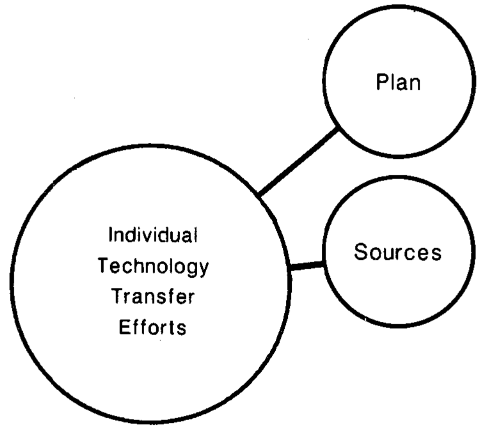
Select a Team To Implement the Transfer and Assign Team Members' Responsibilities. We usually cannot do it alone. The team consists of those people with the special skills and knowledge needed to help implement the transfer. The team can be any size or configuration--whatever it takes to do the job.

Plan the Costs. There are four main considerations in planning technology transfer costs: (1) the cost of implementing the technology transfer plan; (2) the cost of implementing the technology on the ground; (3) annual operating costs and any other costs specific to the particular technology; and (4) whether or not the necessary resources--personnel, funding, and materials--are available. After we have estimated all the costs, we need to estimate the benefits that will be realized once the technology is accepted and used. If the benefits outweigh the costs, and the resources are available, we should go ahead with the transfer.

Determine How the Technology Transfer Process Will Be Evaluated. We need to evaluate our effort so we know if our objectives are being met. The lessons learned in our evaluation also will help us to do a better job next time.

Sources

If we want our technology transfer efforts to succeed, we not only need to plan them, but we need to know how to find transferable technology. By transferable technology, we mean technology helpful to end users.



Sources of Technology

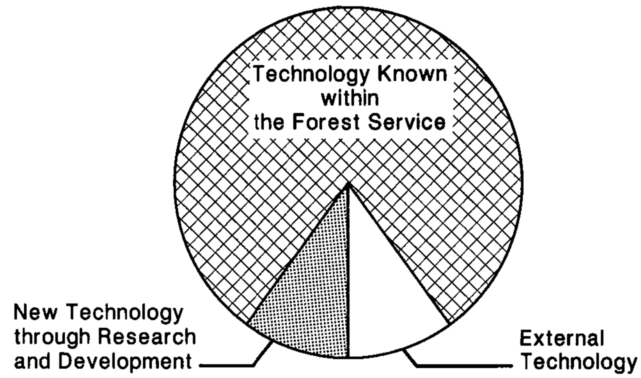


Figure 1.--Sources of technology.

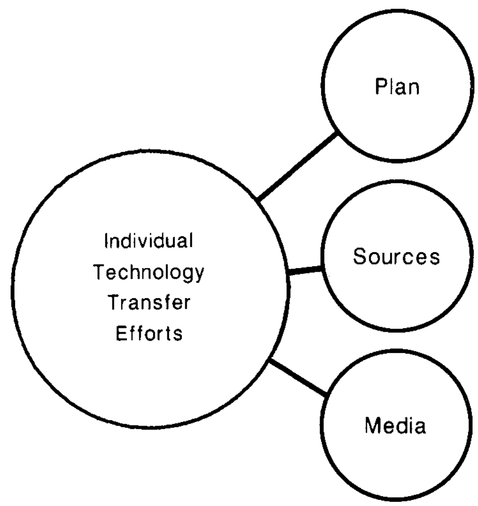
The technology available through research, development, and external sources is important but accounts for only a small fraction of the technology available for transfer (figure 1). Almost all transferable technology is already known and being used somewhere in the Forest Service or forestry community to solve problems or do work more efficiently. Large numbers of our people are innovative and can be found "tapping" internal and external sources. They have the knowhow; they now need to make the effort to share it.

So, we need to look in our own backyard, or in the next District, Forest, or Region, before we look outside to come up with a solution to a problem. Somewhere, somebody in the Forest Service probably has a technology--a tool, a system, or a technique--that could solve the problem. On the other hand, we may have an innovative way of doing something--a technology that nobody else knows about. Shouldn't others profit from our ideas and experience? And shouldn't we profit from theirs? For that matter, couldn't we also benefit from learning about each other's mistakes and not duplicating each other's efforts?

We could say, then, that the best place to find needed technology is to find someone who has faced the same problem. We have to put out the word. We each have a network of contacts and they have other contacts and associates. But suppose we're faced with a problem new to us and to our contacts. That still doesn't mean it's new to the Forest Service. We need to develop a problem-oriented data base to integrate the contacts we all have into a Forest Service resource--one that would put people with work-related problems in touch with people who have dealt with similar problems.

Media

Perhaps the most important thing we need to know is how to select the right medium or media to sell our technology to intended users. When we transfer technology, we need to sell--that is to actively convince others to adopt our ideas. We need to get the audience's attention and hold it.



Most of us don't know which medium is best when it comes to convincing users to adopt new or different technology. For this reason, the following deals with the relative degrees of media effectiveness.

Personal contacts are more than 10 times as effective as print media in transferring technology (see figure 2). In the case of the other two media--audiovisual and electronic--users find them more than twice as effective as print media, but they still fall far short of personal contacts in overall effectiveness. The people we need to reach are influenced more than twice as much by personal contacts as by all other media combined.

Personal Contacts. There are six personal contact categories and the most effective, by far, are peers and demonstration projects (figure 3). Peers are more effective because we have the advantage of

Relative Degrees of Media Effectiveness

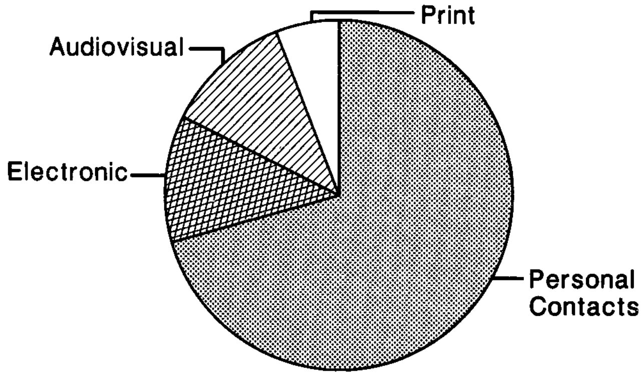


Figure 2.--Relative degrees of media effectiveness.

Personal Contacts

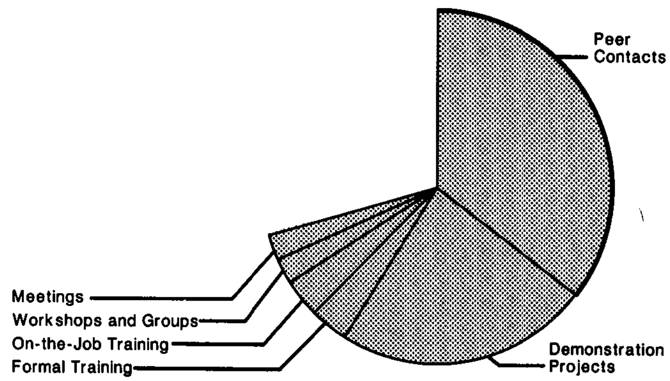


Figure 3.--Personal contacts.

meeting one-to-one. When we have a problem, we can pick up the phone or stop by the person's office, and we have the added comfort of knowing the person, knowing that here is someone whose knowledge and experience we respect. We all have a network of personal contacts like these--people who have helped us and people we have helped. The point is to use them and extend them. It is the most effective way to transfer technology. As for demonstration projects, we not only have the personal contact element, but we have our audience in an ideal situation where they can actually see and even use the technology.

The other four categories--formal training, on-the-job training, workshops and groups, and meetings--are more or less equal in effectiveness, but far less effective than peer interaction and demonstration projects.

Electronic Media. By far the most effective tool for technology transfer in the electronic media spectrum is the problem-oriented data base mentioned earlier (figure 4). Using this type of data base, someone with a problem can locate others who have faced similar problems and contact them for solutions or more information.

The other four categories--electronic mail, bulletin boards or conference systems, programmed instruction, and bibliographic data bases--are more or less equal but not very effective. Electronic mail is print media online, and no more effective than print

Electronic

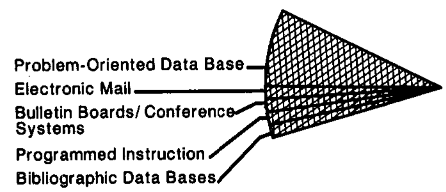


Figure 4.--Electronic media.

media. Bulletin boards or conference systems are not very effective because the volunteers who are willing to serve as contacts in various disciplines may not have worked on the problem you are trying to solve, and may not know anything about it. Programmed instruction has its place, but lacks the personal contact that an instructor can provide. Bibliographic data bases provide citations to research reports and scientific and technical journal articles by subject, but they are difficult to search without specialized training and experience, and seldom provide practitioners with timely solutions. Copies of cited reports and articles are often difficult to obtain, and frequently don't effectively address the issue.

Audiovisual Media. Audiovisual media (figure 5) can be effective, and films and videos are considerably better than the other two--slide/tape programs and slides or vugraphs.

Relative effectiveness aside, Forest Service audiovisual presentations could be much more effective than they are if we would seek professional help in developing them. When we think about the importance of personal contact again, we see that audiovisual media are able to make a direct appeal to a broader audience, with the audience able to hear a real voice, see a real face, and even watch technology in action. Used at their best, audiovisual presentations can both train and motivate.

Print Media. From the technology transfer standpoint, technical publications and journals (figure 6) are a little more effective than newsletters, memos, reports, and laws and regulations, but as we can see, Audiovisual

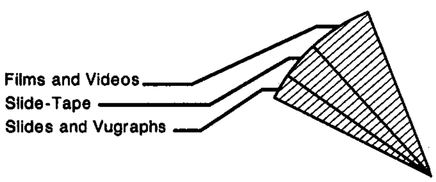


Figure 5.--Audiovisual media.

Print

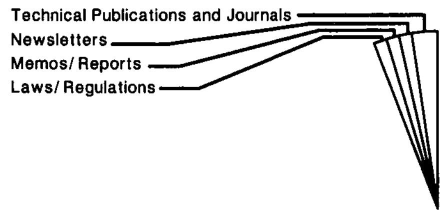


Figure 6.--Print media.

the print medium is the least effective means of encouraging users to accept new technology--10 times less effective than personal contacts and only half as effective as either the electronic or audiovisual media. But, the print medium can be useful when it is used to complement other media--especially if a greater effort is made to tailor print materials to the needs, interests, and perspectives of intended users.

Now that we know how effective personal contact is in persuading intended users to adopt technology (figure 7), we can say that we should strive to make any medium we use as personal and informal as possible. After all, we have to consider the intended audience, their location, and availability of resources. Often we will want to combine media to increase effectiveness. For instance, we say that workshops are one of the least effective personal contact categories, but, if we organize a workshop that features a demonstration project and plenty of peer interaction, then we have an effective media set that can bring about good technology transfer.

When we are attempting especially important, complex technology transfers, especially those that involve different groups of users with sometimes competing concerns, we need to consider using outside consultants to help us design a technology transfer plan and develop its major components.

BENEFITS

The benefits to be derived from individual technology transfer efforts are the same as those resulting from the open work environment--reduced costs and more efficient resource management.

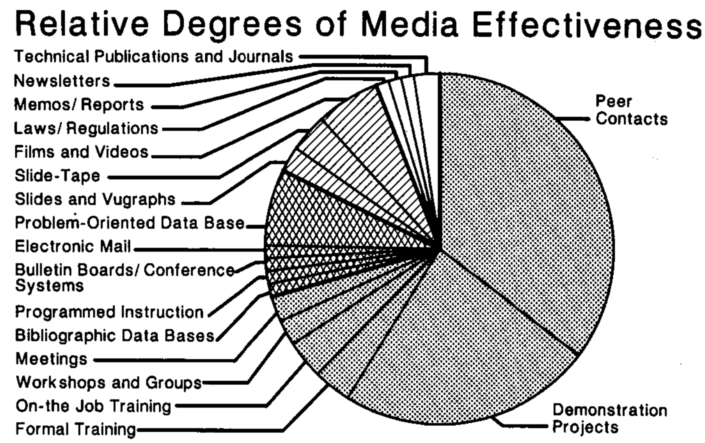


Figure 7.--Relative degrees of media effectiveness (detailed).

SUMMARY

We can sum up by saying that all the elements we need, both to create our open work environment and to make our individual technology transfer efforts acceptable to our intended users, combine to form the technology of technology transfer. We need to understand this concept if we are to make successful technology transfer a reality in the Forest Service.

We began with a small step--understanding technology transfer, what it is, and what it does. Then we learned that there are two equally important factors that combine to ensure successful technology transfer.

The first factor is the open work environment in which ideas and information are exchanged freely. We can create this environment--through change, innovation, and accepting risk.

The second factor is effective individual technology transfer efforts. We make our transfers effective by preparing and following a plan, knowing the sources of useful technology, and choosing the most effective media.

When these two factors--an open work environment and effective individual technology transfer efforts--combine, we have a blueprint for a successful technology transfer program (figure 8).

Now it is up to you. You know what your goals are and what the pressures are. You know how much you are expected to perform. Good technology transfer can help you. Together, we can make it work.

Blueprint for Successful Technology Transfer

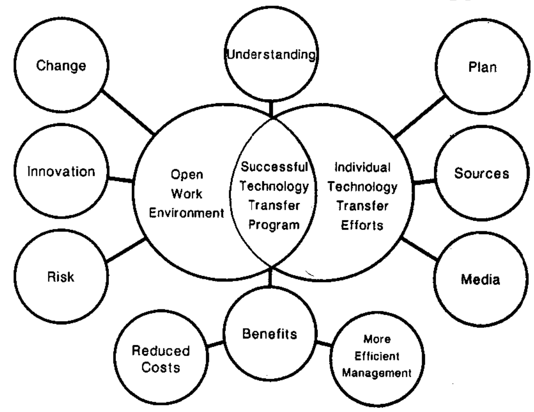


Figure 8.--Blueprint for successful technology transfer.

The technology of technology transfer is a blueprint for success. We need to accept it and use it. Can we afford not to? EFN

SLIDES

Note: A set of 35-mm slides, similar to the illustrations contained in this article, were distributed to each Regional Office by WO-E Deputy Director Furen's 7100 letter dated May 30, 1986. For more information, contact Connie Connolly on 235-3111.

I Rip 'Em Flexes Its Muscles—Case Studies of IRPM Use in the West

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Designed as a long-haul, eighteen-wheeler for handling heavy cargo, the Integrated Resources Planning Model (IRPM) (5) is proving its ability to perform like a cross between a sports car and an all-terrain vehicle. Built on an ADVENT chassis, IRPM has a retooled drive train and a beefed up transhipment suspension for handling rough, curvy mountain roads; it is slipped into a classic body and comes complete with a slick, personalized user's guide.

INTRODUCTION

The mixed-integer mathematical Integrated Resources Planning Model (IRPM) originally was designed to address resource and transportation issues for large area plans and Forest planning simultaneously, but as analysts became familiar with the model, they found that it could be used in a variety of ways. Successful applications of the model to road system management have led to discoveries of even more potential uses, such as developing comprehensive management plans for annual maintenance programs, exploring tradeoffs between traffic service levels, analyzing commensurate share maintenance, establishing construction cost recovery schedules, and developing multiyear capital investment programs. In each case, alternatives are easily developed under a variety of program budget level constraints.

Further tests are now being conducted to link IRPM with the Aggregate Transport Model (7). Since Transagg currently does not have any means of examining network efficiency in terms of operating costs, some IRPM formulations use Transagg solutions to manage both the rock resources and the road network for large tracts of National Forest land.

SUMMARY of CASE STUDIES

Area Planning

Seven area analyses have been completed using IRPM for approximately 150,000 acres of National Forest land in California, Washington, Idaho, Montana, and Oregon, representing several hundreds of millions of dollars in proposed transportation and timber harvesting activities. Tests conducted in Region 6 and by the Intermountain Research Station indicate that economic efficiency can be increased as much as 50 percent over conventional manual analysis methods (1).

Although these applications used similar formulation techniques, each formulation was tailored to fit the local resource issues. A variety of resource constraints and investment opportunities were modeled:

Wildlife. Deer and elk winter range with cover/forage relationship constraints, indicator species concerns, and migration routes were modeled.

Visual Resources. Several alternative timber intensities and road densities were modeled, which reflected meeting visual quality objectives at different levels and determining the associated economic tradeoff.

Water Quality. In Umpqua National Forest, a stream was modeled as a "network," and threshold values were introduced as constraints on individual reaches of the stream to control delivered sediment.

Timber. Several alternative timber harvest and silvicultural intensities and scheduling were modeled.

Logging Methods. Alternative logging methods were proposed, including conventional as well as more exotic methods. In some cases, alternative logging methods required alternative entry points into the transportation network as well as different road standard requirements.

Transportation Systems. Many alternative road standards, road locations, and road densities were considered in the study areas.

While analyzing three areas in Idaho and Montana, researchers from the Intermountain Research Station produced actual data on the below-cost sale issue that were entered into congressional testimony (2).

Forest Planning

Six National Forests in Region 6 have successfully linked IRPM to FORPLAN solutions to test their spatial feasibility and to estimate the effects of projected FORPLAN outputs on the Forest road network over time.

Analysis areas outputs of a FORPLAN solution were disaggregated to individual watersheds. Each watershed was assigned to a "centroid" node representing the transportation system entry points for that watershed.

Along with solving for the best transportation network for the FORPLAN solution, other tests are made as well:

Spatial Feasibility. Since constraints on harvest area openings, commonly referred to as dispersion or adjacency of harvest openings, are expressed in FORPLAN as percent openings per decade over very large areas, it cannot be known, without further analysis, whether the results can be implemented on smaller watersheds. The only known methods of making this analysis are either mapping the FORPLAN solution and inspecting it visually or analyzing an IRPM solution, which considers spatial arrangement. One Forest in Region 6 has found that the FORPLAN constraint on adjacency commonly breaks down at the smaller area level; in other words, the FORPLAN solutions are technically infeasible. With the IRPM, however, Forests were able to modify the FORPLAN constraint and rerun the model, thereby achieving some convergence of FORPLAN and IRPM solutions. Full agreement between the two models indicates a technically feasible solution.

Cumulative Effects. Some Forests are investigating cumulative effects of timber harvest on watersheds with IRPM. FORPLAN solutions are disaggregated to watershed levels to allow the analyst to estimate and evaluate cumulative effects associated with timber harvest and transportation activities.

Road Management

In Region 6, Deschutes and Umpqua National Forests used IRPM as a road management tool. Results are very promising and other Forests in the Region have expressed interest in applying the model in a similar manner. Since IRPM is a descendant of ADVENT, program development and budgeting for a transportation system appears to be a promising natural extension of its use. Following are two Region 6 examples.

In the first example, two large development corporations made separate proposals to expand a major ski area by building a new ski lodge with increased parking space and a new feeder road. The total impact on the connecting road was evaluated using IRPM. The analysis proved that it would not be feasible to expect the area to operate at full capacity because the existing access road to the area would not provide the capacity without additional lanes. One corporation therefore decided to temporarily drop the expansion plan. The corporation proposing a road to feed into the access road was granted permission on the condition that a mandatory $300,000 deposit be made to construct an overpass at the intersection of the two roads for safety reasons. The State Highway Commission decided to construct some passing lanes on the access highway as a possible solution to the traffic congestion problem.

In the second road management example, IRPM was used to predict traffic across the Forest, based on timber harvest plans and observed recreation use levels. As a result of the analysis, annual maintenance programs were developed, commensurate shares between cooperating parties were calculated, and multiyear capital investment programs have been proposed. The user Forests now are formulating models that will respond to budget funding levels and address the issue of assigning traffic service levels.

CONCLUSION

The Integrated Resources Planning Model has proved trustworthy and reliable in the classical applications for Forest planning and area analysis. Now it is proving a tool for managing existing transportation systems, enabling land managers to respond quickly and responsibly to changing issues and current management concerns.

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Aggregate Design Considerations

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INTRODUCTION

While Road Technology Improvement Program (RTIP) Team 4 members surveyed people for cost-effective aggregate design technology, they gathered many "basic" or widely known ideas, which this article presents. These are not always major items or always applicable; however, they provide a good checklist of ideas and alternatives for the designer. Designers sometimes apply some of these ideas to low-volume roads, but forget them while working on higher standard roads. Some of these ideas have been used unofficially because people believed they were not "officially" allowed. Obviously inappropriate or wasteful techniques certainly are not desirable, but imaginative approaches and alternatives to aggregate use are not only desired, but encouraged.

With these thoughts, RTIP Team 4 offers the following techniques for design consideration.

PURPOSE of the DESIGN

The choices of whether to use aggregate and of the thickness required will depend on service needs, acceptable failure criteria, and potential resource impacts. The designer should realistically evaluate these needs. Aggregate may not be needed for traffic service level D roads, and reduced aggregate thickness for an optimum design may be a valid management decision. However, the designer should clearly define the results of reduced aggregate thickness and the risk of failure for the manager.

The designer must also assess physical conditions in the field and the natural variability of soils.

SEASONAL USE

Keeping traffic off roads during wet periods can result in considerable aggregate savings. A thickness design procedure for seasonal haul conditions soon will be available in the Forest Service Surfacing Design and Management System (SDMS) Handbook FSH 7709.56a. Regions have received draft copies, and the final version is scheduled for publication in 1987. Currently, designers must estimate the seasonal variation of subgrade soil strength for aggregate surfaced roads. Several studies have been made or are in progress to measure these seasonal variations. However, the results have not been fully analyzed and specific design guides for SDMS have not been developed.

On roads designed for seasonal use, the Forest Service must manage traffic to conform to the design assumptions. Timber sale contracts may specify or the Forest Service may require seasonal haul restrictions on roads. Enforcement is a management responsibility, and there are no simple ways to measure or verify field conditions related to road closures or hauling restrictions. Again, there are several studies underway, but until these data are available, judgment must be used to make field decisions.

ALTERNATIVE SPECIFICATIONS

The designer should write aggregate specifications for the intended use, considering economically available materials and local experience. Marginal aggregates may be acceptable where high-quality, commonly specified materials are not economically available. Forest Service standard specifications contain several options on quality, gradation, and processing. The designer should take care in selecting the proper specifications for job conditions, and should examine the specifications to see that all requirements are economically justified. If specification requirements can be reduced or waived without sacrificing performance, the designer should write special project specifications.

One example of an alternative specification is the plasticity index (PI) requirement for aggregate surfacing. In many parts of the country, naturally occurring materials meeting the PI requirement are not available. However, some rock types display adequate binder that does not show up in the PI test. A way to improve the binding properties with PI is to specify a finer or denser gradation. If PI will not be required or tested for, delete it from the specification.

Another example is the use of degrading aggregate (with marginally low durability index test results) for surfacing. If the rock is crushed to a coarser gradation initially, it may degrade under traffic and provide satisfactory performance for some time. These same rock types may provide natural binder through degradation, actually improving performance.

Tailoring the specifications to the source may make otherwise adequate sources available. Blending, scalping certain sizes, wasting certain sizes, or washing may make materials in a source acceptable if these options are recognized in advance and provided for in the specification.

SOIL STRENGTH/ SOIL TYPE CORRELATION

A soil strength/soil type correlation is an aid available to the designer of road base and surfacing. This type of correlation is developed by cataloging all of the soil strength tests (CBR, R-Value, and so on) performed on the Forest with the corresponding soil type or soil classification. This allows the designer to develop alternative designs using a minimum amount of new testing. This would be most beneficial during the preliminary stage of design. Once the alternatives have been evaluated and reduced to a few, a verification strength test could be performed for the final design if investments and risks warrant. The construction engineering personnel also could use this correlation to evaluate actual subgrade soils against what was anticipated during design.

A refinement of this aid would be plotting the information on a map of the Forest. With this graphic display, the locator could consider alternatives over the better soils.

AGGREGATE DECISION TREE

The first step in designing an aggregate-surfaced road is to make a rational determination of whether surfacing is necessary. The two basic reasons for surfacing are traffic and management (structural considerations) and resource protection. Each reason has a set of factors that the designer should examine.

Traffic and management considerations include rutting potential of the soil; anticipated traffic or timber haul volume and timing of the traffic; timing and amount of administrative activities; commitment to road management, such as seasonal closures; road surfacing economics; road grades; recreation use; political pressures; availability of funds; and management direction. Resource considerations include whether road closures or roadway surface drainage and erosion protection adequately mitigate impacts; whether roadways will significantly affect water quality; and whether roadway effects outweigh repair and maintenance costs.

If traffic considerations do not dictate surfacing, and if resource impacts are not significant or can otherwise be mitigated at lower cost, then the road design should not include aggregate stabilization. Instead, it should use other measures, such as drainage and dust abatement. If either consideration necessitates stabilization, use aggregate surfacing or other methods such as paving.

A logic flow chart of some type can assist the decisionmaker. Figure 1 is a chart that was developed by a Geotechnical Engineer on the Plumas National Forest and is being used on the Forest.

SURFACING THICKNESS VARIATION ALONG the ROAD

Many designers provide only one or two surfacing thicknesses for a road, usually for the worst conditions, primarily because it is "safe" and because they believe it is inconvenient and uneconomical for contractors to vary thickness frequently. However, some Forests find that contractors have no problem changing depths for 20-foot sections, or spreading just a 2- or 3-inch layer. Typically, "worst" conditions do not exist over a large portion of a given project. Also, cut sections or compacted embankments of competent materials need less surfacing than transition sections, fills of less adequate materials, or low wet areas.

SPOT SURFACING

Some planned new construction includes sections of structurally adequate native soils that do not need aggregate surfacing and soft sections that do need aggregate surfacing. The extent and boundary of these sections may not be reliably located without an extensive subsurface soils investigation. Estimating sections needing surfacing and the amount needed may be adequate. The contractor can then adjust the actual limits and amount of spot surfacing during construction.

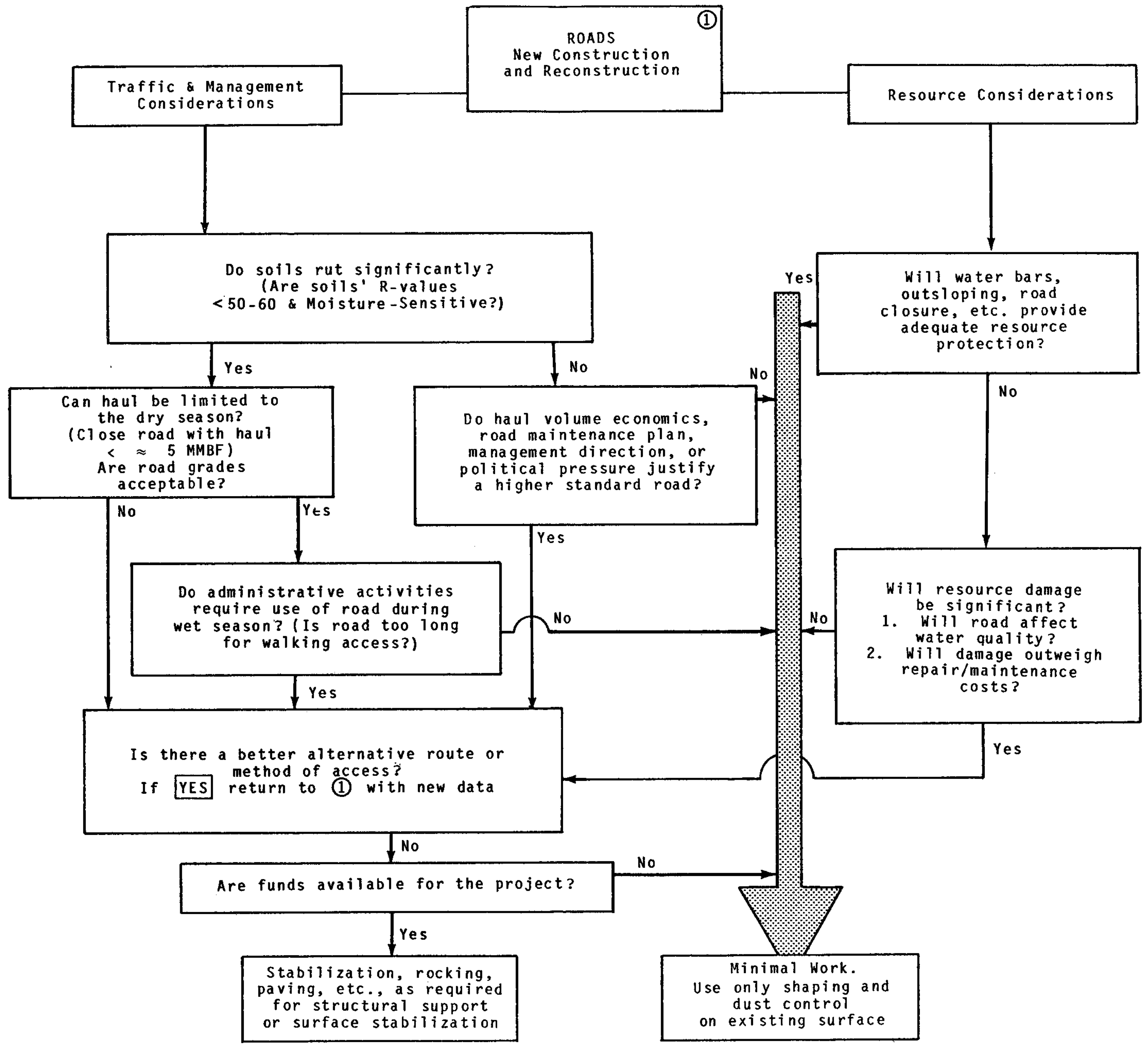

Figure 1.--Rocking criteria.

TRACTION or EROSION CONTROL

Some native surfaced roads provided adequate structural support but need aggregate for traction or erosion control on steeper grades. In these cases, the design may include 1 to 2 inches of open graded aggregate for the steeper grades.

SURFACING WHEEL PATHS

Wheel path ruts often develop on old native surfaced roads. Placing aggregate in these wheel path ruts provides additional traffic support and levels the road for better driving and drainage while using a minimum amount of aggregate. The contractor truck-spreads material along the road and uses a motor grader, crawler, or wheel tractor to spread it into the ruts. The working equipment and user vehicles compact the aggregate.

NOT SURFACING TURNOUTS

Where traffic and subgrade conditions warrant, the designer can save aggregate on low volume roads by not surfacing turnouts or by reducing aggregate depth on turnouts.

MARGINAL AGGREGATES

Marginal aggregates often exist in areas having little or no quality aggregate. Marginal aggregates do not meet the common standards of quality aggregate--they may have poor gradation, excessive fines, poor resistance to traffic or weathering, or excessive deterioration to plastic fines. However, in some climates, standard specified quality may represent an excessive requirement. Greater depths of marginal aggregate may adequately resist traffic wear. Mixing the marginal aggregate with quality aggregate or other additives also may provide a more cost-effective alternative. The results of weathering, such as in sandstone, may still be acceptable. ASTM Technical Publication #774, and FHWA Reports RD-81-176 and RD-82-056 provide recommendations on using a variety of marginal aggregates. The designer also should evaluate local experience with local marginal materials.

STABILIZATION

Stabilization can improve a marginal aggregate for base or surfacing or increase the engineering characteristics of the subgrade material. The many different types of stabilization methods and materials include Portland cement, lime, fly ash, bitumens, chlorides, organic cationic compounds, and others. In many cases, simply mixing a poor material with a higher quality material, such as adding clean sand to a poor silt, can provide stabilization.

The type and amount of stabilizing agent depends on many factors, and each agent has its own strengths and limitations. The many sources of information available for selection and use of these agents include manufacturer's associations such as the Portland Cement Association, the Lime Association, and the Asphalt Institute; textbooks such as Yoder and Witczak's Principles of Pavement Design; professional publications such as ASTM, AASHTO, and TRB; Forest Service reports; and manufacturers' technical literature. Some of the publications contain aids such as charts and graphs for selecting the type and approximate quantities of stabilizing agent. One such aid is table 9.1 in the Yoder and Witczak test. The designer also should not overlook local experience as a source of information.

SAND STABILIZATION WITH TOPSOIL or PLASTIC CELLS

Sand can be an excellent road-building material if stabilized or confined. Mixing topsoil and organic duff during construction or maintenance helps to stabilize sand. Plastic honeycomb cells filled with sand also provide a stable surface.

CRUSHED AGGREGATE

The Fernow Experimental Forest in West Virginia, NE Station, evaluated erosion from unsurfaced roads and from 1-inch crushed aggregate and 3-inch clean crushed aggregate surfaced roads. They found that erosion from the 3-inch clean aggregate was no worse than from the 1-inch aggregate sections. Also, they found that on minimum standard roads, the 3-inch rock, one layer deep, stabilized the subgrade well. The rocks worked into the subgrade during wet periods until the soil matrix firmly held the rocks, and the rocks adequately carried the traffic loads through the soft material to the more competent material below. The 3-inch rock will not lend itself to routine grader blading, but these roads are not planned for routine blading. They might be touched up by a small dozer after several years of logging traffic. The soil-aggregate matrix is similar to cobblestone surfacing. Preferably, the 3-inch aggregate should not contain fines so that there is room for the subgrade soil to move between the aggregate particles. This proved to be an excellent spot surfacing technique for otherwise unsurfaced roads, and this technique is particularly applicable for soils that "mud up" under traffic but that are not wetted from springs below the surface.

GEOTEXTILES

In designing aggregate surfaced roads over poor soils, the designer should consider the use of geotextiles (also called filter fabrics). The two uses of these materials in surface design are separation and subgrade restraint. In both cases, the required amount of aggregate surfacing material can be reduced with the proper geotextile. The concept of separation is a filter barrier preventing two dissimilar materials from mixing, the most common use would be to prevent or minimize the movement of weak subgrade soils into aggregate bases or surfacing. Geotextiles as subgrade restraint reduce soil movement and soil strain by confinement.

Many publications can assist the designer in selecting and specifying geotextiles in surfacing, including manufacturers' literature and the comprehensive "Guidelines for Use of Fabrics in Construction and Maintenance of Low Volume Roads," Report No. FHWA-TS-78-205, USDA Forest Service and FHWA, June 1977.

SUMMARY

Members of the Road Technology Improvement Program Team 4 gathered the aggregate design considerations presented in this article by surveying people for cost-effective aggregate design technology. These techniques and considerations should provide a useful checklist for road surface designers. EFN

Engineering Expert Systems

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INTRODUCTION

After 25 years of development, artificial intelligence (AI) is becoming a promising tool to solve real-world problems. AI has been defined as behavior by a machine that would be called intelligent if performed by a human being, and that is used in robotics, expert systems, general computing, and resolving questions of intelligence and language. The worldwide AI market is predicted to reach $250 million in 1986 and $3 billion to $12 billion in 1990. From 1986 to 1990, AI's share of the computer market will increase from 0.2 to 4 percent. This article discusses the potential of using "expert systems" to improve engineering performance.

Expert Systems

An expert system is a computer program that performs at the level of a human expert in a complex but narrow field or uses human traits like logic to solve problems. Expert systems are not black boxes that mysteriously arrive at conclusions to problems presented to them. Instead they model the experience and expertise of human experts in a given domain.

Expert systems have proven useful in diverse areas such as medical diagnosis, chemical analysis, geological exploration, military operation, and computer system configuration. To model the problem-solving expertise of a human expert within a particular field, an expert system requires two types of information: specific knowledge or expertise of an expert, including factual knowledge and heuristic or empirical knowledge, and general problem-solving strategies, such as drawing inferences and controlling the reasoning process.

METHODOLOGY

The methods used for developing expert systems are rule-based technology, frame-based technology, or a hybrid of the two.

Rule-Based Technology

The rule-based system gives an organization the ability to solve only clearly defined, stand-alone problems. The basic assumption is that the skills an expert uses to solve a given problem can be extracted effectively and efficiently as rules of thumb and incorporated into an expert system through the process of knowledge engineering. Figure 1 shows generic architecture of a rule-based system and its three major components: a rule base, a blackboard, and an inference engine.

The rule base is a collection of statements, each in the form "If C, then A," where C represents a condition and A, an action. Knowledge also can be represented as tree-shaped networks of related objects or concepts, known as semantic networks. In these networks, facts are clumped together in "nodes," which are interconnected by all possible paths such as "is-a" (a logging truck is a vehicle) or "has-a" (vehicles have wheels). These pathways, when followed, lead to a conclusion or inference (a logging truck has wheels).

The blackboard is a collection of items that, taken together, describe the state of the world in which the expert system operates. It can include facts, measurements, observations, and similar elements.

The inference engine is the component designed to solve any given problem. It consists of a control mechanism and a control strategy. The control mechanism uses a predetermined strategy to search

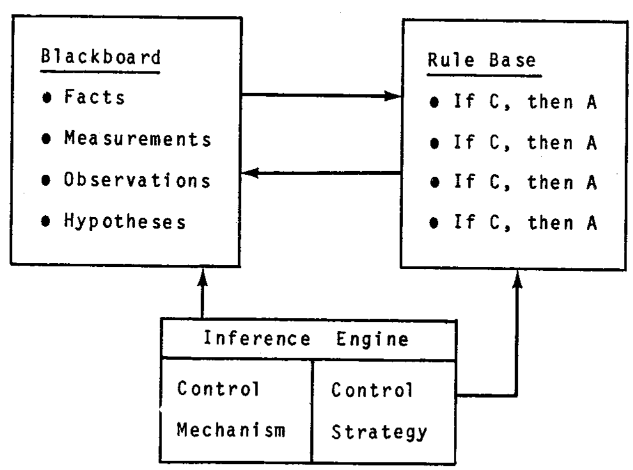

Figure 1.--Rule-based system.

through the blackboard and the rule base for solution to a given problem, and the control strategy imposes a set of constraints on the control mechanism to prevent it from wasting time on stray leads.

The two strategies used in rule-based expert systems for solving search problems are called "forward-chaining" and "backward-chaining." Forward-chaining systems (also called "data-driven") reason from initial data or facts contained in the rule base and the blackboard to find a solution, while backward-chaining (also called "goal-directed") systems start at a goal and work backward to find evidence to support that goal.

Forward-Chaining Control Mechanism. This strategy begins with a premise and looks through the rule base and the blackboard to find possible solutions. The mechanism matches the condition (C) of every rule against all the elements on the blackboard. The action (A) of any rule that matches the elements adds to the blackboard as a newly inferred fact. This process continues until the control mechanism can make no further inference.

Backward-Chaining Control Mechanism. This strategy begins with a tentative solution (a hypothesis) and looks through the rule base and the blackboard to find justifications for that solution. Backward-chaining control mechanisms match the hypothesis against the action (A) of every rule, the condition (C) of any rule that matches the hypothesis gets tested against the blackboard. Any match of a rule condition to a blackboard element serves as justification for the hypothesis. All mismatches point out other possible hypotheses, which the control mechanism tests in turn.

Frame-Based Technology

A frame-based system is formed by a set of knowledge bases and its shape is determined by the interaction of frames and slots. Frames are lists of various concepts' features and relationships to other concepts. Slots are more specific pieces of information, typically values and procedures, that are included in the frames and further describe the concepts.

Figure 2 shows a frame-based system's knowledge base, which consists of trainings and characteristics such as subject matter, objectives, duration, location, instructor, and date. Each circle on the

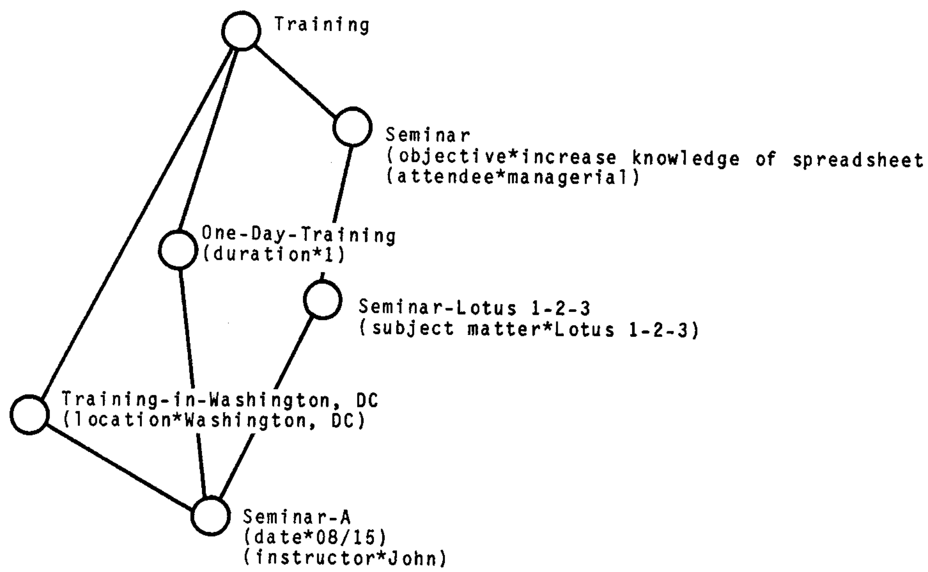

Figure 2.--Frame-based system.

diagram represents a frame, and each set of parentheses represents a slot. The diagram indicates that the concept "Training" can be described by a set of frames including Training, One Day Training, and Training in Washington, D.C., and also can be described by both frames of Seminar Lotus-1-2-3 and Seminar A.

Hybrid Technology

Hybrid systems combine the features and capabilities of rule- and frame-based technology. The development of hybrid systems is limited.

DIFFERENCES FROM TRADITIONAL PROGRAMS

Data

Data Structure. In a conventional program, the data pertinent to the problem and the control knowledge exist in the same structure. The expert system, on the other hand, separates the problem's specific knowledge and the mechanism that controls the operation of the system.

Size of Data Base. For the conventional computer program, the size of data base varies. Expert systems require a large knowledge base and "if-then" rules to manage the knowledge base.

Completion of Data Base. Many expert systems can handle incomplete or uncertain data by making inferences from the knowledge base.

Type of Data. Most traditional computer programs deal with a numerical data base; expert systems can accommodate non-numeric, qualitative, or symbolic data.

Language

Conventional programming uses computer languages like FORTRAN and PASCAL, which were designed for manipulating numerical problems and not well suited to expert system applications. Most expert systems in the United States employ LISP for list processing. LISP operates by linking lists of data and can match, concentrate, shuttle, or take apart lists as needed to get the desired information. Recently the computer software industry has offered software such as EXSYS that allows users to communicate with expert systems in normal or "natural" languages. However, in Europe and Japan a language called PROLOG is favored. A PROLOG program starts with a logical statement and tries to determine whether it is true or false.

Approach of Problem Solving

An expert system does not need an explicit problem-solving algorithm because a separate knowledge processor determines when, where, and how to apply every individual knowledge element. In other words, the problem-solving approach is deterministic for the traditional program and heuristic for the expert system.

Outcome Presentation

Expert systems provide an explanation for their conclusions and offer a reasonably "natural" user-interface dialogue.

ADVANTAGES & DISADVANTAGES

Listed below are the advantages of an expert system over traditional approaches (with and without the aid of computer programs) in solving engineering problems:

(1) The expert system provides reliable and consistent decisions.

(2) The expert system explains or justifies final answers.

(3) The construction of the expert system formalizes the problem area.

(4) The expert system serves as an expert colleague or expert consultant on difficult problems.

(5) The expert system is more easily expandable than conventional software.

(6) The symbolic language used by the expert system facilitates communication in natural English.

(7) The expert system preserves expert knowledge that would otherwise be lost through retiring key personnel. The expert system can train new personnel in a tutorial context.

(8) The expert system can pool the expertise of a body of human experts to produce a system that is more effective than any one person working alone.

(9) The expertise of the expert system generally is very high-level expertise, which is very scarce and costly in human terms.

(10) The expert system makes more expert knowledge available because the program can be duplicated and located in multiple locations and can solve multiple problems simultaneously.

Like other computer software, expert systems have drawbacks. The following are some disadvantages:

(1) Expert systems are not as creative as real experts.

(2) They are not as adaptive as real experts. At their current stage of development, expert systems have difficulty learning from their environment or adapting to new situations the way humans can.

(3) Expert systems have difficulty understanding their own limitations and may attempt problems that they are not qualified to solve.

APPLICATIONS

Expert systems are still in an embryonic stage of development, and successful applications of the system to solve engineering problems are few. Table 1 shows systems in use or in development. The following two systems applied to bridge design and pavement rehabilitation illustrate uses of expert systems.

Table 1.--Engineering expert systems.

Expert System	Domain
System in Use	
DIPMETER	Oil well logging
PROSPECTOR	Mineral exploration
HI-RISE	Building design
FAX	Failure analysis
SAGE	Structural analysis
SACON	Structural analysis
BDES	Structural design
SPERK	Assessing earthquake damage to buildings
HYDRO	Watershed management
RI	Computer system configuration
System in Development	
CHINA	Highway noise behavior design
DIRECTOR	Urban transportation education
TRALI	Traffic signal setting
SCEPTRE	Pavement rehabilitation

Source: The data on this list were obtained from the Annual Meeting of the Transportation Research Board, Washington, D.C., January 13-16, 1986. The list is not inclusive.

Application 1: BDES for Bridge Design

The Bridge Design Expert System (BDES), which encompasses the ideas of AI with the bridge design process, was developed by J. G. Welch and M. Biswas. BDES currently considers only superstructures of short- to medium-span bridges. BDES can design structural steel and prestressed concrete girders. Figures 3 and 4 show a bridge geometry and its girder cross-section selected by BDES for a design problem.

Application 2: SCEPTRE for Pavement Rehabilitation Plan

SCEPTRE is the Surface Condition Expert for Pavement Rehabilitation, which was developed by S. G. Ritchie, C-I Yeh, J. P. Mahoney, and N. Jackson. It evaluates pavement surface distress and recommends feasible rehabilitation strategies for detailed analysis and design. SCEPTRE was developed based on a pavement rehabilitation process that evaluates pavement surface conditions, analyzes and evaluates structural adequacy, develops alternative strategies, and selects an optional strategy.

Figure 5 shows a solution that SCEPTRE selected as a rehabilitation and maintenance strategy for a given road segment to deal with alligator or fatigue cracking in the wheelpaths. The four recommended strategies, which have varied life expectancies, are to do nothing, to fog seal, and to add a thin asphalt concrete overlay and a medium asphalt concrete overlay.

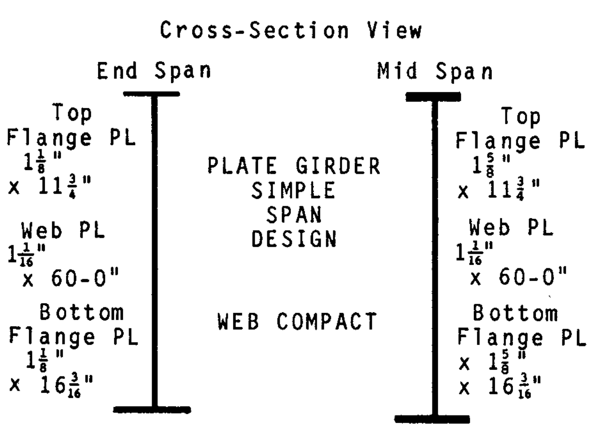

Figure 3.--A girder cross-section selected by BDES.

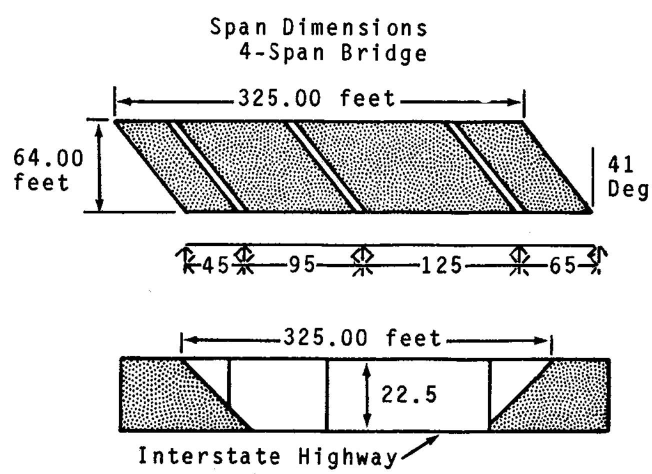

Figure 4.--A bridge geometry selected by BDES.

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YOUR MINIMUM DESIRED RAM SERVICE LIFE FOR THIS SECTION IS
6 YEARS.
IN THE OUTPUT BELOW, P IS THE PROBABILITY THAT THE ACTUAL SERVICE LIFE
FOR EACH RAM WILL BE AT LEAST THIS LONG.

THE LIST OF FEASIBLE STRATEGIES FOR THIS PAVEMENT SECTION IS AS
FOLLOWS:

DO-NOTHING                          P =  7%    (EXPECTED LIFE = 3 YEARS)
FOG SEAL                            P = 25%    (EXPECTED LIFE = 4 YEARS)
THIN ASPHALT CONCRETE OVERLAY       P = 50%    (EXPECTED LIFE = 6 YEARS)
MEDIUM ASPHALT CONCRETE OVERLAY     P = 84%    (EXPECTED LIFE = 9 YEARS)

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Figure 5.--Feasible pavement rehabilitation and maintenance strategies determined by SCEPTRE.

HOW TO START an EXPERT SYSTEM

Expert systems can be an effective tool to assist Engineers in solving engineering problems. However, expert systems can be effective only when they are applied to the proper problem domain. Therefore, the Engineer should evaluate the feasibility of an expert system for a particular problem domain before developing and using the system. The evaluation should determine the need of the organization; define the problem/situation; identify the resources need; determine the value, such as the productivity increase; and select the proper tools.

Current expert systems tend to be large, complex, costly, and difficult to build. Yet commercially available software tools, or shells, have existed for several years and can make the expert system development more manageable. The number of these tools is growing; table 2 lists different shells available and their supporting hardware. During the next few years, more shells will become available and shells will become more powerful and useful for operational systems, and shell price will come down as market pressures and competition increase. However, comparing the features of the expert system shells currently in the market can help Engineers select an appropriate one to support the expert system development effort.

Table 2.--Shells for developing expert systems.

Shell	Developer	Hardware
RULE-BASED SYSTEM		
Forward-Chaining Control Mechanism		
Exper OPS5	Expertelligence Corp.	Apple Computer Inc., Macintosh
OPS5+	Artelligence, Inc.	IBM PC and Unix Processors
OPS5	Digital Equipment	VAX-11/78
AMS	Transform Logic Corp.	IBM mainframe
Personal Consultant Plus	Texas Instruments	IBM-PC and compatibles
Expert System Development Environment/MVS	IBM	IBM mainframe under MVS
Backward-Chaining Control Mechanism		
S-1	Technowledge, Inc.	IBM-PC-AT, DECVAX-11/780, and various LISP- and Unix-based machines.
M-1	Technowledge, Inc.	IBM-PC
EXSYS	EXSYS	IBM-PC and compatibles
Personal Consultant	Texas Instruments	IBM-PC and compatibles
Personal Consultant Plus	Texas Instruments	IBM-PC and compatibles
Expert System Development Environment/MVS	IBM	IBM mainframe under MVS
Knowledge Workbench	Silogic	Motorola 68000, Unix supermicrocomputers
FRAME-BASED SYSTEM		
Not available on the market.		
HYBRID SYSTEM		
Automated Reasoning Tool	Inference Corp.	Data not available
Knowledge Engineering Environment	Intellicorp	Data not available
Knowledge Craft	Carnegie Group, Inc.	Data not available

SUMMARY

This article has presented an overview of the application of expert systems to improve engineering performance. Two engineering expert systems developed by the Virginia and Washington State Highway Departments illustrated expert system application.

Although expert systems offer opportunities to increase productivity and reduce costs, they cannot solve all engineering problems. As with other computer programs, the Engineers should perform a feasibility study before initiating expert system development.

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Identifying Haul Speeds Controlled by Grade & Surface Type or Horizontal Alignment & Road Width for Forest Development Roads

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Region 3

SYNOPSIS

Travel time (and thus haul costs) used by the Forest Service is based on the Logging Road Handbook by Byrne, Nelson, and Googins (hereafter referred to as BNG) published by the USDA Forest Service in 1960. It states that the speed of a truck operating on a Forest Development Road is controlled mainly by the grade and surface type or the horizontal alignment and number of lanes. FSH 7709.56.4.32 states that speeds for loaded trucks are governed by grades greater than 8 percent for favorable haul and 3 percent for adverse hauls.

The current method used in Region 3 to determine travel times does not reflect this principle. Our practice has been to assume that any improvement in surface type, width, or horizontal alignment would decrease travel time and thus haul costs. The "break-even" point occurs when an adequate volume of timber hauled over the road at a "reduced" haul cost offsets the costs of improvements. Although improving a road surface can reduce truck operating costs and road maintenance costs, benefits from reduced haul times are not as great.

Identifying which road characteristics, when altered, will affect travel times makes our method more accurate. Since this may result in less economic differences between alternatives in a transportation analysis, the transportation analysis must display costs of concerns mitigated by each economically efficient alternative. ID teams and land managers must base recommendations and selections on the costs and benefits of mitigating the various concerns in economically effective alternatives.

DISCUSSION

Data for BNG were collected from March to August, 1948, during the winter of 1958-59 in the western United States, and in 1952 in the eastern United States. Most agree that this publication is the most up-to-date study on operating logging trucks. BNG indicates that travel speeds, when controlled by the grade of the road and the surface type, are increased by less than 5 percent when a native surface is improved to an aggregate surface or an aggregate surface is improved to an asphalt surface. BNG attributes this reduction in travel time to the change in the rolling resistance between the various type surfaces. Therefore, if the horizontal alignment and road width control the speed, improvements to the road surface will have minimal effect on decreasing travel times.

The current method of analyzing truck speeds and costs in Region 3 is based on the latest edition of the Manual Network Analysis Method for Transportation of Resources (hereafter called Manual Network Analysis) by Ronald Tangemen, Clyde Weller, and Bill Woodward published in October, 1982 (this publication also is the basis for Region 3 MINCOST tables at FCCC). Table 1, Haul Classes, on page 36 of the Manual Network Analysis divides roads into 320 haul classes related to the number of lanes, road surface, horizontal alignment, and grade of the road. Table 2 in the Manual Network Analysis gives the travel times in minutes per mile for each class of road described in Table 1. Table 2a in the Manual Network Analysis gives the speeds of a loaded and empty truck hauling on a road described in Table 1. Tables 2 and 2a of the Manual Network Analysis were developed using BNG corrected for a 1976 truck having 400 horsepower, for the 55 mph speed limit, and for a "B" value of 0.85.

The Manual Network Analysis originally was published as an aid to transportation planners, to compare relative transportation costs associated with road improvements in determining which improvements could be economical. However, the Manual Network Analysis now has been incorporated into Region 3's timber appraisal procedure by Amendment 33 to FSH 2409.22. Region 5 also is modifying Tables 1, 2, and 2a in the Manual Network Analysis to be included in their appraisal process. Considering this added importance given the Manual Network Analysis, travel times derived from its use must be accurate.

ANALYSIS

The travel speed for a truck traveling on the forest development system is controlled by design features of roads that limit the physical capabilities of the truck and affect the driver's psychological comfort level. Consider the case of a truck that can do 45 mph on a double-lane road with an excellent alignment. If this truck is operated on a 12-foot-wide single-lane road without a ditch with the same grades and alignment as the first road, the driver will feel less comfortable. As a result, the driver will operate the truck at a lesser speed than if the only limits were the physical capabilities of the truck. This difference in operating speeds results from the psychological effects of the different situations on the driver's comfort level rather than on physical changes in the road.

Determining which characteristic primarily controls the speed of a truck is important when considering the economics of improving a road. Charts 1 and 2 in the Manual Network Analysis indicate trucks operating on a single-lane, graded, and drained road with a poor alignment and an adverse haul of from 4 to 7 percent will require a travel time of 10.00 minutes per mile (min/mi). These charts also indicate that an aggregate surface placed on this road would reduce the travel time to 7.01 min/mi, a reduction of 2.99 min/mi or 30 percent. If we assume the grade controls the speed of the truck operating on this road, as stated in FSH 7709.56, the travel time should be reduced by less than 5 percent, or less than 1 min/mi based on BNG. These charts also indicate that if the alignment were changed from poor to fair the travel time would be reduced to 7.47 min/mi. This would be true only if the alignment and width of the road controlled the truck speed. If the grade controls the speed, as in the first assumption, the travel time should not be reduced from improved road alignment.

Data regarding travel time are contained in BNG as a series of graphs. The first series of graphs in Figures 3 through 8 in BNG relate travel time in minutes per mile to the grade for roads with various types of surfaces and a "B" values. The "B" value is the relationship of the horsepower (hp) of the truck to the gross vehicle weight (GVW).

The second series of graphs, in Figures 10 through 13 in BNG, relate the travel time in minutes per mile to various radius curves, the number of curves per mile, and the width of the road. Road widths are double lane, lane and a half, single lane with ditch, and single lane without ditch.

Figure 16 in BNG relates the percent increase in travel time for an empty truck traveling on a lane-and-a-half or single-lane road because of conflicts with oncoming traffic that relate to the turnout spacing and the traffic volume on the road (in vehicles per hour).

This analysis considers a standard truck having a 375-hp engine hauling 4,800 board feet per trip. The GVW of the standard truck considered in the analysis was 86,000 pounds loaded and 30,000 empty. The truck is assumed to operate at an elevation of 6,000 feet above sea level. The "B" factor for this combination of features is 2.66 for the loaded truck and 7.63 for the empty truck.

Analyzing the first series of charts in BNG for the standard truck operating on an aggregate-surfaced double-lane road resulted in the chart shown in figure 1 of this article. The speeds are those a loaded and empty truck can sustain on a road with no consideration given to alignment.

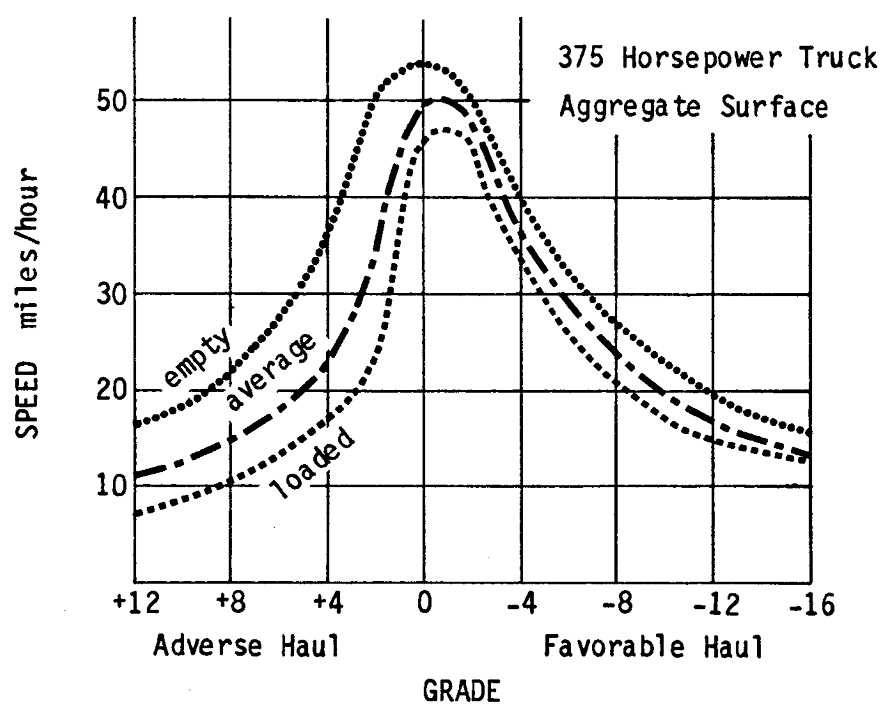

Figure 1.--Speed in miles per hour versus percent grade.

Table 1 of this article shows the speeds resulting from analyzing the second series of charts in BNG for the standard truck operating on roads with the various horizontal alignments and widths as defined in the Manual Network Analysis.

Superimposing the speeds shown in table 1 on the graph in figure 1 results in a series of graphs showing the maximum speed a truck can maintain as restricted by grade and surface type and/or the horizontal alignment and number of lanes. Figure 2 shows the resulting graph for a double-lane road with fair alignment. The maximum speed of the truck is restricted by the horizontal alignment to 34.5 mph for an empty truck for grades of between +4 and -5 percent and to 31.9 mph for a loaded truck for grades of between +2 and -4 percent.

Table 1.--Maximum speeds controlled by alignment and width.

Alignment	K Factor	Load on Truck	Double Lane	Lane and a Half	Single Lane With Ditch	Single Lane Without Ditch
Excellent	167	Loaded	47.2	41.7	39.0	38.2
		Empty	47.2	42.9	40.8	39.7
		Average	47.2	42.3	39.9	39.0
Good	63	Loaded	40.0	33.3	31.6	30.2
		Empty	42.3	40.8	34.1	34.1
		Average	41.4	36.7	32.8	32.0
Fair	30	Loaded	31.9	25.8	24.3	23.0
		Empty	34.5	29.3	28.3	25.2
		Average	33.1	27.4	26.1	24.0
Poor	13	Loaded	26.8	21.1	20.3	19.3
		Empty	29.7	24.7	23.3	22.7
		Average	28.2	22.7	21.7	20.9
Primitive	8	Loaded	16.7	15.0	14.0	13.6
		Empty	20.0	17.6	17.1	16.7
		Average	18.2	16.2	15.4	15.0

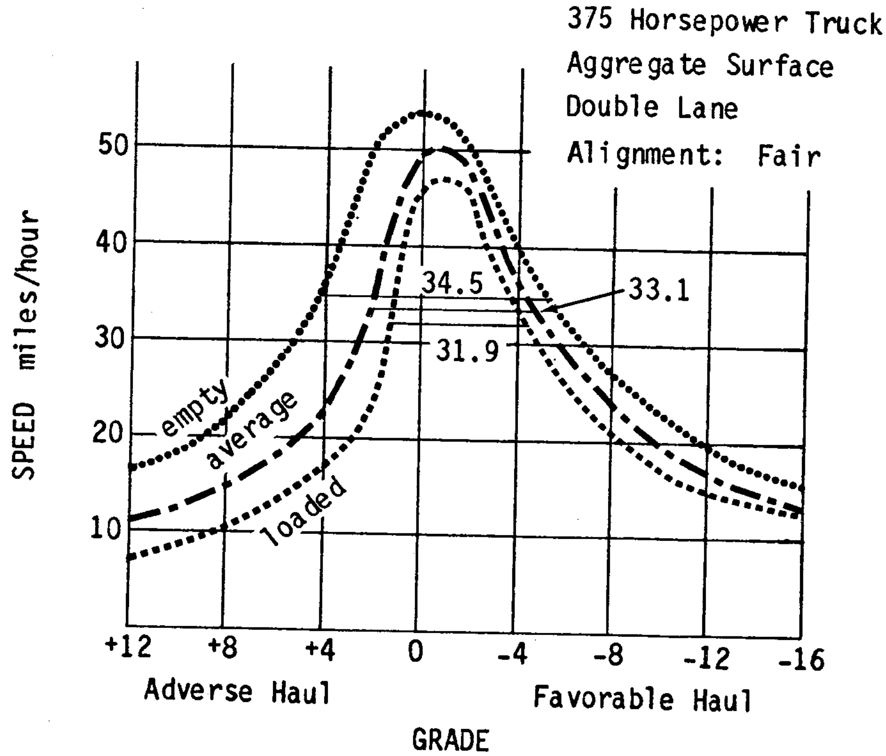

Figure 2.--Speed in miles per hour versus percent grade on a double-lane road without a ditch and a fair alignment.

Figure 3 shows that for a single-lane gravel-surfaced road with a fair alignment maximum truck speed is restricted to 25.2 mph for an empty truck for grades of between +7 and -9 percent and to 23 mph for a loaded truck for grades of between +3 and -7 percent.

Speeds determined from this series of graphs were then adjusted to surface type where the speeds are controlled by the grade and surface type. The speed of the empty truck operating on a single-lane or lane-and-a-half road were then reduced by 10 percent to account for conflicting traffic of 12 vehicles per hour with turnouts spaced at 1,000-foot intervals. Figure 4 shows the results as speeds in miles per hour and figure 5 shows travel times in minutes per mile.

Several judgments affect the selection of factors to determine speeds and travel times for figures 4 and 5. The first was where to break the charts for grade and surface type. The class for primitive road

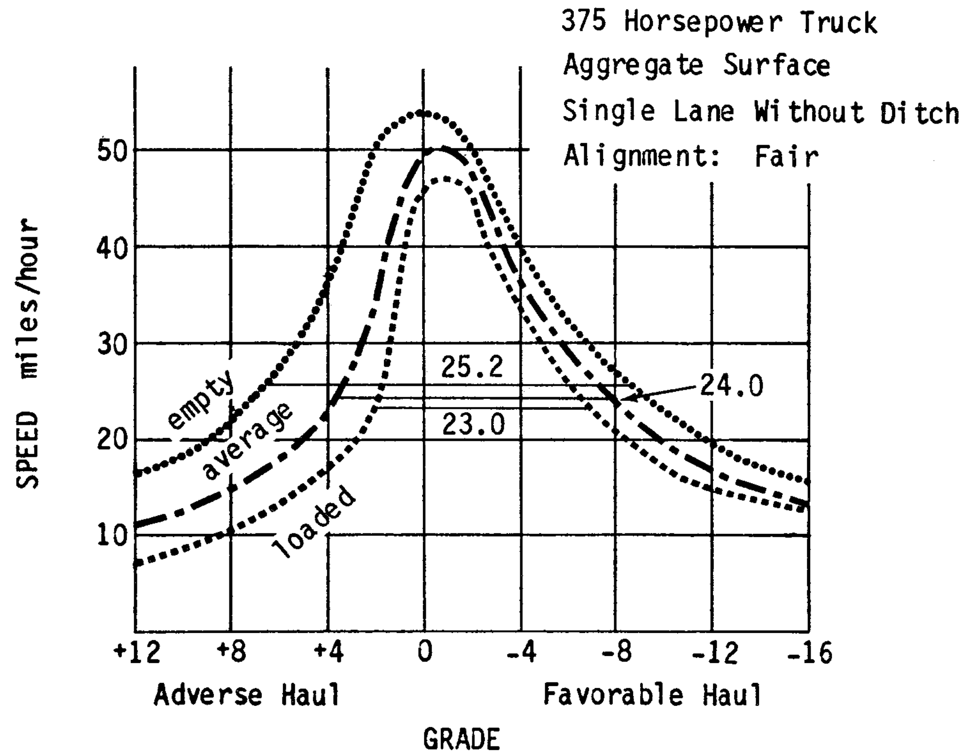

Figure 3.--Speed in miles per hour versus percent grade on a single-lane road with fair alignment.

surface has been deleted for the single-lane road because there is no road surface less than a native surface road. In a timber sale appraisal, allow adequate cost to provide an adequate running surface on the road for economical truck operations.

Figure 1 indicates that the speed of a truck operating on a double-lane aggregate-surface road varies from 50 mph at 0-percent grade to 40 mph at +2-percent grade to 23 mph at +4-percent grade. This change is a speed reduction of 20 percent between 0- and 2-percent grades and of 50 percent between 0- and +4-percent grades. Therefore, dividing the grade range of +4 to 0 percent into grade ranges of +4 to +2 and +2 to 0 appears appropriate.

CONCLUSION

The analysis to identify road characteristics that control speeds resulted in different travel times from those in the Manual Network Analysis. Many of the travel times are identical, but there are 76 different ones. The number of haul classes increased

No. Lanes	Type Surface	Alignment	Grade								
			Adverse Haul (+)					Favorable Haul (-)			
			10+	10-7	7-4	4-2	2-0	0-4	4-7	7-10	10-
Double Lane	Paved	Excellent	12.32	8.73	6.51	4.04	2.78	2.61	4.18	5.16	6.75
		Good				4.04	2.93	2.93			
		Fair				4.32	3.59	3.59	4.18		
		Poor		8.73	6.51	4.61	4.07	4.07	4.31	5.16	
		Primitive	12.32	9.00	7.29	6.53				6.53	6.75
	Aggregate	Excellent	12.32	8.73	6.84	4.29	2.86	2.61	4.18	5.16	6.75
		Good				4.29	3.01	2.93			
		Fair				4.57	3.59	3.59	4.18		
		Poor		8.73	6.84	4.86	4.07	4.07	4.31	5.16	
		Primitive	12.32	9.00	7.62	6.53				6.53	6.75
	Native	Excellent	12.32	8.73	7.32	4.59	2.90	2.61	4.18	5.16	6.75
		Good				4.59	3.05	2.93			
		Fair				4.87	3.59	3.59	4.18		
		Poor		8.73	7.32	5.16	4.07	4.07	4.31	5.16	
		Primitive	12.32	9.00	8.00	6.53				6.53	6.75
Lane and a Half	Paved	Excellent	12.86	9.00	6.79	4.23	3.04	2.97	4.38	5.36	7.08
		Good				4.43	3.64	3.64	4.38		
		Fair			6.79	4.92	4.62		4.62	5.36	
		Poor		9.00	6.89	5.47				5.47	7.08
		Primitive	12.86	9.75	8.04	7.75					7.75
	Aggregate	Excellent	12.86	9.00	7.12	4.48	3.12	2.97	4.38	5.36	7.08
		Good				4.68	3.64	3.64	4.38		
		Fair			7.12	5.16	4.62		4.62	5.36	
		Poor		9.00	7.22	5.47				5.47	7.08
		Primitive	12.86	9.75	8.37	'7.75					7.75
	Native	Excellent	12.86	9.00	7.50	4.78	3.16	2.97	4.38	5.36	7.08
		Good				4.98	3.64	3.64	4.38		
		Fair			7.50	5.47	4.62		4.62	5.36	
		Poor		9.00	7.61	5.77				5.77	7.08
		Primitive	12.86	9.75	8.75	7.75					7.75
Single Lane Without Ditch	Paved	Excellent	12.86	9.00	6.79	4.28	3.25	3.25	4.38	5.36	7.08
		Good			6.79	4.54	3.94	3.94	4.38	5.36	
		Fair			6.89	5.22				5.22	
		Poor		9.00	7.14	6.02				6.02	7.08
		Primitive	12.86	10.00	8.29						8.29
	Aggregate	Excellent	12.86	9.00	7.12	4.52	3.29	3.25	4.38	5.36	7.08
		Good			7.12	4.79	3.94	3.94	4.38	5.36	
		Fair			7.22	5.47	5.22		5.22	5.47	
		Poor		9.00	7.47	6.02				6.02	7.08
		Primitive	12.86	10.00	8.62	8.29					8.29
	Native	Excellent	12.86	9.00	7.50	4.82	3.33	3.25	4.38	5.36	7.08
		Good			7.50	5.09	3.94	3.94	4.38	5.36	
		Fair			7.61	5.47	5.22		5.22	5.47	
		Poor		9.00	7.86	6.02				6.02	7.08
		Primitive	12.86	10.00	9.00	8.29					8.29

ALIGNMENT	K
Excellent	K < 100
Good	100 < K < 50
Fair	50 < K < 20
Poor	20 < K < 10
Primitive	K < 10

$$K = \frac{\overline{R}}{N}$$

Where:
R = Average radius of curvature between nodes.
N = Number of curves per mile between nodes.

NOTE:
1. For 0 Grade use the favorable haul.
2. Speeds between the lines are controlled by ALIGNMENT.
3. Speeds outside the lines are controlled by GRADE.

Figure 4.--Round trip travel time on highway logging trucks by road's physical characteristics (minutes/mile).

No. Lanes	Type Surface	Alignment	Grade: Adverse Haul (+) 10+	10-7	7-4	4-2	2-0	Favorable Haul (-) 0-4	4-7	7-10	10-
Double Lane	Paved	Excellent	7/16	10/22	14/27	23/42	40/47	45/47	26/32	21/26	16/20
		Good				23/42	40/42	40/42			
		Fair				23/35	32/35	32/35	26/32		
		Poor		10/22	14/27	23/30	29/30	29/30	26/30	21/26	
		Primitive	7/16	10/20	14/20	17/20				17/20	16/20
	Aggregate	Excellent	7/16	10/22	13/27	21/42	38/47	45/47	26/32	21/26	16/20
		Good				21/42	38/42	40/42			
		Fair				21/35	32/35	32/35	26/32		
		Poor		10/22	13/27	21/30	29/30	29/30	26/30	21/26	
		Primitive	7/16	10/20	13/20	17/20				17/20	16/20
	Native	Excellent	7/16	10/22	12/27	19/42	37/47	45/47	26/32	21/26	16/20
		Good				19/42	37/42	40/42			
		Fair				19/35	32/35	32/35	26/32		
		Poor		10/22	12/27	19/30	29/30	29/30	26/30	21/26	
		Primitive	7/16	10/20	12/20	17/20				17/20	16/20
Lane and a Half	Paved	Excellent	7/14	10/20	14/24	23/37	40/39	42/39	26/29	21/24	16/18
		Good				23/33	33/33	33/33	26/29		
		Fair			14/24	23/26	26/26		26/26	21/24	
		Poor		10/20	14/23	21/23				21/23	16/18
		Primitive	7/14	10/16	14/16	15/16					15/16
	Aggregate	Excellent	7/14	10/20	13/24	21/37	38/39	42/39	26/29	21/24	16/18
		Good				21/33	33/33	33/33	26/29		
		Fair			13/24	21/26	26/26		26/26	21/24	
		Poor		10/20	13/23	21/23				21/23	16/18
		Primitive	7/14	10/16	13/16	15/16					15/16
	Native	Excellent	7/14	10/20	12/24	19/37	37/39	42/39	26/29	21/24	16/18
		Good				19/33	33/33	33/33	26/29		
		Fair			12/24	19/26	26/26		26/26	21/24	
		Poor		10/20	12/23	19/23	21/23			21/23	16/18
		Primitive	7/14	10/16	12/16	15/16					15/16
Single Lane Without Ditch	Paved	Excellent	7/14	10/20	14/24	23/36	38/36	38/36	26/29	21/24	16/18
		Good			14/24	23/31	30/31	30/31	26/29	21/24	
		Fair			14/23	23/23			23/23	21/23	
		Poor		10/20	14/21	19/21				19/21	16/18
		Primitive	7/14	10/15	14/15						14/15
	Aggregate	Excellent	7/14	10/20	13/24	21/36	37/36	38/36	26/29	21/24	16/18
		Good			13/24	21/31	30/31	30/31	26/29	21/24	
		Fair			13/23	21/23	23/23		23/23	21/23	
		Poor		10/20	13/21	19/21				19/21	16/18
		Primitive	7/14	10/15	13/15	14/15					14/15
	Native	Excellent	7/14	10/20	12/24	19/36	36/36	38/36	26/29	21/24	16/18
		Good			12/24	19/31	30/31	30/31	26/29	21/24	
		Fair			12/23	19/23	23/23		23/23	21/23	
		Poor		10/20	12/21	19/21				19/21	16/18
		Primitive	7/14	10/15	12/15	14/15					14/15

ALIGNMENT	K
Excellent	$K < 100$
Good	$100 < K < 50$
Fair	$50 < K < 20$
Poor	$20 < K < 10$
Primitive	$K < 10$

$$K = \frac{\bar{R}}{N}$$

Where:
R = Average radius of curvature between nodes.
N = Number of curves per mile between nodes.

NOTE:
1. For 0 Grade use the favorable haul.
2. Speeds between the lines are controlled by ALIGNMENT.
3. Speeds outside the lines are controlled by GRADE.

Figure 5.--Speeds by road's physical characteristics (on-highway-logging-trucks) (miles/hour).

from 320 to 405. Determining the horizontal alignment of roads with grades of greater than 4 percent is less critical since the travel time is the same for the excellent, good, fair, and poor alignment except on single-lane roads. Determining the grade for single-lane roads with fair, poor, and primitive alignment also is less critical since the travel times generally are the same for the various alignments for all grades of between +7 and -7 percent.

Figures 4 and 5 show the travel times and speeds for various haul classes by the physical characteristics; this should make the tables easier to use. The haul classes to use with MINCOST at FCCC can be coded with 4-digit numbers, as follows:

(1) The first digit represents the number of lanes: 1 = double lane, 2 = lane and a half, and 3 = single lane without a ditch.

(2) The second digit represents the surface type: 1 = paved, 2 = aggregate, and 3 = native.

(3) The third digit represents the alignment: 1 = excellent, 2 = good, 3 = fair, 4 = poor, and 5 = primitive.

(4) The fourth digit represents the grade: 1 = +2 percent to 0 percent, 2 = 0 percent to -4 percent, 3 = +2 percent to +4 percent, 4 = -4 percent to -7 percent, 5 = +4 percent to +7 percent, 6 = -7 percent to -10 percent, 7 = +7 percent to +10 percent, 8 = less than -10 percent, and 9 = greater than +10 percent.

As an example, a single-lane road without a ditch and with an aggregate surface, fair alignment, and a grade of between +4 and +2 percent will be haul class 3233.

Remember that these tables apply to Forest Development Roads (FDR's). Generally, alignment controls the maximum speed on low-standard roads. However, on a few FDR's, speeds in excess of 55 mph can be sustained for long distances. This situation is similar to that of the Federal Aid System Roads, where the 55-mph speed limit is the limiting factor for considerable distances. Travel times on State and county roads, and on FDR's where the alignment and grades allow sustained high speeds, should be determined from observations of the legal speed limits.

Facilities Maintenance Management

George J. Lippert
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This fall marks the formal start of a Service-wide emphasis to improve facilities maintenance. Implementation of a structural maintenance management process was one of the two recommendations provided by an inter-Region/Station team that reviewed building maintenance practices Service-wide.

The first recommendation, structured maintenance management improvements, will be implemented using a videotape presentation and an Engineering Management (EM) series publication. The former will provide an overview of maintenance management principals and elements. This is for use at Supervisor/ Ranger meetings, workshops, and other meetings to ensure a broad understanding and support for maintenance management improvements.

The EM publication will provide further detailed information, guidance, and examples of existing maintenance management systems. This publication may be distributed in conjunction with videotape presentations.

The structured facilities maintenance management framework is included in the draft revision of FSH 7309.11. This handbook will be reissued to replace Interim Directive #1, (February 19, 1986), FSH 7309.11. This also is slated for distribution this fall.

The second recommendation dealt with improving maintenance training. This training, aimed at improving inspection skills, is in the formative stages. You will be hearing more about this in the next few months.

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