environmental considerations in planning, design, and construction

Subject areas

11 Transportation Administration
15 Transportation Economics
21 Photogrammetry
22 Highway Design
24 Roadside Development
27 Bridge Design
31 Bituminous Materials and Mixes
33 Construction
41 Construction and Maintenance Equipment
81 Urban Transportation Administration
82 Urban Community Values

Special Report 138

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contents

3 preservation of recreational, natural, and historical values

4 visual quality in highway design

5 effects of highway construction on the environment

foreword

The theme of the Fifth Summer Meeting of the Highway Research Board was "Highways and the Environment." The papers presented during the sessions on environmental considerations in planning, design, and construction are contained in this Special Report. Other sessions were devoted to highways and motor vehicle noise control, highways and air quality, and environmental effects of de-icing chemicals. Papers presented at those sessions will be published during 1973 in other special reports or in the Highway Research Record series.

The Fifth Summer Meeting was held July 31-August 2, 1972, at Madison, Wisconsin. The meeting was planned and organized by the HRB Task Force on Highways and the Environment and was conducted in cooperation with the Wisconsin Department of Transportation.

1 where do we stand?

america's highways: where are they taking the environment?

John T. Middleton
Environmental Protection Agency

The thesis of Alvin Toffler's thought-provoking book, Future Shock, is that man is careening into the future at so great a rate that he is undergoing a vast psychological and sociological upheaval. Toffler notes that, in 1914, the typical American traveled about 1,640 miles per year and about 88,560 miles during his lifetime. Today, by contrast, the average American automobile owner drives 10,000 miles a year, and it has been estimated several million human beings will have covered 3 million miles or more during their lifetimes.

Toffler goes on:

> The aggregate figures are staggering. In 1967, for instance, 108,000,000 Americans took 360,000,000 trips involving an overnight stay more than 100 miles from home. These trips alone accounted for 312,000,000,000 passenger-miles.
>
> Even if we ignore the introduction of fleets of jumbo jets, trucks, cars, trains, subways and the like, our social investment in mobility is astonishing. Paved roads and streets have been added to the American landscape at the incredible rate of more than 200 miles per day for at least the last twenty years. This adds up to 75,000 miles of new streets and roads every year, enough to girdle the globe three times. While United States population increased during this period by 38.5 percent, street and road mileage shot up 100 percent. Viewed another way, the figures are even more dramatic: passenger-miles traveled within the United States have been increasing at a rate six times faster than population for at least twenty-five years.

I am neither a social scientist nor a highway engineer. But I think that contemplation of figures such as these suggests, at least in part, an answer to the question posed in the title of this paper: America's Highways: Where Are They Taking the Environment? At the very least, it seems clear that they are taking environmental problems to the farthest reaches of our nation—and doing it mighty rapidly.

What, then, are some of these problems, and how should they concern us?

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The impact of highways on water pollution is perhaps not so obvious, or so direct, as is the case with other environmental difficulties, but an example may serve to show the kinds of solutions we should be looking for.

The Environmental Protection Agency recently conducted a study of erosion and sediment deposition resulting from highway construction and land development activities. It concluded that the cost of correcting these problems often is unjustifiably transferred to the taxpayer rather than to those benefiting from the development; that the technical capability of controlling erosion and sediment deposition is available; that the cost of effective control probably is minimal; and that the principal problem lies in achieving effective administrative control and enforcement by concerned agencies.

A more obvious environmental insult related to highways—or, more properly speaking, to their use—is noise. An estimated 250 square miles adjacent to freeways or highways have a noise impact affecting about 2.5 million Americans. Of the 3 billion total highway vehicle-miles traveled in 1970, better than half were within town or city limits. In addition, traffic over the 96,000 miles of major arterial roads in suburban communities exposes 7 to 14 million persons to objectionable noise levels.

Tires are the dominant noise source when vehicle speeds are greater than 50 mph. The amount of tire noise is also a function of the road surface, axle loading, and tread design and wear condition. Truck tires are generally noisier than automobile tires. Engine-generated noise is normally dominant for trucks and automobiles at speeds below 35 and 45 mph respectively. This noise is radiated directly from the engine exhaust and intake openings and from the vibrating engine casing. The turbulent aerodynamic flow over the vehicle body and the rattling of loose mechanical parts are also sources of highway noise.

Improved engineering design may be expected to bring decreases in noise from all types of vehicles. Ultimately, however, we may have to look to changes in highway design features to provide shielding between the highway-generated noise and those who live and work near highways.

Finally, in the area of air pollution, we may have the most complex problem—both to define and to resolve. It is not my intent to go into detail on the subject. But a brief overview of some of the major factors is necessary to direct attention to the areas in which further study and planning are most vital.

In setting the national ambient air quality standards on April 30, 1971, for 6 major air pollutants, the EPA Administrator noted that Americans in several urban areas may have to change their commuting habits if the standards for the motor-vehicle-related pollutants are to be achieved. Much publicity has arisen in many of these communities about the need for one or more forms of transportation control—including, for example, vehicle inspection and maintenance, traffic flow improvements, increased transit usage, car-pooling, motor vehicle restraints, and work-schedule changes.

At the present time, our data base is too narrow to allow us to quantify the total potential environmental impact of each of these possible emission reduction approaches. Most are being studied intensively either by our staff or under contract. Although we can speak to probable qualitative results, we cannot yet clearly define how, and to what total degree, air quality in cities will be affected.

Basically, of course, the federal program to restore clean air—as it relates to motor vehicle emissions—depends on whether vehicles can retain their low emission characteristics under all conditions of operation, including those imposed by present road and highway strictures. Indeed, federal vehicle emission standards and testing procedures are based on driving patterns dictated by the way people drive their cars in cities. But those driving patterns are, in turn, dicated by present street and highway patterns.

However, those strictures pose some intriguing problems. In addition, several transportation control measures that have been contemplated are based on restricting emissions from the vehicles themselves and obtaining additional reductions in emissions, where needed, by restructuring the way in which the present street and highway system is used.

For example, studies are now being complated to show how much additional reduction in total emissions could be gained by installing retrofit control systems on uncontrolled or partially controlled vehicles. These, of course, assume that the vehicles will continue to be driven in the same way and over the same street systems as they now are.

The same is true of related ideas such as conversion of a portion of the vehicle population (fleets especially) to other fuels such as liquefied petroleum gas or liquefied natural gas. In the latter cases, of course, consideration must also be given to possible unfavorable trade-offs. Diverting natural gas to vehicle use in a given urban area, for instance, could mean that this fuel would be less available for use in heat or power generation. And this, in turn, might well result in increased consumption of fuels that would increase emissions of sulfur oxides.

Other methods considered for vehicle pollution reduction assume no further control of individual vehicle emissions but consider altering the way in which the vehicles use the existing street and highway systems.

In particular, thought has been given to methods for improving traffic flow. Typically, these methods are directed toward decreasing number and length of delays, idle times, and stops and starts on the vehicle-carrying system. The net effect of these changes would be to increase average vehicle speed. For a given traffic volume, carbon monoxide and hydrocarbon emissions decrease with increasing average speed. On the other hand, improving traffic flow is likely to result in increasing the total volume of flow. Thus, traffic flow improvements related to increased average speed might be counter-productive. Again, our present knowledge does not allow us to quantify the environmental impact.

Let me suggest, briefly, 2 other interesting concepts worthy of thought.

Absent any reduction in individual vehicle emissions, or gross alteration of traffic flow patterns, one should expect atmospheric pollutant levels in the central city portions of our major urban areas to approach, asymptotically, a relative maximum, as the street system becomes saturated. Thus, the additional development of street and highway systems in the total urban area would result in expanding the area of pollution impact outward from the central city. This effect, in fact, has been noted and measured. Increasingly, then, the expanding highway system has extended the area of impact into the suburbs. The development of the street and highway system has allowed people to escape the environmental insult of the city but has brought the environmental insult along with them.

The Interstate Highway System provides for travel around many major urban areas. Presumably, emissions from vehicles using these routes would not add to pollution levels in the central city area. But, clearly, they will add to levels in the suburban areas where these beltways are typically located. Although we cannot quantify the effect at this time, there may be a greater impact on the central city area than first considerations might indicate. Because of the highway configuration, vehicle emissions will ring the city; and, no matter what the wind direction, the air moving across the city will contain contaminants from the vehicles.

How do all of these many factors interrelate? What is the net impact when all of the trade-offs are considered? How can we optimize the combination of vehicle emission control, vehicle use, and highway design and location? Unfortunately, we are unable to say at this time. But, these questions must be asked, they are being asked, and we are developing the answers.

We started with the question, Where are highways taking the environment? The answer is, To where it now is—at least as far as motor-vehicle related pollution is concerned. However, the real question is, Where should the environment take highways? Quite likely, honest and objective answers to that question will result in sweeping changes in the future development of the total transportation system.

environmental requirements of the federal-aid highway program

Michael Lash
Federal Highway Administration

The enormous environmental pressures placed on highway programs today come from many different directions. They come from federal legislative provisions, state laws, and court decisions, which often result in modifications to earlier interpretations of federal law. They come from actions of federal and state environmental agencies, private environmental groups of many kinds, and local citizen groups. And, of course, they come from the increasing number of books and newspaper and magazine articles.

Highway agencies are being asked to deal instantly with a vast number of new subject areas, including noise, air pollution, water quality, and social and economic matters such as civil rights, relocation, and tax base. Highway agencies are expected to make in-depth studies of these factors not only on projects just beginning but also on those advanced to the construction stage. Yet, in many areas, the knowledge is meager, the state of the art is primitive, and the experience is slim.

Of course, we are not alone in this predicament. Similar pressures are being felt in other large-scale public works programs such as those for energy, airports, and water resources. Moreover, the pressures are being felt not only in the United States but in many other countries including England, Germany, Sweden, and Japan.

For us in the highway field, the question is not whether we will respond but how we can best respond. Our response must be more than a series of expedient reactions to momentary crises if we are to build a lasting foundation for the future highway program. A review of several key pieces of federal legislation related to environmental issues may be helpful in showing what directions we have already taken in building that foundation:

1. A law enacted in 1956 created a means to inform the public about planned highway projects and to receive public comment. In 1958 the public hearing requirement was expanded to apply to a greater number of projects.

2. Legislation in 1962 required that the urban transportation planning process be carried on in urban areas of more than 50,000 population, that highway plans be properly

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coordinated with an area's comprehensive plans, and that local officials play a significant role in transportation system planning.

3. In 1966 a provision, commonly referred to as the 4(f) requirement, was incorporated both in the Federal-Aid Highway Act and in the Department of Transportation Act that required special effort to avoid taking lands from a park, recreational area, wildlife and waterfowl refuge, and historic site in the planning of a transportation improvement.

4. The National Environmental Policy Act of 1969 required a written evaluation of the environmental impacts of a proposed project and further required that the evaluation be circulated to interested agencies and made available to the public for comment. In addition, the National Environmental Policy Act required that a systematic multidisciplinary approach be used in the development of projects and that the study of projects include consideration of a variety of alternatives.

5. Section 136(b) of the 1970 Federal-Aid Highway Act had several far-reaching environmental provisions. The first was a mandate for the Secretary of Transportation to prepare guidelines to ensure that adverse environmental impacts are adequately considered in highway decisions and that highway decisions are made in the best overall public interest and consider the need for fast, safe, and efficient transportation, public services, and the costs of minimizing adverse economic, social, and environmental effects. Section 136(b) also required the preparation of highway noise level standards and air quality guidelines.

This sketchy review of federal legislation that bears on the highway program reveals some important directions. First, public and local officials have greater opportunity to become informed about and to give information and reactions to proposed projects. Second, highway agencies are expected to develop a capability to identify possible adverse impacts in an objective manner. In addition, the National Environmental Policy Act stressed the need for a systematic interdisciplinary approach and the need to evaluate a variety of alternative solutions.

In preparing the environmental guidelines called for by Section 136(b) of the 1970 Federal-Aid Highway Act, we resolved quite early that we would try to avoid heaping another batch of detailed procedural requirements on the states. What we wanted to do was prepare guidelines that would deal with fundamental issues and that would help the highway program to meet environmental challenges in a lasting way. This approach was entirely consistent with the language of Section 136(b), and our consultations with our legal staff confirmed this view.

The result of all this is the process guidelines. These guidelines call on each state to prepare an action plan that outlines the organizational arrangements and the procedures the state will adopt to ensure that the following 4 fundamental objectives are accomplished in the development of a highway project:

1. State highway departments must develop a real competence to identify and objectively study economic, social, and environmental effects of proposed highway projects. This means that a highway department should have an in-house capability to make such studies in more than a superficial way. Other agencies can often assist and may offer comments on such impacts, but each highway department needs to have its own independent competence in making such studies. Without such competence, highway agencies will continue to be viewed by the public as narrow and indifferent to values and problems other than those related directly to transportation. They will be in a poor position to make valid judgments about the proper weight to be given to various environmental effects in relation to related transportation impacts. In addition, they will be vulnerable in the courts where they may be unable to prove that their decisions are based on a genuine balancing of both transportation and economic, social, and environmental effects as required by several federal laws.

2. An interdisciplinary approach must be used in the development of highway projects from system planning to design. The purpose of this objective is to ensure that the knowledge and viewpoints of other disciplines identify, describe, and evaluate nontransportation impacts. Those with training in other fields should not only assist in

the study of nontransportation effects but also help bring a broader perspective to the making of highway decisions.

3. Other agencies and the public must be involved in system planning, location planning, and design. Such participation is needed to identify potential effects that may not be revealed by staff studies, to indicate the relative importance the public places on various effects, and to achieve public confidence in the decisions reached.

4. Alternative solutions must be considered. This objective requires the highway agency to examine all options available and allows the public to compare costs and benefits of taking various courses of action including no action at all.

The process guidelines call on the states to describe in the action plan how they will accomplish these 4 objectives. They are allowed a year to prepare the action plans and are given the opportunity to revise their plans if they find better ways to meet the objectives.

We have tried to develop guidelines that will provide a suitable foundation for the future highway program. We believe the guidelines can provide the needed foundation for meeting the environmental requirements of the highway program both in the present and in the future.

incorporating social and environmental factors in highway planning and design

Marvin L. Manheim and
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Masschusetts Institute of
Technology

The Urban Systems Laboratory of the Massachusetts Institute of Technology has been doing research on the theme, "Incorporating Social and Environmental Factors in Highway Planning and Design," for approximately 4 years. We have felt the necessity for a strong base of theoretical research on which to build. More fundamental work on the theories of transportation systems analysis, decision-making, and design was conducted prior to the start of our research on transportation and community values in 1968. Our efforts to focus on the practical problem of incorporating social and environmental factors in highway planning and design began when we first received research support in this general area from the National Cooperative Highway Research Program. Since then, additional research support has been provided by the California Division of Highways and most recently by the Federal Highway Administration through its Office of Environmental Policy. In addition, in the early stages of this research, we had some start-up support from a Ford Foundation grant.

Each of the 3 major sponsors has asked us to produce practical results, capable of being implemented immediately and directly responsive to their needs as they perceive them. For us, this has been a challenging and productive opportunity. The problem itself is broad and difficult and pertains not only to the highway field but also more generally to the role of technology in modern society, the relation of the individual to the political process, and other equally extensive and philosophical issues. For each of these sponsors, we have been producing directly operational results (or so we hope and believe!). Therefore, we find it particularly useful to take this opportunity to step back from our research, to summarize the basic principles that are reflected in our recommendations, and to determine where we stand.

We start by summarizing the basic principles of our approach to transportation systems analysis and the process of reaching decisions about transportation and highway projects. In subsequent sections, we summarize briefly the practical results that have followed from application of these principles to three problem areas. For the National Cooperative Highway Research Program, we have produced a procedural guide (2),

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which is being used on an experimental basis by several state highway departments in cooperation with M.I.T. For California, we have just completed and submitted conclusions and recommendations from a 2-year program of research on incorporating community and environmental factors in highway and transportation planning in California. Finally, for the Federal Highway Administration, we have produced a set of process guidelines in response to Section 136(b) of the Federal-Aid Highway Act of 1970.

BASIC PRINCIPLES

Our conclusions regarding some basic principles on which planning and analysis of transportation systems should be based have evolved during a period of years and serve as a framework for our more specific recommendations to NCHRP, California, and FHWA.

Single Multimodal Transportation System

> A governmental transportation organization should work to provide transportation as a service, using all modes of a region and all options, including not only investment in fixed facilities but also pricing and operating policies.

Planning and analysis of transportation systems should treat all modes of transport in a region together and emphasize their complementary and competitive relations. For example, transit, highway, and other modes must be considered simultaneously in an urban transportation planning study, and aviation, rail, bus, automobile, and truck should be considered together in a statewide transportation study. As special issues emerge, the scope of analysis may focus on a single mode or facility.

Alternatives and Options

> A range of transportation options are available and should be developed at all levels of technical studies to bring out the issues and to assist the community in clarifying its objectives and reaching a decision.

A wide range of options are available in regional as well as facility-oriented transportation studies and should be examined as part of any decision-making process. These include:

1. Investment in either new or improved fixed facilities such as highways, transit lines, busways, airports, terminals, and parking facilities;
2. Operating policies such as flow metering, traffic surveillance systems, restriction of lane usage, exclusive or priority use of lanes for buses, public transportation routes and schedules, exclusion of automobiles from certain areas, and other policies affecting congestion or demand;
3. Pricing policy such as transit fares, parking charges, toll facility charges, and various mechanisms to increase car-pooling; and
4. New technologies such as people movers, personalized rapid transit, automated guideways, and area-wide demand-responsive bus systems.

A variety of other options are also available and include land use controls and staggered work hours. Transportation options should be effectively coordinated with replacement housing, impact amelioration programs, and joint development.

Effects

> Identification and prediction of social, economic, and environmental effects should be based on the people and group affected.

Traditional impacts determined for the users of a transportation system include changes in travel time, vehicle operating expenses, and other aspects of the cost or level of service that travelers perceive. Impacts on nonusers of the transportation system include changes in the competitive patterns of shopping and industrial areas in the central business district and suburban communities, changes in population distribution and land use, displacement of families and jobs, and tax losses.

The incidence of all impacts should be identified. When changes to a transportation system are implemented, some people will be adversely affected while others will benefit. The incidence and the manner of these gains and losses should serve as the primary orientation of impact-prediction activities.

Social, economic, and environmental data should be developed in parallel with project alternatives and related engineering data, and the development should begin early in technical studies. Impact information should be timely and responsive to the needs of a transportation study. Procedures available to predict particular kinds of impacts range from quick and approximate techniques to detailed, in-depth investigations. The choice of technique will depend on the particular needs of a study.

Analysis Tools

> The technical analysis tools, particularly those for system studies, should be responsive to the principles of supply-demand equilibrium and to community-environmental impacts.

The complete set of models, computer programs, and other analysis tools used in developing transportation projects should be relevant to the issues, be free of built-in biases, and be based explicitly on the theory of supply and demand equilibrium in transportation networks (1). This means that the way in which congestion occurs must be accurately represented and that the volume of travel should be assumed to be not independent but a function of travel time, fare, and other factors that consumers consider to be important.

This also means that a variety of attributes of service should be considered. The time it takes to get access to the system, such as walking from an office to a parking lot, moving over local streets to an expressway, or moving by foot or bus to a rapid transit facility, must be considered in addition to the time spent on the line-haul portion of the system. Furthermore, the problems of short- and long-run equilibrium need to be addressed specifically. Behavior of traffic in the short run as well as behavior of the land use system in the long run should be dealt with explicitly.

The analysis tools used for transportation planning should give increased emphasis to the variety of social, economic, and environmental impacts. In general, existing models concentrate primarily on user impacts and do not consider nonuser effects.

Uncertainty

> The transportation decision process should explicitly recognize uncertainty.

There are many ways in which transportation environment is changing. Changes in demand, technology, and priorities that reflect individual values must be anticipated. This means that, instead of a master plan being developed for a target year based on highly uncertain estimates of probable impact, a plan should be developed that involves a series of decisions taking place over time. A master plan has certain advantages in that it is tangible and easy to visualize, but it tends to be fixed and unable to respond to new information, revised impact estimates, or changes in land use, socioeconomic activity patterns, and operating policies. A plan formulated on a strategy of staged decision-making is flexible and can more adequately account for uncertainty. As particular stages of the plan are implemented and as events are discovered to be different than those originally anticipated, the strategy can be revised. It is important to maintain an attitude of searching for flexible plans in the face of uncertainty, keeping options open, and determining what future options are being foreclosed by current decisions.

An emphasis on uncertainty also means that attention is paid to experiments and demonstration projects as important actions to undertake because of their value in reducing uncertainty.

Evaluation

Evaluation of a planning process should occur periodically throughout the course of studies and should guide a process by suggesting priorities for subsequent activities.

Evaluation should do more than simply compare alternatives or analyze impact data. Evaluation must account for both the incidence of all significant impacts and the different viewpoints held by those affected.

Evaluation should be based on the premise that a consistent and operational statement of goals cannot be ascertained. The wide variety of interest groups potentially affected by a project will each have different objectives. Different interest groups will likely not be able to agree on goals except at a very abstract and nonoperational level. Instead of trying to reach agreement on goals, decision-makers should try to develop an action on which the various interest groups can agree. This means that the emphasis in planning is on the development of such actions.

The fact that a community cannot articulate a set of goals should not be taken to mean that a range of acceptable alternatives or policies cannot be identified. In any community such a range can be roughly defined from an examinination of past policy decisions on related matters. Similarly, there are other policy goals that clearly lie outside the perimeters of acceptability to a given community.

Evaluation should occur continually throughout the planning process. Information developed during explicit and periodic evaluation analysis should help to determine priorities for subsequent study activities. Evaluation thus can structure the learning that should take place among all the participants in a transportation planning process. The various technical staffs must learn about action alternatives available and about alternative objectives that might be achieved. The various interest groups also must learn about actions available and must communicate a wide variety of information to the relevant technical teams.

Public Involvement

Interaction between the technical team and potentially affected communities should occur at all planning levels.

Constructive involvement of the public and of local officials and private groups is necessary and desirable in all phases of transportation planning. It should start during system planning and continue through corridor, location, and design studies, and even into construction. Public involvement should be broadly defined as the two-way process of interaction and communication between the technical team and all communities and through which the technical team and the communities learn about each other and work together.

Interaction involving a wide range of interests can be used to help identify and predict both the incidence and the magnitude of social and environmental impacts. For example, the effects of a proposed facility on community cohesion can best be determined through developing an understanding of the community affected via face-to-face contact. Community interaction enables the technical team to learn what various groups consider to be important and unimportant issues. Also, community groups can serve as a useful source of solutions to transportation and related community problems.

The public must provide inputs to the decision-making process. Efforts should be made to search out and involve all elements of the public, especially those who may be reluctant to participate, so that a decision-maker can effectively weigh the full range of different viewpoints.

The tone of community interaction should be one of assistance and cooperation and of clarifying the issues of choice. A position of attempting to "sell" a particular kind of transportation facility should not be taken.

Decision Process

> The process through which decisions are reached should provide opportunities for negotiation among affected interest groups.

A decision-making process should be participatory yet decisive and have agreed-to time tables for necesary decisions. Some even argue that decisions in today's political climate cannot be decisive without public participation.

In a participatory decision process, the role of technical analysis is different from that in a non- or low-participatory process. The premise that professionals are best able to determine what is in the best overall public interest is no longer accepted. The role of professional staff in a participatory process should be to clarify the issues of choice and to assist the total community in reaching a decision. This places the professional staff in a role of stimulating debate among those affected rather than one of recommending a particular course of action.

Equity

> Transportation decisions should be based on the principle of equity.

Transportation decisions should internalize to the fullest extent possible adverse and beneficial social, economic, and environmental effects. In most situations implementation of a particular transportation plan is likely to impose costs on some and bring benefits to others, thus creating a transfer among interest groups. In some situations, this may be desirable, as for example when transit service to suburban job locations is subsidized to increase employment opportunities for central city residents. However, in most transportation situations, the existence of a transfer from one group to another is not a desirable policy. According to the principle of equity, groups that bear costs in order that other groups may benefit should be compensated in an acceptable way. Compensation to residents displaced by highway construction is an example. Prior to recent legislation, families displaced by highway construction frequently had to absorb certain tangible and intangible costs for which they were not fully compensated.

Institutions

> The arrangement and the organizational structure of political and technical institutions influence the degree to which social and environmental considerations are incorporated into transportation decision-making.

Decisions should be made at the lowest level of government practicable. Affected individuals and groups should be represented or participate directly in decision-making processes. Conflict is inevitable among interest groups and institutions, and the structure should make it possible for such conflicts to be resolved constructively. The appropriate institutional structure depends on the local situation. State governments can encourage local institutions to develop capabilities that will allow them to take more responsibility for transportation decisions.

The Transportation and Community Values Project of the Urban Systems Laboratory at M.I.T. is performing research on the impacts of highways on environmental values under sponsorship of the National Cooperative Highway Research Program. The major objective of these research studies, begun in October 1968, is to develop practical approaches for incorporating community and environmental factors into all phases of highway planning, location, and design. The major product of the studies to date is a report submitted to the research sponsors in September 1971 (2).

Out of that research has come the following statement of the objective of the technical team doing highway planning studies: The objective of the technical team is to achieve substantial effective community agreement on a course of action that is feasible, equitable, and desirable.

That objective reflects the principles described earlier and a basic conclusion that significant changes in current attitudes and work styles are necessary if social and environmental factors are to be fully incorporated into transportation analyses. Its implications are quite different from those of objectives frequently used: to construct a highway. The proposed objective focuses on achieving agreement on a course of action, not agreement on values. The role of the highway professional is to assist the community in reaching a decision and to enhance the political process by stimulating the constructive involvement of interest groups and individuals who do not usually participate as well as those who usually do. The proposed objective is based on the concepts of equity and openness, particularly with respect to the clarification of issues relevant to potentially affected interest groups. Although full achievement of this process objective is admittedly difficult, we believe that it should serve as the goal of every location team.

Five basic kinds of activities are implied for a location team: development of alternatives, community interaction, impact prediction, evaluation, and management. To assist in achieving the process objective, these activities can be structured into an overall 4-stage process strategy of initial survey, issue analysis, design and negotiation, and ratification.

An initial survey is desirable prior to the development of proposed solutions to acquire a base of social, economic, political, transport, and environmental data and to develop an initial understanding of potentially affected community interests.

In the issue analysis phase, the technical team develops a variety of alternative actions and presents them in various formal and informal ways to a large number of groups and individuals. As a result of continual interaction, the technical team learns what issues are important to different groups and receives ideas and suggestions about problems that might be solved in the community in coordination with the highway program and about alternative actions that might be of particular interest to particular segments of the community. Issue analysis should stimulate identification and expression of conflicting values. The objective is to develop a clear understanding of the issues for both the location team and those potentially affected in the community. This should be accomplished while a wide range of possible solutions is available and not after the location team has narrowed its choice to one or two alternatives. These solutions normally will involve basically different design standards and nonhighway or compensatory program elements as well as variations in location, design, and structural geometry. Presentation of a wide range of basically different alternatives early in the process will stimulate community groups to question and clarify their own objective and to be willing to interact with the location team.

In the design and negotiation stage, emphasis shifts from developing a wide range of alternatives to exploring variations on a few alternatives. The objective is to develop one or more actions that have high potential for achieving substantial, effective agreement. There must be opportunity for meaningful negotiation among conflicting interest groups in reaching an agreement on what comprises an equitable distribution of gains and losses.

The role of the required public hearings and other formal decision processes should be that of formal ratification of previously agreed-upon actions. The hearing cannot serve as a substitute for meaningful and constructive community interaction in previous stages of the process.

The proposed process objective and 4-stage strategy serve as a framework or guide for a location team. Many specific kinds of techniques are required throughout the duration of planning, location, and design, and part of the NCHRP research has concentrated on developing such specific techniques. For example, various aids have been developed to assist a location team in identifying those who may be potentially affected by a proposed transportation project. Also, a well-designed program of community interaction activities will normally employ a number of techniques for communicating with groups in the community and for soliciting a wide range of information from them. Techniques may include small meetings, field work, use of the media, newsletters, and field offices.

The research conducted for NCHRP synthesizes the described principles, especially those for evaluation, public involvement, equity, and decision process, into a systematic approach for incorporating social and environmental factors into all aspects of a transportation planning process. Current studies are examining the problems of treating community and environmental effects during metropolitan area and statewide systems studies. Selected states are cooperating in implementing and "testing" the procedures and recommendations developed to date. The research team has visited 10 state transportation agencies distributed geographically throughout the country. They include small and large states; those that have rural, recreational, and urban areas; and those that have centralized and decentrailized operations. Based on the results of these visits, in-depth cooperative activities are being initiated with the Georgia Department of Transportation and the Michigan Department of State Highways.

CALIFORNIA

The Massachusetts Institute of Technology has been cooperating with the California Division of Highways since July 1, 1970, on research studies concerned with community and environmental factors in transportation planning. The objectives of the research are as follows:

> To develop an approach and techniques for giving systematic consideration to community and environmental factors throughout the total span of the transportation planning process, from system planning and programming to design. Particular attention is to be given to the interaction of system planning and programming and route location and to the integration of this approach with the planning, programming, and budgeting system of the California Division of Highways.

Work on this project began on July 1, 1970, and was completed on June 30, 1972. During this 24-month period the M.I.T. team worked not only in Cambridge but also in California in various offices of the Division of Highways, the Department of Public Works, and the Business and Transportation Agency. Part of the research was focused directly on project planning and design, while other parts focused on urban and statewide system planning and on the development of means of more effectively integrating project and system studies.

The major focus of the project-oriented effort was the Los Angeles district, where the M.I.T. team worked with a combined route planning and community and environmental factors unit (CEFU) team on the location of the Slauson Freeway, a major east-west facility being planned for the area just south of central Los Angeles. In addition, the M.I.T. team also participated from time to time in work on other freeway projects and interviewed extensively many people in the right-of-way, design, advance planning, administration, and freeway operations of the district offices. The team also worked with the headquarters project people and also visited district offices in San Francisco, San Bernadino, and San Diego to become familiar with their operations. This approach enabled the M.I.T. team to work in-depth in one particular area, yet retain sufficient breadth so that the research findings and recommendations would be applicable to all districts.

The major base of the system planning-oriented research studies was initially in Los Angeles and subsequently in Sacramento; time was also spent in the metropolitan areas of San Francisco and San Diego. In Sacramento, the M.I.T. team worked closely with personnel in the headquarters offices, especially those in the urban planning and CEFU groups. In addition, contact and coordination were maintained with personnel in the Department of Public Works and in the Business and Transportation agency, especially the Office of Planning and Research.

This method of approach to the research can best be described as one of "participant-observation" in which members of the M.I.T. team worked with counterparts in California on the solution of actual location, planning, and policy problems while simultaneously observing operations of the state transportation organization through work experiences, interviews, and meetings. This same basic approach is being followed in our cooperative activities with Georgia and Michigan. One of the major characteristics of the approach is the opportunity to work closely with professional staff from all levels of an agency. The experience in California has been extremely stimulating and rewarding, particularly the opportunities to observe the processes of policy formulation and implementation, and we are extremely grateful to the state of California for this opportunity of viewing its operations from the perspective of many different levels.

Detailed findings from our Californian studies are presented as part of 6 in-depth reports covering each of the major areas of investigation. We have, however, synthesized certain basic findings from these more detailed observations. Although these findings are based primarily on our California experience and observations, they are broadly applicable to many, and possibly most, highway agencies, according to our observations in other states.

Our primary observation is that, although many states have responded to the challenges posed by the increased concerns for community and environmental considerations, significant problems still exist. The problem is manifested by the public concerns expressed in various ways that social and environmental factors should be considered more centrally in highway planning and decision-making than has traditionally been done. Some segments of the public feel these sentiments so strongly that there is a substantial base of anti-highway opinion within almost every state. Those who hold that opinion are found in many state legislatures and in politically active citizen groups, and their goal is to block most if not all major highway improvements. These actions suggest a "crisis of confidence." Many segments of the public no longer have confidence in highway engineering professionals and, rightly or wrongly, highway engineers are perceived as being opposed to many of the things that these citizens think are important.

The changes in public attitude, coupled with the recent almost complete reliance on Interstate-standard facilities, has also resulted in what can be called a "crisis of solutions." People no longer automatically accept the notion that a limited-access, multilane highway may be "needed." They, along with the U.S. Congress, are requesting that "need" be based not primarily on the provision of fast, safe, and efficient transportation but related to the costs of eliminating or minimizing adverse social, economic, and environmental effects [Federal-Aid Highway Act of 1970, Sec. 109(h), 23 U.S.C., Sec. 136(b)]. This implies that explicit consideration must be given to the options of no new highway construction, different standards or types of highway improvements, and other modal forms.

These crises of confidence and solutions have resulted in a high level of concern regarding the processes by which highway projects are developed and decisions made. This represents a major shift from the traditional almost exclusive concern with the projects, or products, resulting from this process. Highway agencies have sometimes considered these processes, and their associated assignments of responsibility, to be internal operations, but they are now being increasingly subjected to public scrutiny. People are reluctant to have confidence in the decisions of a highway agency and to accept a highway project when the process used to plan and develop that project does not itself merit confidence.

Problems also are manifested in terms of issues within state transportation organizations. There are problems of morale as professional staff within these agencies become increasingly frustrated by citizen opposition and question their roles and objectives in light of this increasing public concern. As a result, there is considerable uncertainty about the direction in which these agencies are or should be moving.

Many organizations are aware of these problems and are actively searching for new directions, new techniques, and new philosophies. Even though many states have taken important and constructive steps, these actions represent only the beginning of a response. Actual practices change slowly within organizations as large and complex as many state highway and transportation departments. Many constraints and problems still exist.

Among the findings resulting from the collaboration on project studies in California, and confirmed by our observations on other states, are several of particular importance.

1. Implementation of major new approaches takes time. The M.I.T. approach as developed in the NCHRP research is fundamentally different in many ways from present practices within most highway agencies. We have found that implementation of such a new approach takes a substantial period of time, measured in years rather than in days or weeks.

2. People of a high professional caliber, such as the staff within a state transportation agency, cannot be forced to do things in which they do not believe. Stated another way, to bring about change within an organization, the professional must first become convinced that change is necessary and that the proposed direction of change is useful and productive. Unfortunately, many people in highway agencies are not now convinced that problems exist and that change is necessary.

3. Many significant, hidden organization pressures work against the consideration of possible adverse effects of a proposed facility. For example, different status levels are associated with different professional specialities; right-of-way, environmental, and system planning groups are generally considered to be of lower status than either route location or design groups. As a consequence, environmental or planning-oriented groups in many agencies immediately have several strikes against them at the outset.

4. The reward structure as perceived by professional staff is critically related to the success of planning procedures. Most route planners see that their promotion and advancement opportunities are directly related to their success in getting a route developed and implemented. Yet, a major tenet of the M.I.T. approach is that the decision not to build a freeway may in fact be the best decision, provided that the community has reached that decision with full information about the alternatives and their consequences. Thus, the basic reward structure, as perceived by personnel with direct responsibility, may work against adoption of the M.I.T. approach.

5. Attitudes and constraints existing within all organizations tend to inhibit innovation and experimentation and to encourage patterns that have worked well in the past, even in the face of signs that those patterns may not work well at the present.

In summary, within an agency are many significant organizational and procedural obstacles to implementing a new approach. This is not to say that new approaches cannot be implemented. In fact, we have observed over time gradual acceptance within California and elsewhere of the recommended approach, with changing attitudes and work styles as a consequence. This acceptance, however, has been slow and indicates to us the real depth to which efforts must go to successfully bring about change within any state highway agency.

A few states, including California, are initiating basically new approaches and policies for the analysis of transportation corridors. A great deal depends on how these policies are implemented. For example, the California corridor policy involves the signing of a cooperative agreement between the state and each affected town or city, indicating among other things the kinds of studies to be undertaken. In addition, a corridor study is to determine the kind of highway improvement needed, if any, and the relation of the proposed highway improvement to other transportation modes.

There may well be serious problems in getting local governments and the affected communities to believe that the highway division truly intends to take a broad, multimodal approach in corridor studies if the division is unable or unwilling to fund alternatives other than freeways. To achieve acceptance, the division must demonstrate that it really means to do a true multimodal transportation study at the corridor level and that the option of a no-highway improvement is in fact an alternative that will be given serious consideration.

A true corridor study should provide a close and responsive link between system planning and corridor studies and between corridor studies and design. Many of the options that local communities may wish to explore in corridor studies will likely have implications for the overall system plan for a metropolitan area or region. Unless a continuing system planning process exists and is responsive to the corridor study needs, a proposed system will not be reappraised and these issues will not be addressed. Similarly, to determine the feasibility of a corridor for a specific type of transportation facility and to enable the full set of impacts to be predicted requires that specific alignments be identified and designs developed. It may even be necessary to make certain design commitments or at least to set design "performance standards." A corridor study will have serious credibility problems if a close and responsive integration with system planning and design is not achieved.

We note also several indications that the philosophy inherent in planning and decision-making at the urban and statewide system level lags seriously behind the philosophy that has been emerging in planning and decision-making at the project level (again, observations are based on an in-depth analysis of California, but general experience indicates that the points are equally applicable in most other states as well).

1. No explicit or systematic provisions currently exist for the treatment of social and environmental factors during either statewide or urban area system planning.

2. Little effective community interaction occurs in system planning.

3. The alternatives considered are constrained because of limits in funding (i.e., ways and areas in which funds can be spent) and because of a mandated and highway-based master plan.

4. The present use of the needs study and the functional classification contribute to the problems of credibility and acceptance between a highway agency and the public. In fact, one could argue that in some respects the needs study and the functional classification evade the very issues with which many local communities and many significant sectors of the public are most concerned, for they provide no capability for dealing with community and environmental factors or for dealing with transportation as a multimodal system.

5. The models and analysis tools currently used in system planning do not adequately address the equilibrium between supply and demand in a transportation system, thereby ignoring effects of congestion and contributing to inaccurate traffic forecasts and impact predictions.

6. Current institutional arrangements are such that relatively little effective decision-making responsibility or authority and relatively little technical analysis capability rest with metropolitan areas or local communities. As such, channels for the input of viewpoints from these levels of government are not so effective as they might be.

These basic findings have led to a series of specific action-oriented recommendations to the state of California. A summary follows of our major conclusion and our primary recommendations regarding mission, institutions, and personnel.

Conclusion

Effective treatment of community and environmental factors thoughout all stages of transportation planning requires major changes. What is needed is a broad program of action consisting of (a) a clearly articulated philosophy, (b) a coherent strategy for implementing this philosophy, (c) actions in addition to those already undertaken, and (d) changes in mission, procedures, and organization.

Mission Recommendation

The mission of a state transportation organization should be to assist communities in reaching decisions about transportation and implementing those decisions.

1. A state must determine the extent and the character of its role in transportation decision-making. We believe that the mission of a state transportation organization should be to assist in reaching decisions, not to make those decisions for communities. The role of the state transportation organization should be as a catalyst and stimulus to decision-making by political bodies at state, regional, metropoltian, and local levels.
2. The decisions reached should reflect substantial, effective agreement on courses of action that are feasible, equitable, desirable, and consistent with the recommended approach to project planning.
3. An organization's primary strength is in the professional skills and services it provides.

Institution Recommendation

A state transportation organization should work to develop the capabilities of regional institutions to reach transportation-related decisions and work to provide transportation as a multimodal service.

1. The state's transportation objectives must be defined as distinct from the transportation objectives of its urban areas.
2. Maximum responsibility for regional and local area transportation planning and programs should be placed at the lowest possible levels of government.
3. The state must identify and encourage the development of institutions through which local determinations relating to transportation can be made. Incentives should be provided through funding and other devices to strengthen appropriate regional institutional capabilities to fulfill these responsibilities.
4. Institutional arrangements should be of a form appropriate to each region. Different forms within a region or subregion should be encouraged where necessary and desirable.
5. The structure of the decision-making process should be clearly articulated and the role of each institution clearly identified. The relation of state, regional, subregional, and local institutions should be developed to facilitate an orderly process of reaching decisions about transportation, including restructuring of current district level responsibilities. Where possible, individual decisions should be made at a single institutional level.
6. Fiscal constraints that may inhibit the freedom of an organization in taking a truly multimodal approach to transportation should be removed at the state and at the federal levels.
7. Multiyear financial programs should be multimodal in nature and should include not only investments in fixed facilities but also options such as operating policies, experiments, and demonstration projects.
8. Consistent with the recommended mission of a state transportation organization, the attitude of all personnel should be one of providing transportation as a "service," not construction or completion of a preconceived system.
9. The relation of highway improvements to other transportation modes should be considered throughout systems and project planning. Both the long-range and short-range impacts of a proposed highway project on the viability of existing or possible future uses of nonhighway transport modes should be predicted. In other words, what options are being foreclosed by implementation of a particular course of action?

Personnel Recommendation

Personnel, promotional, and reward policies should be reviewed and realigned where necessary.

1. New training programs for present and new personnel are required to increase skills in community interaction, impact prediction, and management and to increase the ability of individuals to work effectively as part of interdisciplinary teams.
2. The present system of personal rewards, informal as well as formal, should be reassessed. Service to communities should become a major criterion for advance-

ment, consistent with the proposed mission of assisting communities in reaching transportation-related decisions and in implementing those decisions.

3. Important qualifications for a manager of a project team should be the abilities to manage an interdisciplinary team effectively and to work with community groups effectively and constructively.

4. Career patterns should be developed to provide meaningful advancement opportunities within the agency without requiring individuals to assume management responsibilities. Although opportunities for management positions should not be closed to any person, opportunities for advancement in grade and salary without management responsibility should also be available. The creation of such multiple avenues of advancement would provide promotional opportunities including status and financial reward for those persons who are particularly well qualified in an individual technical area but who do not have the interest or capability to assume management responsibilities.

5. The functional organization should be revised to promote the use of interdisciplinary project teams on all major projects. A single team would be responsible for all phases of project planning through the approval of plans, specifications, and estimates. Where numerous small projects exist, these might be handled by a single subarea team. The team should be located in one physical location to promote intragroup dynamics and communication. Team members should include representatives of various disciplines such as political science and sociology and of functional departments such as systems planning, design, and right-of-way. Personnel can be adjusted with needs; the composition of the team would continually change. Team members are responsible to their respective teams, not to their functional departments.

6. The present engineering-oriented qualifications for project management and for management at various levels within the organization, especially the top levels, should be revised to allow positions to be filled by professionals other than civil engineers. Many of us on the M.I.T. research team are civil engineers, so we believe we can make this recommendation with some objectivity. We see no reason why engineers are more competent to deal with transportation problems than are many other professionals. This is not to say that engineers should be excluded from these important positions, rather that no specific advantage or requirement should be given to those with engineering background as opposed to those with other kinds of professional backgrounds.

FEDERAL HIGHWAY ADMINISTRATION

Since September 1971, M.I.T. has been working with the Federal Highway Administrations' Office of Environmental Policy to develop guidelines in response to the Federal-Aid Highway Act of 1970 [Sec. 109(h), 23, U.S.C., Sec. 136(b)]. Section 136(b) states in part:

> Not later than July 1, 1972, the Secretary [of Transportation], after consultation with appropriate federal and state officials, shall submit to Congress, and not later than 90 days after such submission, promulgate guidelines designed to assure that possible adverse economic, social, and environmental effects relating to any proposed project on any federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for fast, safe, and efficient transportation, public services, and the cost of eliminating or minimizing such adverse effects. . . .

The guidelines will be issued as a policy and procedure memorandum for use by state highway departments in developing an action plan. The action plan is to describe the organization and processes, existing and new, to be followed in the development of federal-aid highway projects from initial planning through design. The plan must be consistent with the requirements of the Federal-Aid Highway Act of 1970, the National Environmental Policy Act of 1969, the Civil Rights Acts, Policy and Procedure Memoranda 20-8 and 90-1, and other applicable statutes and administrative directives. A state's action plan is to address 3 primary areas: conduct of studies, process management, and implementation of the action plan.

The process guidelines are aimed at accomplishing the purpose of Section 136(b) by influencing processes and assignments of responsibility through which federal-aid highway projects are developed rather than by attempting detailed supervision or control of plans or projects or by stipulating rigid technical requirements to be fulfilled. To quote from the report submitted to Congress:

> . . .the guidelines, while requiring that certain questions be answered by the state in preparing its action plan, leave considerable leeway to the states on how they are to be answered. The process guidelines require, for example, that each highway agency develop a procedure and assign responsibility for the early identification of economic, social, and environmental effects, but it will be up to the individual highway agency to determine the way in which these general requirements are to be met. The federal interest will be to ascertain that the response is adequate to the problem rather than to prescribe the form or substance of the response.

The M.I.T. research team has played a major role in the development of these guidelines, including the initial drafts and a number of successive revisions in coordination with the Federal Highway Administration, state and local officials, and representatives of environmental groups. The approach of these guidelines reflects many of the basic principles described earlier.

We have recommended to California that the requirement of the Federal Highway Administration for the development of an action plan be used as a stimulus for implementing the M.I.T. recommendations and other desirable changes to support the state's current planning procedures. Similarly, we recommend to all states that the action plan be used as a unique opportunity to systematically and comprehensively review current procedures, organization, and assignments of responsibility with the objective of ensuring full consideration of possible social and environmental effects, positive as well as adverse, in developing proposed highway projects.

The manner in which an action plan is prepared will affect both the content and the eventual acceptance and realization of that plan.

1. In developing an action plan, the state should examine the total mission, structure, and process of the state transportation organization at all levels of activity from systems studies to decisions at the project level.
2. Priority should be given to the early identification of potential legislation and administrative directives that are required to help an agency more effectively adjust its mission and procedures.
3. There should be wide involvement of an agency's personnel in the process of developing an action plan to promote and stimulate the attitudinal changes that will be required if the organization is to be more truly responsive to social and environmental effects. Those involved in preparing a plan should be selected because they are knowledgable and respected and not simply because they are available.
4. Individuals who will be responsible for carrying out an action plan should be involved actively in its preparation. These people should have a clear understanding of how the changes outlined in a plan will affect the entire organization. They should also command the respect of and be granted the authority to make changes by all who will have responsibility for the new activities.
5. Top level executives from the organization should be involved early in an action plan so they fully understand and support those parts that require changes in legislation or administrative policy.
6. Adequate time and resources should be made available to develop an action plan effectively and appropriately. Individuals involved in the preparation of a plan should be relieved of some other duties so they can devote the necessary time to this activity.

SUMMARY

We have reviewed the theoretical perspective from which we have approached our investigations and its influence on specific practical recommendations to the National

Cooperative Highway Research Program, the state of California, and the Federal Highway Administration. Perhaps the best way of summarizing this discussion is as follows: Effective consideration of social and environmental factors in highway planning and design cannot be accomplished simply by additional paperwork or additional technical studies. Rather, major changes in our conception of our roles as professionals and as public agencies are required to truly respond to the public's concern regarding social and environmental issues.

We must respond to the need for these changes. We have worked closely with many highway professionals in many agencies during the last decade and particularly during the past 4 years. We have been impressed by the number of people in various agencies who perceive this problem and who are thinking, and thinking deeply, about how to respond to it. The highway profession has the capability to do so, provided we recognize the seriousness of this challenge and the depth of response required.

We have enjoyed very much our close collaboration with individuals in many agencies in many states during the course of this research. We look forward to working further with many of them as we all strive as individuals and as organizations to respond to the challenge facing us.

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The opinions and conclusions expressed or implied are those of the authors and the research agency. They are not necessarily those of the sponsoring agencies.

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environmental goals for highway organizations

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I believe we can agree that we hold one assumption in common: Those of us in highway organizations have a deep and an abiding concern for environmental quality. We are all passengers, whether we like it or not, on the spaceship Earth, and we have no choice but to do our part in keeping the ship in working order. It is quite possible that we in highway organizations can make a sizable contribution toward improving the quality of the environment.

Our contribution is primarily made through the manner in which we conduct our operations in the areas of construction and maintenance. In a way, we are experts in a specialized form of land use—land use for transportation purposes. In his Sand County Almanac, Aldo Leopold, the respected wildlife conservationist, stated a concept about land that we should consider: "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."

I would like to suggest three overall goals and some subgoals and functions for highway organizations, and I believe they are in accord with the goals and objectives of others in our society who are concerned with environmental protection.

The goals are (a) avoid any detrimental effects on the environment; (b) minimize detrimental effects on the environment, if they cannot be completely avoided; and (c) enhance the environment whenever it is possible to do so.

The most obvious means of achieving the first goal is to do nothing—build no new highways and make no improvements to existing highways. I suggest that the first criteria to be applied to proposed new construction or improvement is whether it should be done at all. That is the equivalant of the management consultant asking why a function is performed at all before he addresses the question of how to perform it more efficiently.

It seems reasonable to assume that every highway organization in this country has been subjected to the charge of having built a roadway where a minimal need, if any,

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existed. Accordingly, the question of whether a particular project or facility should be undertaken is a valid consideration and is indeed the first question that should be asked by responsible members of a highway organization. The second question is, If a facility is required, are there alternatives available that would have less damaging environmental effects? Alternatives would include other possible modes of transportation. Only after these questions are answered can a meaningful analysis be made of ways to balance the need for mobility against the environmental effects, the social costs, the economic costs—in short, all the complex factors that go to make up a rational decision as to public policy.

The second goal, minimizing the effect of a needed roadway or roadway improvement on the environment, may require a reorientation of many traditional thoughts and attitudes that have influenced highway design, construction, and maintenance. I am thinking, particularly, of the traditional concern for costs of highway construction. In Minnesota highway designers and those in charge of construction have tried to get as many miles as possible for each dollar of tax funds available. Quite often, the results were detrimental to the environment in terms of cuts, fills, destruction of vegetation, upsetting water erosion, and so forth. It is not fair to fault those designers and builders because they were being extremely responsive to the public will, which was to spend as little as possible and get as much road as possible. Only recently has an equal concern been expressed for the environment to be taken into account, even though costs may be increased as a result.

Another aspect of achieving the goal of minimizing environmental consequences is to make sure that the initial investment is adequate to care for needs as far ahead as we can see. Quite often we have not built facilities either large enough or sophisticated enough to really provide the service that is subsequently desired. Improvements must then be made to the initial construction, creating an additional impact on the environment during and after construction. Stated another way, we have support from the public for additional expenditures to minimize the environmental impact of facilities and to provide facilities that can sufficiently serve for longer periods so that disruptions can be avoided.

There is an equal responsibility placed on those who work in departments of natural resources or departments of conservation. They must recognize that people desire mobility and economic growth. Their response simply cannot be that whatever is proposed is going to be bad for the spawning habits of fish, for game production, or for the vegetation in the area. They must join with us in balancing the cost of the detriment to the environment with the desire for a transportation facility so that we can determine the right course of action.

The third goal of having highway programs enhance the environment is entirely appropriate, even though some of our critics would believe such an event can never occur. I am thinking of the enhancement of already built-up, man-made areas, particularly within our cities. A highway facility may provide an opportunity for many individuals to enjoy a parklike facility or a beautiful garden setting.

In this area of potential environmental enhancement, we must assume that we will have a beneficial effect on the environment through technology, legislation, and enforcement relating to the control of emission of noise and air pollutants from automobiles. When those pollutants have been significantly reduced, an opportunity will be provided for highway facilities to actually enhance the urban environment. Although a freeway can split a neighborhood, it can also define and limit neighborhoods into areas that lend themselves to innovative and creative lifestyles that may truly be the wave of the future. Such an area in Minneapolis is the Cedar-Riverside area, often called "a new town in town" by officials of the U.S. Department of Housing and Urban Development, who are extremely interested in this entire project.

I would strongly urge highway organizations to have a deep and compelling commitment to environmental goals, primarily because I think that that is a responsibility of all public servants. Highway department employees are not merely highway advocates but rather public servants engaged in the design, construction, and maintenance of highways. Similarly, employees of state agencies concerned with environmental protection are not advocates for a single group or a single cause but rather public servants who have particular skills and who serve all the people to the best of their ability.

There are some activities in which we who work in highway organizations can engage that will serve our own benefit and better enable us to serve the public. One of these is a willingness to meet with, talk with, debate with, and take part in discussions with those who espouse environmental concerns and social values as their primary interest. In this way, we can contribute to a balance between our desire for mobility and the need to preserve the environment. We should strongly support the efforts of those who are most concerned with environmental degradation and support legislation designed to eliminate the source of detrimental effects on the environment. There are documented instances of ill effects and ill health suffered by individuals as a result of noise and air pollution from automobiles. School children in Los Angeles were not permitted to play outside during certain times of the day, and football players in New Jersey suffered chest pains and respiratory illness directly traceable to these emissions. We cannot make apology for those instances; we should not be expected to do so in our role of serving the whole public.

We should also resist the extreme positions advocated by those who would impose a narrow lifestyle on everyone and those who are self-styled, instant experts on the environment and ecology. I suggest that you read Peter Drucker's article Saving the Crusade in the January 1972 issue of Harper's magazine. He said, "The sewage-treatment plants that are urgently needed all over the world will be designed, built, and kept running not by purity of heart, ballads, or Earth Days but by engineers working in very large organizations, whether businesses, research labs, or government agencies."

Highway organizations and those who work in them should support, and in fact, should initiate contacts and discussions with other departments and governmental agencies at the state, municipal, and federal levels to provide opportunities for training and education of their staff members and to expose them to concerns that are being voiced by environmentalists. Although government agencies should work cooperatively, they do not very often do so and can never do so unless their people talk, meet, and work together.

Specifically, we encourage the development and implementation of land use controls on a wider basis than simply within the rights-of-way that are under our jurisdiction. This, obviously, must and should involve other departments. We also encourage the development of policies and procedures that will permit the early identification and preservation of future rights-of-way so that we can design highways that will not have to be compromised because inadequate land-use controls allowed construction to develop before the right-of-way was protected.

In addition, I would suggest that highway organizations strongly support the centering of overall planning in a statewide agency. Overall planning will have a helpful effect on the transportation planning engaged in by the highway organization.

Our design ability has advanced , and we are learning more about the problems of noise and noise attenuation. We are more aware now of the aesthetic values of freeway construction, particularly in the urban setting. The public seems willing to bear the costs for aesthetics and for maintaining environmental quality. We must be careful that we do not become too specialized in viewing our responsibility as providing highways only and as designing highways to gain the greatest distance at the lowest cost.

Finally, it seems to me that those of us in highway organizations are uniquely qualified to take part in the next phase of environmental concerns. To quote Peter Drucker again, "The time for sensations and manifestos is about over; now we need rigorous analysis, united effort, and vary hard work." The ability of people in highway organizations to engage in rigorous analysis, to bring about united effort, and to perform very hard work has already been demonstrated and will be demonstrated again now with a new dimension—a greater emphasis on environmental concerns.

2 environmental planning process

what is a good environmental statement?

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Will Rogers was in England during a period in World War I when the U-boat had almost completely blockaded the British Isles. One evening he attended a dinner party with many generals, admirals, and lords of the Admiralty who spoke only of vast and expansive plans, broad policies, and major decisions. When the meal was completed and the ladies had withdrawn, he announced, over brandy and cigars, that he had an answer to the most difficult problem of the day, the U-boat. This immediately captured the attention of everyone and Will was pressed for his solution. He said it was simple—"Just heat up the ocean until it's so hot they have to come up, then sink them with the guns of the Royal Navy." "But how would you heat up the ocean?" scoffed a senior admiral. Will answered that he was a policy-maker and he would leave that to the technicians.

Some environmental policy-makers have left the engineers and planners in much the same dilemma that Will Rogers left the technicians of the Royal Navy. We have been called on to protect the environment without always having a clear procedural approach that will produce practical actions or solutions.

Although not formally documented in the past, many measures have been used by highway engineers to minimize harm to the environment. Headwalls and sodding to prevent erosion, coordination and communication with other agencies, and bridging to protect streams and aquatic life are but a few of the long existing practices. The passage of the National Environmental Policy Act has required new documentation; a public statement of environmental impacts is now required for all actions that significantly affect the quality of the environment. Since then, a great deal of effort has gone into establishing procedures to ensure that not only the letter of the law but the spirit as well is carried out. This has been a good development. We hope that our experience has now brought us to a point where the procedures are generally in order and we can turn our efforts to producing quality environmental statements.

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What is a good environmental statement? What information should it contain? The number of answers to these questions is proportional to the number of people affected by a project and the number of agencies that review the statement. The Federal Highway Administration has promulgated procedural guidelines in PPM 90-1. (Other memoranda will contain guidelines for noise and air pollution.) These are supplemented almost weekly by letters from the regional or divisional representatives suggesting inputs of all magnitudes of importance, ranging from those dictated by continuing legal action to clerical considerations such as the type of front cover to be used on the report. Comments from the reviewing agencies are difficult to anticipate, for they vary in many ways.

At times, there is a conflict in the opinions of various agencies, and sometimes a field office that assisted in the preparation of a statement will provide a different viewpoint from that of the central office of the same agency. Central office comments also vary with the background of the reviewer. Some situations call for rather precise comment before a project can get approval by others, such as "the impact that increased population, due to better transportation, will have on the local sewage disposal system." Some comments call for specific highway engineering. Others, such as the air diffusion projections of the Environmental Protection Agency or the corridor location by remote sensor of the Department of Interior or "a highway's acoustical impact on the habits of the dusky seaside sparrow," all call for basic but highly complex research. Problems with other agencies could normally be reduced by an early interdisciplinary involvement in the preparation of the statement.

Most governmental agencies do not have the necessary personnel or resources to support this role and prefer to wait and review the draft statement. The tone and length of the environmental statement are problems. It is a technical document that must be usable throughout the planning, design, and construction phases and stand up to technical scrutiny outside the agency. Yet, it must be clear to the layman whom the project ultimately affects. The environmental statement must address the total impact in a thorough and objective manner and should not arbitrarily group or piecemeal projects in a manner that would tend to cover up matters of environmental concern.

The reviewers from Washington and even those at the regional level indicate that too many statements are being submitted and that these statements contain too much unnecessary information. It is, therefore, very difficult to describe how to write an environmental statement that will satisfy all the diverse and varying requirements. Regardless of experience, it is even difficult to write one environmental statement that will not at some time be termed inadequate in some area. The unfortunate outcome of this whole process is that it easily becomes an exchange of words with little change in the actual environmental impact evaluation itself.

What then is a good environmental statement? It is a statement that

1. Complies with not only the letter but the spirit as well of the National Environmental Policy Act;
2. Follows Federal Highway Administration directives and supplementary instructions;
3. Anticipates and addresses the concerns and comments of other federal and state agencies through an interdisciplinary approach to the project;
4. Not only speaks to what is planned but is a commitment that the environment will be protected throughout the planning, design, construction, and maintenance phases of the project;
5. Sincerely determines and evaluates negative and positive environmental, social, and economic benefits and costs of the project and attempts to objectively weigh these factors as they impact on the final course of action;
6. Is a technical report but is clear enough for a layman to understand;
7. Satisfies the local population that the environmental impact is fully considered and the highway decision is made in their best interest;
8. Addresses the total impact of a project or series of related projects; and
9. Does not burden higher reviewing authority with its diffuseness and verbosity.

What is the answer, then, to these seemingly contradictory requirements? My suggestion is that state transportation agencies develop environmental specifications that stipulate the department's policy and procedures in as many general environmental areas as possible. All concerned state and federal agencies, academic institutions, and citizen conservation groups should provide inputs in the formative stages of this policy. This input should be concurrently evaluated from an engineering, planning, and cost viewpoint; the cost evaluation should include the availability of federal funding in implementation. Then, an attempt should be made to resolve differences and formulate policy. In those areas where general agreement on policy cannot be reached through sincere interagency and public communication, the highway agency must reach its own decision, support its position adequately within the text of the report, and accept whatever the outcome may be.

When these general environmental specifications are promulgated and approved, all people concerned, both within and outside the transportation agency, will know how an environmental situation will be resolved. The environmental evaluation will consist of ensuring that all areas of environmental concern are identified. The environmental statement will briefly refer to the environmental specifications on the points identified, describe any deviations from the general specifications and the necessity for doing so, and discuss in depth those not covered by the specifications. All of this should provide a relatively impartial means to evaluate the alternatives. The various trade-offs discussed and perhaps the final decisions reached should be less vulnerable to the charge of partiality as they would be based on a previously approved and documented doctrine.

The iconoclast H. L. Mencken once said, "To every problem there is a solution that is simple, neat, and... wrong." To save my suggestion from the cynic's judgment, I must point out what a complex and difficult task the proposed specification writing will be. However, a form of policy reference is not entirely new. There are several areas now in the environmental statements where the same standard phrases, in reality, reiterate a form of policy that satisfies most reviewers. In Florida examples are

1. A reference to the right-of-way acquisition relocation plan and its standard procedures;
2. A reference to Section 104 of the standard Florida construction contract that covers burning, sodding, and other construction procedures that protect the social and natural environment; and
3. A reference that the project location has been cleared through the state archaeologist for historical considerations, although perhaps this should be expanded to include the department's informal policy of stopping all excavation when unexpected historical finds are exposed in normal construction.

My suggestion is to try to cover many more environmental areas with decisions already postulated in the form of policies that can be appended to but not made a part of the text except by reference. Also, I might add there is an opportunity right now for this doctrine to be established and approved through agencies of the governor and public hearings as part of the federal action plan requirement.

What is a good environmental statement? Good environmental evaluations should be made by qualified professionals and technicians consistently applying the established policy and specifications of an environmentally oriented organization. Good environmental statements are automatic by-products of good environmental evaluations.

citizen participation and environmental considerations in transportation planning

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The task for those in transportation is to furnish safe and efficient transportation, well designed and planned far enough ahead to allow for future overloads. We are all aware that deficiencies are becoming greater, costs are spiraling, and traffic loads are increasing. At the same time, the public is showing increasing concern for the environment and ecological matters.

A major attempt should be made to analyze those environmental factors that are involved in the building of highways and in the use of the internal combustion engine—factors that, rightly or wrongly, have aroused public concern to the extent that it is impeding the development of transportation programs.

There is no definition of "environment" and "ecology" that satisfies everyone. One's concept of the environment is what it means to oneself, one's family, and one's way of life. Environment means those things that affect our daily lives physically, aesthetically, emotionally, and economically. It may be concern about something as fundamental as enough oxygen in the air or as trivial as annoyance at a neighbor who does not cut his lawn.

Ecology, in simple terms, is the study of living things and their environments. Defining human ecology always involves personal views about the environment.

I have been a conservationist for a long time, but today I call myself a "conservative conservationist." By that I mean that I still like our world but I do not think we are doing well by it. We are going to have to change our approach. It cannot be done overnight, for many involved things are essential, and changing or eliminating them too quickly could have disastrous results.

What does all of this have to do with public attitudes? These things and many others are inherent in public attitudes—a mixture of real concerns, of helpless commitment to our industrial system, of irrationalities, and of a great deal of selfishness. Just about everyone wants to have his cake and to eat it too. We deplore the increasingly bad effects of industrialization, but we still, for the most part, refuse to give up any of its benefits.

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Do you roll up old newspapers to make fireplace logs? Do you make compost of your garbage? Would it be practicable for you to ride a bicycle to work? For most, the answer is no, simply because our time commitments to our specialized work in an industrial nation will not allow us to do those things. Perhaps they may become necessary some time in the future if we continue to add 3 million vehicles each year to our traffic.

In addition to this mixture of fears and attitudes is the universal insecurity of the human race. Americans seem to be worse than others, perhaps because the fluidity of our society makes us more status conscious. We compensate in an infinite number of ways. Some of us paint pictures, some make money, some build highways, some write books, and some evangelize. Our compensations, and those things we need to support them, get all mixed up in the ego with our need to feel important or at least secure.

An unfamiliar thing becomes a threat. It can be a freeway or a dam or a power plant or a new factory. When people feel threatened, their reaction is to fight or flee a confrontation. Whether or not it is based on irrational fears, resistance to change is a trait common to many people. They cannot be sold on the basis of the benefit-cost ratio or the economic advantages to the community from improved transportation. They trade off prospects of increased property values for retention of the status quo. They realize that progress is fine for the realtor and the businessman, but the homeowner who is fairly well off in his present situation will get nothing but increased taxes, congestion, and all the other evils of progress, i.e., a deteriorated personal environment.

In the past century, communities actually came to pitched battles over which one would get the railroad. Today they are fighting to keep the freeway out of their communities.

The public hearing process is supposed to allay all of these fears. If you think it does, you are dreaming. As a public relations instrument, the hearing has long been outmoded. The highway department can still use it as a place to display its wares, but, unfortunately, the opposition also recognizes it as a place to show theirs.

Studies have to be started years before the hearing. If the routing is controversial, the word gets around quickly and the opposition begins to shape up. Those who have sincere objections, the evangelists, the fearful, the selfish, and the environmental and ecology buffs join forces and make up most of the audience at the hearing. Those who have confidence in the plan will be out playing golf. Those who will profit by the new facility will be in their offices figuring out how to make the most profit.

Nor is the hearing a very democratic process. It is more like a court trial where the evidence is heard and the decision is made almost simultaneously. And the public is apt to think the jury was rigged.

California is using a new approach. Instead of letting the community choose up sides during the long process between the beginning of the study and the hearing, the state is, in effect, holding a first hearing at the point of project conception.

California has been a very troubled state. All the attitudes I mentioned and a good many others are present in exaggerated form. Routes long in the planning program are meeting so much opposition that they have had to be canceled. Getting any kind of adoption is increasingly difficult.

The new approach in California of shifting the decision-making process farther forward is the result of several years of effort to find a better means of coping with opposition. Official procedure now is to seek to have local officials at the outset sign a study agreement emanating from a request by either local officials or the state agency.

At that time, the proposed project is opened with a well-publicized public meeting. The point is emphasized that the agreement is only to study and that the study may recommend no action.

If the agreement is signed, the regular study procedure commences as a cooperative action between the state and the local officials. The latter are urged to appoint also a citizens' advisory committee of rational, noncommitted representatives of the community. Collection of preliminary information for the draft environmental statement also begins. One district has carried this even farther by collecting preliminary community environmental factors prior to the study meeting to make the public study agreement meeting more meaningful.

The advantages of this approach are apparent. From the beginning no one is committed to any action, and that goes a long way toward stilling community fears. The agreement meeting for all practicable purposes thus serves as a public hearing years before any route adoption must be effected. In the interim there is plenty of time to air the issues thoroughly in as many neighborhood meetings as are asked for and by other means of communication. Everyone who wants to has a chance to make his feelings known long before a decision is imminent and thus to feel he has had a part in the decision. When most citizens are apprised of the issues this early and their fears are allayed, the dissidents have difficulty in attracting support.

The no-action possibility is also important. Of course, federal instructions at present allow for negative decisions, and some states also have such provisions. But publicizing it can be a very disarming device. The no-action possibility changes the emphasis so that the citizen may say, "Maybe we do need this project." The approach at the study meeting must also be on whether the project is needed and has merit. In contrast, a route-adoption hearing says a freeway is needed and here are some choices on where we want to put it.

The advisory committee is also important. The community must know who these people are and that they are involved in the decision. In California, when these committees have been brought into the process early enough, they have veered from attitudes of opposition to cooperation after they began looking at the problem from inside.

Selecting committee members from the local power structure should be avoided at all costs. If it is not, the predictable result is the formation of a second but unofficial citizens' group with which the highway department will have great difficulty communicating. The committee must be composed of intelligent members whose character and personal interests are impeccable from the community's viewpoint.

Another advantage of California's study agreement procedure is the additional lead time given the community to adjust to a freeway if one is decided on by the study. Naturally, no final route can be selected at this stage, but the community has several more years to get used to the idea.

Citizen participation will not always be the answer. Rapidly changing or expanding communities and highly urbanized areas will always present problems. For the latter, California has carried the procedure a step farther with its transportation corridor studies. These seek to establish the most practicable transportation routes through heavily developed areas in corridors that contain dozens of square miles. The potential route adoptions may be many miles in length, and several communities may be involved. Possible decisions might be that several more freeways are needed or that no more are needed at all because development has already exceeded practicable limits.

techniques for assessing trade-offs among social, economic, and environmental effects of public investments in highways

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In the last decade, the United States has begun in earnest the difficult task of learning to live in an era of unparalleled material abundance. In the search for a rational accommodation to affluence, emphasis at the outset has been on broadening the range of factors considered in reaching public policy decisions and on reordering the relative priorities of factors thus considered. Increasing recognition of the interdependence of physical, economic, and social phenomena has stimulated a search for ways to incorporate the interrelated effects of change into decision-making processes. A dual effort has emerged that includes not only the task of redefining the range and magnitude of effects induced by change but also the related task of developing relevant analytical techniques for illuminating the interrelations of variables associated with change.

The general overtone of the last decade has been one of crisis and frustration: crisis because of the urgency associated with a belated recognition of the cumulative negative impacts of change; frustration because emerging problems have appeared intractable and impervious to rational analysis. The primary impetus underlying the accelerated search for analytical techniques capable of assimilating multiple criteria has been provided by reaction to crisis rather than by rational foresight. As in all crises, a pervasive sense of urgency places demands for information that cannot entirely be met. Although the questions asked are straightforward and logical, the answers are often fraught with a degree of hesitation born of uncertainty about measuring the heretofore unmeasurable.

We have embarked on a redirection of analytical alternatives to public policy evaluation from narrow and traditional approaches to complex new frameworks that call for simultaneous consideration of a wide spectrum of interrelated effects of public policies. Accordingly, it is appropriate to provide some methodological perspective about the analytical dilemma in which we now find ourselves and to indicate some directions that further analysis and research must take if future answers to multidimensional questions

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are to improve in usefulness and quality over those answers now being provided. In an attempt to provide such a perspective, this paper will consist of 3 parts: First, the background and evolution of multidimensional analysis of public policies will be reviewed; second, the current status of analytical techniques now being used to evaluate multidimensional issues will be summarized; and third, the directions and implications for future research will be discussed.

EVOLUTION OF MULTIDIMENSIONAL POLICY ANALYSIS

The evolution of multidimensional policy analysis is a logical outgrowth of the continuing transition from evaluating the policies of scarcity to considering the policies of abundance. The task of learning to live with abundance has been found to be fundamentally different from the task of policy formulation throughout centuries of minimal physical survival. Only as the odds for physical survival improved, at least for the majority of people living in the western world, did it become possible to shift attention to the question of how the level of material progress could be enhanced.

The initial process of material enhancement focused primarily on capital formation limited in scope to physical resources. Capital formation could not appropriately begin until the problem of survival had been resolved, for capital formation, by definition, required postponement of present consumption so that future consumption levels could thereby be enhanced. Throughout the early periods of capital formation, decisions were frequently made and acts committed that in retrospect we condemn as socially unconscionable. The use of child labor and slavery and the exploitation of forests, minerals, and water are examples of historical expedients to accelerate growth through capital formation by whatever means were available.

Rapid rates of capital formation produced 2 significant results. First, the timestream of consumption patterns became radically altered as prospects improved for increasing material welfare over time; and, second, to begin to consider a wider spectrum of effects induced by change became not only possible but also necessary so that future consumption patterns and prospects could be determined more effectively. In short, questions of economic, social, and environmental impact that once were relegated to positions of relative insignificance have emerged as paramount considerations in reaching current public policy decisions.

Accompanying spectacular changes in material well-being through a seemingly endless cornucopia of output has been an increasing crescendo of disquiet and concern about where we are either being led or where we are leading ourselves. From another era, Jeremiah, a harbinger of gloom and doom, might well have been the leading economist of his time (1). "And I brought you into a plentiful country, to eat the fruit thereof and the goodness thereof; but when ye entered ye defiled my land, and made my heritage an abomination."

Perhaps the most significant impact of living in a wealthy society as compared with living in a society dominated by minimal physical survival is the necessity of shifting relatively more attention from the present to the future (2). The reason for this shift of emphasis on time span is that the future becomes relatively more significant than the present in a wealthy society because the primary focus in such a society is no longer on short-run survival. The question of future considerations in a survival-level society must continually be subordinated to the crisis of meeting current needs. In an abundant society, however, rational foresight calls for considering the time span of the effects of past and current decisions. Increasingly, a wealthy society more than a society of short-run scarcity focuses greater concern both on the time distribution of resource use and consumption and on the composition of total output.

In summary, the principal impact of the transition from the economics of scarcity to the economics of abundance is a lengthening of the time span of analysis with relatively greater emphasis shifted from the present to the future. This transition has had an enormous impact on the directions, quality, and capabilities of affected disciplines to deliver answers required by policy-makers as their vision becomes less myopic and stretches farther into the future. It might be uncharitable to say, but traditional methods of analysis appear to have been caught largely unprepared to deliver the answers now expected to complex questions posed by new directions in public policy.

The lengthened time span for public policy analysis has produced an accelerated search for a common denominator for appraising public policy impacts. This search for a common denominator has resulted in a convergence toward a similar theme from a wide variety of disparate disciplines. Increasingly, whether the point of origin be engineering or economics, ecology or sociology, the quest for answers broader than the originating discipline has provided impetus for a broad search for identifying and measuring relevant variables associated with a particular outcome and for evaluating trade-offs among these variables.

When a common denominator was needed to serve as a central proxy for all economic activity, the concept of gross national product emerged. Though factories and highways, ice cream cones and liquor were all counted in different physical units, each entered the mainstream of economic activity through conversion into a central aggregate measure.

With GNP as a central and objective measure of aggregate economic performance, economic-efficiency analysis took on added significance. The availability of a common denominator for economic performance allowed the evaluation of trade-offs to be done with considerably more precision. Economic analysis, in particular, became dominated by efficiency criteria that specified that limited resources must be allocated to produce maximum output. Little attention was paid to constraints on maximizing output or on the quality of the output.

Gradually, however, it became apparent that factors other than the incremental rate of GNP growth were crucial to public policy. Although the concept of GNP was never intended to measure social well-being, increasing criticism has been leveled against it for not doing so. It has also become apparent that no single yardstick can serve as a universal measuring rod for all of society's penalties and rewards (3).

Thus, a search is now under way for new common denominators or analytical approaches that can accommodate diverse multidimensional criteria for assessing public policies. The problem is that researchers are being asked to produce results as if such analytical frameworks had already been perfected. In fact, what we have, as mentioned previously, is a rather fragmented convergence of a variety of approaches, administrative procedures and directives, and analytical techniques, all addressing themselves in a common direction and seeking similar answers.

A possible list of approaches and procedures would include the budgeting process, the planning process, the economic impact analysis, the public expenditure analysis, regional science, and various strands from engineering and sociology. Although many similar answers have been sought from all of these approaches, the specialization and institutionalization of government and various administrative processes have produced varying viewpoints, jargon, methods of analysis, and concepts in each of these areas. Although an economist would reduce this list to the generic category of traditional economic-efficiency analysis, this simplification overstates the traditional differences among approaches followed to achieve various administrative objectives. Although similar types of questions have been asked through all approaches, the compartmentalization of disciplines, the variations in administrative goals, and the narrow frameworks within which the impacts of public policies have been considered have produced answers with as many dimensions as existed in the originating disciplines. Because new approaches to multidimensional analysis call for considerable inputs of ecumenicism, it should not be surprising that some of the initial dialogues are reminiscent of the Tower of Babel.

Regardless of the context within which the effects of a particular public policy are considered, all public expenditures must ultimately be channeled through the public budget. The budget, therefore, serves as a central point for considering diverse public programs. Trade-offs in the budget process are made in terms of additions to and subtractions from various requests for public spending. Only within recent years has supportive analysis for budget requests assumed any degree of sophistication (4). When the range of governmental activities and expenditures was minimal, the level of analytical sophistication required for supporting program funding levels was also minimal.

The budget process initially was one of narrow incrementalism, in which the overriding question usually was that of determining how much it would cost to run a particular program for the next year or biennium.

After national budgeting was implemented in 1921, it took nearly another half century before budget analysis was transformed into a process of specifying goals, evaluating alternative ways of reaching them, selecting the most efficient alternative, and evaluating performance (5, 6). To several generations of budget analysts, legislators, and lobbyists accustomed to viewing tangible line-item sums rather than intangible goals and performance evaluations, such a transformation was met with considerable consternation. The threat of superimposing some degree of objectivity on a system operating through trade-offs among power groups caused new concerns that obscure clerks generating benefit-cost ratios would supplant the elected representatives of the people in terms of policy-making influence.

Despite the difficulties involved in the transition from line-item budgeting to goal- and performance-oriented budgeting, the most significant impact of the transition may simply be that of effecting an irrevocable shift in basic conceptual approaches to thinking about public spending. The process of introducing objective analysis into the public-spending process was in itself no small accomplishment, even though the analysis conducted produced only incomplete or unsatisfactory answers. As one writer has indicated (5):

> What analysis provides is an exercise in logical coherence, hopefully with knowledge of and respect for the underlying technical, economic, and organizational data. Coherence does not insure the "correctness" of policy. In fact, an incoherent policy will sometimes be closer to correct than a coherent one. But the incoherence itself scarcely makes a contribution. It is almost invariably a source of waste, and typically of policy muddles.

Although public expenditure analysis is a subset of budget analysis, research in the area of public expenditures is also conducted for reasons other than those related to budgetary objectives. In the first place, budget analysts have often had an accounting orientation, while economists have had the domain of public expenditure analysis. The emergence of public expenditure analysis is so recent that a brief comment is in order about the late appearance of an area of analysis that would appear to be necessary but that has been relatively nonexistent until the past few years.

Public finance analysis has meant tax analysis until recently. Even recent college courses in public finance usually included only a belated lecture on the mechanical aspects of budgeting and consisted primarily of a review of institutional and economic effects of specific taxes. Although some attempt has been made since the mid-1930's to examine benefits and costs of water resources, few similar analyses of other public expenditure categories were made until the 1960's. Moreover, the focus on most public expenditure analysis conducted by economists has been on adherence to rather strict tenets of traditional economic efficiency analysis. Accordingly, emerging pressures for examining trade-offs among economic, social, and environmental or physical aspects of public policies have strained the existing capabilities of analytical techniques developed within the area of budgetary and public expenditure analysis (7).

Another of the converging approaches to examining public policies is the planning approach. Although the planning approach is a subset of public expenditure analysis, planning is done by people who call themselves planners and who come from a wide variety of disciplines. Thus, the approach taken by planners is more often than not a function of the disciplinary perspective provided by the background of the planner. Moreover, planning has evolved through its own concepts and procedures. Planning originally focused on engineering and design criteria with primary emphasis on the physical environment and on the enhancement and control of this environment. A counterpart focus on physical dimensions of public policy was manifest through the budget process, in which fund appropriators long showed strongly ingrained preferences for the capital budget over less tangible monuments to budgetary wisdom such as human-resource and administrative expenditures. A bridge or a building could be seen and represented as a "wise" use of resources; expenditures on people could not be seen and, therefore, left no cornerstone to judicious use of public funds.

An appropriate distinction between the concern for physical criteria and the concern for other related considerations has been made by Boulding (8):

> If I am going to live below a dam I would much rather have it built by an engineer than by an economist. Nevertheless, the economist comes into the picture perhaps by asking the awkward question as to whether the dam should have been built in the first place.

The term "planning" is still an ambiguous appellation for a wide variety of overlapping, disparate activities, all focused on improving the rational use of public resources in coping with the effects of economic and social change. Planning is seen today primarily as an alternative to chaos and inefficiency rather than as a threat to the operation of free-market forces. Planning received a major impetus in the last decade through rapidly expanding federal matching programs, each of which invariably required some sort of rational plan for spending the money so the feds would feel that the states knew how they would spend the money. Requirements for instant plans placed pressures on the planning profession not unlike the pressures placed on public expenditure and budgeting analysts. In some unknown percentage of cases, planning was seen as a process of producing a document as a necessary step to obtaining federal funds and was not entered into seriously as a continuing process that could be a potent adjunct to rational decision-making. Once the funds were allocated, planning was forgotten as a distasteful waste of funds that could have been spent on tangible program objectives.

As mentioned previously, the magnet drawing all of these approaches together is that provided by the need to develop a method for assessing trade-offs among multiple phenomena or effects of public policies. The ability to assess trade-offs requires forecasting the anticipated absolute and relative effects of the trade-offs. The success of any process of assessing trade-offs, therefore, will depend in large part on the relevance and accuracy of the forecasts. Recent experience with forecasting lends little confidence in our collective abilities to anticipate the future. Moreover, forecasts and data inputs required to produce them have taken on a mantle of political sensitivity and, in some cases, have been overtly interpreted in a political rather than an objective vein.

In summary, several approaches to public policy analysis, including the planning process, the budgetary process, and public expenditure analysis, with various permutations and combinations, have been converging toward a common goal of seeking common denominators for assessing trade-offs among multidimensional effects of complex social, economic, and physical phenomena. Were it not for the fact that planners, budget analysts, and economists have all tried to form the world into their own molds in different ways, these approaches could all be lumped together. The discussion will turn now from broad approaches to specific kinds of analytical tools and shift to an appraisal of specific techniques for assessing multidimensional trade-offs.

ANALYTIC TECHNIQUES FOR ASSESSING MULTIDIMENSIONAL ISSUES

Basically, the task of estimating multidimensional trade-offs consists, first, of establishing individual accounting frameworks for estimating each category of effects crucial to the analysis of a specific policy outcome and, second, of determining some common denominator for establishing objective trade-offs among categories. The experience of the Water Resources Council in developing background work in support of its proposed revised standards for appraising water-resource projects is directly relevant to this discussion. The work involved in developing these standards represents one of the few recent comprehensive efforts to develop multi-account appraisals of public policy.

First, a bit of background is in order. Beginning with the Flood Control Act of 1936, public expenditures on flood control were to be evaluated according to whether the benefits "... to whomsoever they may accrue" exceed estimated costs. As a result of this legislation and as a result of the inherent economic logic of the benefit-cost comparisons, water-resource projects were appraised for nearly 4 decades strictly according to their potential contributions to national economic development, i.e., according to net increments to national income. The initial directive of the Flood Control Act of 1936 was augmented by Budget Circular A-47 (9), the 2 "Green Books" (10, 11), Senate Document 97 (12), and the report of the Special Task Force of the Water Resources Council (13).

The approach of the Water Resources Council represents the first fundamental shift in evaluation standards for public projects in several decades. Originally, the council proposed a multiple-objective framework for assessing costs and benefits of public water-resource investments. These objectives included national economic development, environmental quality, social well-being, and regional development (14).

Nineteen tests of the proposed evaluation standards were conducted by various universities and consulting groups. In each case, the proposed standards were applied to specific water-resource projects. At the completion of the test cases, the council summarized the results and concluded (15, p. ii):

> The tests have indicated that the multi-objective approach to planning is practical. Meaningful results can be accomplished and reasonably uniform comparability in application can be achieved by establishing carefully structured principles, standards, and procedures.

The conclusion reached is more optimistic than the results of most of the test cases warrant. With regard to measurement of environmental benefits and well-being, the council concluded (15, p. iii):

> Environmental benefits were generally given only cursory attention . . . and were reported in rather elementary physical terms. . . . Well-being benefit measurement was also fairly elementary, but there was fair agreement on the types of effects to be measured.

The proposed standards were published in the Federal Register in December 1971 (16, p. 24144), and extensive hearings were held on these standards in the spring of 1972. The objectives defined in the Federal Register as relevant to water-resource planning include enhancement of national economic development, enhancement of the quality of the environment, and enhancement of regional development (16, p. 24145). The procedures proposed for development of requisite information in support of the contribution a particular project should make toward the enhancement of these objectives consist primarily of developing a "... complete display of accounting of relevant beneficial and adverse effects" (16, p. 24145). Beneficial and adverse effects of water-resource projects are to be displayed for national economic development, the environment, regional development, and social factors (16, p. 24146). Beneficial and adverse effects are to be estimated both with and without the proposed project, and recognition is given to the fact that many environmental and social factors can be estimated only in nonmonetary terms.

The conclusion reached here is that techniques for measuring the impact of the separate accounts have not been perfected, to say nothing of the unavailability of techniques for assessing trade-offs among the separate accounts. If we take as a starting point the analysis of the impact of public investments—be they highways or dams—on the basis of national economic efficiency criteria alone, there is even considerable debate over the adequacy of impact models, over the identification and range of costs and benefits, and over the estimates produced by the models. In some cases, such as that of inland navigation standards, Congress has legislated provisions that deliberately prevent federal agencies from determining an objective stream of benefits and costs and, thus, artificially biasing the results against economic efficiency. Recent outcries from those fearing loss of their proposed projects when a realistic interest rate is used for discounting the stream of future benefits are also indicative of the problems involved in introducing objective criteria into the analysis of public expenditures. A further dilemma occurs because "the state of benefit-cost analysis is such that it does not provide a complete analytical framework for evaluating public investment decisions, even if the analysis were conducted with a high degree of precision" (17, pp. 1-3).

A further indictment of the knowledge base against which conclusions are reached concerning impact of public investments on regional economic development is provided by Back (18, p. 1446):

> The knowledge base necessary for developing defensible procedures for estimating the contributions of water projects to regional economic development does not exist. . . . To the agencies that want to construct water projects and to the people who want them, projects are considered economically justified in the absence of definite proof to the contrary.

In transportation analysis, inroads have been made only recently in the quality of estimates developed to represent the economic impact of transportation investments, including highways. Early highway impact analysis consisted primarily of physical land-use analysis, an outgrowth of the premise that highway impact ultimately could be resolved into visible shifts in land use and measurable changes in its value; thus, land use served as the common denominator for assessing economic shifts resulting from transportation investments. Early attempts to estimate economic effects of highways, either directly or indirectly, took the form of "before-and-after" estimates, or what I call the "five-gas-pumps-before and five-gas-pumps-after" method. Many of the early attempts at estimating highway impact were primarily statistical compendiums of data believed to relate in some way to the changed economic activity induced by the highway.

Recently, a major attempt has been made to examine the interrelated economic effects of highways by the use of models that are designed to incorporate interdependent economic effects of new public investments (19, 20, 21). The use of input-output analysis has produced a somewhat more logically consistent estimate of the aggregate economic impact of a specific public investment on a geographic area (22).

The problem with most traditional methods of research is that they are primarily static; they have no time dimension. The cumulative impact of social, economic, and environmental phenomena and effects is a process that occurs over time, and static answers are likely to ignore this cumulative process.

Although we have scarcely solved the problems of estimating separate display accounts for social, economic, and environmental factors, let alone come to grips with methods of estimating trade-offs among the accounts, we must, nonetheless, look ahead and ask what kinds of research techniques are available that can contribute to the solution of these kinds of multidimensional problems. Once increasing numbers of interdependent variables were introduced into the analytical frameworks of research, attempts were made to devise some method that remedies deficiencies of traditional, static models and produces results relevant only to a particular point in time and to the particular circumstances then in existence. The ideal analytical framework would, of course, be a multi-account framework within which each dimension or account would be measurable in comparable units and in which additions to or subtractions from each account could be done so that trade-offs could be assessed.

One approach that appears to warrant careful scrutiny in the examination of multidimensional effects is the simulation technique (23, 24, 25, 26). Simulation involves developing an abstract representation of the way systems function in the real world. The objective of simulation is to understand how the real world functions. Unlike most programming models, simulation techniques are not designed to estimate optimal resource-allocation patterns and are, therefore, relatively free from assumptions and constraints (23, p. 13). Simulation involves a trial-and-error approach to approximating reality; successive efforts improve understanding of the system being simulated.

Simulation offers a constructive alternative to isolated sector analysis. In fact, it can be argued that one of the reasons we have environmental problems is precisely because we have paid too strict attention to specific sector outcomes, without worrying about inter-sectoral effects. As a result, common-property resources have been vastly underpriced, leading to high rates of overuse and culminating in the environmental dilemma in which we now find ourselves.

The conceptual leap from analysis of individual sectors to the murky world in which everything is related to everything else is an enormous leap, and one that many are not prepared to take. Only when the cumulative interaction of economic, social, and physical phenomena over time can be accounted for, however, will it be possible to net out the effects of each class of phenomena and to provide an objective basis for assessing trade-offs. The analytical problem confronting us would be infinitely simpler if it were possible to invent a "quality-of-life index," measurable in terms neutral of the units in which the data were originally expressed. Trade-offs could then be expressed in terms of impact on the overall index. Because such a common denominator does not appear on the horizon, simulation analysis warrants a serious look as a conceptually promising approach to examining impacts of interrelated phenomena over time.

In an attempt to consider the interrelations between ecology and economics, Isard and his colleagues examined 4 basic analytic tools from regional science in terms of their potential contribution to resolving ecologic problems (27). These techniques include the comparative cost approach, the input-output technique, the industrial complex analysis, and the gravity model (27). At the end of their pioneering research, the authors concluded:

> Perhaps the most significant result of this research is the discovery that, by such extension and reformulation, it is feasible to handle jointly, and in combined fashion, both the economic and ecologic systems with all their mutual relationships and interdependencies. . . . The system of linkages governing natural and social phenomena is extremely complex. There are . . . few, if any, systems which are simple. We are operating in a world in which variables are all intricately interrelated. It is for this reason that there are some investigators who avoid empirical investigations because this approach cannot possibly portray accurately and comprehensively the interdependent web of real life.

Following a similar conceptual approach, Kneese and his colleagues developed a model "to study public policies directed toward ameliorating the social inefficiencies created by nonpricing of environmental services" (28, p. 89). The basic rationale for the model is that residuals from resource use patterns can be established through a materials balance general equilibrium model. The authors conclude:

> We see an urgent need to develop more relevant and operational economic models for dealing with pervasive and subtle externality phenomena. A few economists have observed that external diseconomies increase rapidly (nonlinearly) and become more pervasive with economic and population growth, but comparatively little has been done to formulate analytical or normative models based on this insight.

In summary, the evolution of analytical techniques for appraising the impact of public investments has not progressed very far or very rapidly. Preoccupation with short-run crises and with compartmentalized policy problems within narrow spheres of political influence has prevented adequate attention from being placed on the complex interrelations of various phenomena over time. Most impact-oriented research has dealt with a relatively narrow problem in a specific geographic area. Because few alternatives existed, the predominantly descriptive early work was an attempt to gather together under one cover every indicator and data on every possible factor that might have a bearing on the outcome of a particular public policy. The contribution of such studies lies primarily in the role they performed in the transition toward the consideration of economic effects that, in many cases, were not previously considered at all. Such studies contributed relatively little, however, in terms of operational techniques or evidence that could enhance the quality of public planning. Much of the work was ex post facto, which meant that little impact could be made on patterns of public expenditure analysis through the findings of the research.

IMPLICATIONS FOR FURTHER RESEARCH

One of the major theses of this paper is that we are going through a transition in which the economic policies of scarcity are being transformed into economic policies of abundance. The results of this transition include the following: (a) The time span for public policy analysis must necessarily lengthen as short-run contingencies become less crucial and as long-run cumulative impacts of change become more crucial; and (b) analysis of the effects of public policy must become increasingly multidimensional, and analytical approaches must increasingly take into account a widening range of economic, social, and physical phenomena.

The fact that analytical techniques have not been perfected for measuring relevant physical, economic, and social phenomena and for assessing their trade-offs should not concern us so much as should the directions that current research and planning efforts are now taking. Provincial, single-interest objectives must give way to comprehensive analyses in which simultaneous consideration is given to a complex array of effects of public policies. This task will not be easy, either conceptually or operationally. Many disciplinary purists argue that the net result will dilute the rigor of analysis and produce ambiguous answers devoid of meaning. This argument, it seems to me, misses the point: The point is that policy-makers are requiring administrative agencies to incorporate multidimensional criteria into their decision-making frameworks, whether academic purists like it or not. As, step by step, our comprehension of real-world systems improves, and as our ability to approximate or simulate real-world behavior continues to develop, the role of objective analysis in public-policy discussions will continue to grow.

It seems to me irrelevant to overly concern ourselves with assessing blame for not being able to cope with multidimensional problems any better than we now are. The fact remains that narrow agency goals result from specific administrative and congressional mandates and that the resultant view of the world and its components is often restricted to single-dimensional effects. How this process will change is not quite clear. Just as in the case of a pure public good, in which no single individual would pay for it for he would benefit from the good anyway, there is little incentive for a single agency to bear the cost of analytical work that does not impinge directly on the operation of that agency.

Moreover, the politics of reaction, rather than foresight, hardly lend much support to a future-oriented research framework. Initial attempts to consider environmental factors, for example, often take the form of insurance policies; i.e., an attempt is made to make sure that the agency is covered from every direction by having taken into account every possible source of complaint and every possible effect. Thus, current environmental analysis often takes the form of checklists, in which every possible contingency is allowed for.

There is another problem that must be mentioned: Evaluation standards require some yardstick against which effects can be compared and against which performance can be measured. In the case of national transportation policy, no clearly articulated set of goals exists. The completion of the Interstate System was a goal that could be clearly understood. But highways are a means to other ends, and not ends in and of themselves, just as in the case of all other transportation facilities. Most national policy statements tend to be ambiguous and nonoperational, or they would never pass over opposition.

In conclusion, considerably more attention must be given to substantive research efforts designed to come to grips with the issues discussed in this paper, namely, the identification and measurement of relevant economic, social, and environmental effects and the development of methods for assessing trade-offs among these effects. Single-dimensional, short-run crises must continually give way to a lengthened time span of analysis in which the future progressively becomes more important than the present. Attainment of these objectives will depend primarily on whether this point of view gains ascendancy among decision-makers confronted with making multidimensional appraisals of public policies.

Tunnard and Pushkarev (29, p. 159), in a landmark volume on problems of design in the urbanized landscape have concluded:

> The highway as a cultural asset is long overdue for consideration in the United States. . . . Everyday we are missing opportunities to bring this beauty into our daily lives, an increasing proportion of which is spent on the highway—going to work, going to play, shopping, or going to school. Who knows? Familiarity with the mediocre, dull, or downright ugly in our travels may in future be as detrimental to the American Spirit as the in-city slums which we are now all committed to remove.

And finally, this quatoation from Mumford, one of America's most articulate spokesmen for environmental considerations in highway and urban design (20, p. 236):

> Perhaps the first step toward regaining possession of our souls will be to repossess and replan the whole landscape. To turn away from the processes of life, growth, reproduction, to prefer the disintegrated, the accidental, the random to organic form and order is to commit collective suicide; and by the same token, to create a countermovement to the irrationalities and threatened exterminations of our day, we must draw close once more to the healing order of nature, modified by human design.

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the "no-build" alternative: what it is, why it is necessary, and how it can be handled

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The "no-build" alternative represents vastly different things to different groups and individuals. To those outside the highway agency, the no-build alternative is uncomplicated. It merely means not adding more pavement to the surface of the earth. The advantages include forcing the development of transit, discouraging the purchase of additional automobiles, and preserving environmental values.

Those of us who work within the highway agency perceive the problem to be much more complex. For example, if a section of highway is deteriorating structurally, is carrying traffic volumes in excess of its capacity, and has a poor safety rating, can we accept the no-build alternative? Since the highway agency has the responsibility for building and maintaining highways, it must at least maintain the structure of the highway in an adequate condition. Thus, the no-build alternative could be thought of as normal maintenance of a surface so that automobiles are not destroyed and safety is not decreased.

In many cases, the no-build alternative consists of maintaining a 2-lane highway in a satisfactory condition so that it provides the function for which it was originally designed and constructed. However, because many highways resulted from incorporating original land service routes into the state and federal-aid systems, that option may not represent a rational alternative. Routes of that type often have extremely poor vertical and horizontal alignment, have narrow free-access right-of-way, and were constructed far below existing standards. Their normal maintenance would not result in a highway facility that the highway agency has a statutory responsibility to provide.

It could reasonably be accepted that reconstruction of such a facility to modern, safe, and structurally adequate standards without increasing capacity would be consistent with the philosophy of the no-build alternative. However, in many cases, existing traffic volumes are greater than the facility can handle except at the lowest levels of service. If the highway agency reconstructed the facility at the same capacity, it would not adequately handle existing traffic, let alone encourage increased volumes.

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The highway agency may decide to increase capacity on the facility without altering the basic characteristics of the highway in terms of its structural design and limitations on access, i.e., reconstruct the 2-lane highway into a multilane highway but not a controlled or limited access or divided facility.

Our experience shows that most people consider one of those alternatives, rather than actually doing nothing, to be the no-build alternative. Agreeing on just what the no-build alternative really is is less difficult than agreeing on the necessity of its consideration in the highway planning process. Philosophically, that consideration relates to how highways benefit all of society and not just the highway user. A proposed highway would be viewed with regard to how it fits into the whole social, environmental, and economic fabric of a community and would not be based on a single objective of providing service to the highway user.

Achievement of that objective requires full participation of a wide range of community groups and interests. Community involvement will bring a variety of divergent priorities and values to the highway agency. To achieve a beginning of agreement will require a common and accepted base from which to assess the benefits and losses that will derive from the proposed project. That base is the evaluation of the do-nothing alternative.

An objective assessment of the existing condition of the community and its transportation resources and of the need for improved facilities provides the starting point for evaluating the trade-offs among the social, environmental, and economic values that will result from either building or not building a proposed highway.

Identifying and evaluating the trade-offs are the best ways of setting forth the actual costs and benefits of a proposed new facility. That process provides a mechanism for determining the external diseconomies that will result from the project. The diseconomies of a highway project that are paid for by the loss of social and environmental values provide the major concern of many groups and individuals. The identification of the potential diseconomies of each alternative can contribute to the selection of the most palatable alternative compared to the do-nothing base.

Any of man's activities have an impact on the environment. An alteration to the environment that adversely affects natural balance, reduces diversity, or affects behavioral stability must be considered a negative impact. Changes that reduce the quality and enjoyment of life or endanger public health are negative impacts. Negative impacts to the environment must be balanced by gains, but we must also answer the question, Who benefits and who loses?

The base for all of those evaluations is the existing condition and the comparison is with the do-nothing alternative. From that point we can establish the increasing losses over time that will result from not building the project. Most important, the no-build alternative must be looked at as a positive decision-making tool and not as an antihighway attitude or a desire to protect the status quo. When we consider it as a method for determining the actual need of a proposed facility, we will be better able to justify needed projects and eliminate unneeded ones.

As part of that positive approach, the question of benefits must be placed on a scale consistent with the overall impact on the environment. For example, we must recognize the significant improvement to the standard of living and the quality of life that has resulted from improved transportation. The entire food delivery system, developed for a highly urbanized society, is dependent in great measure on the level of transportation service. The life style of large segments of our population is largely based on highway transportation. Those factors as well as the specific benefits and losses resulting from the project itself must be weighed.

The no-build alternative implies an evaluation of existing conditions; a projection of existing conditions based on the best available information on population increase, density, and location, the availability and use of resources, and the conditions of the environment resulting from available transportation; and a comparison of the existing and projected situation after the improved transportation system is provided.

Functionally, that process is more easily proposed than implemented. Few major projects being considered are independent of a long-range system plan. The result is often a shallow, pointless discussion of whether a vital link in a system of highways should or should not be built.

From a system standpoint, then, there can truly be a do-nothing alternative. The alternative is based on additions to a system or the development of an additional system. For example, in the southeast Michigan region, the comprehensive transportation planning process has developed a regional freeway plan. The system is currently not completed, but already additions to the system are being proposed, primarily by local governments who are beginning to foresee additional problems developing as a result of existing and projected land use. The no-build alternative from a systems basis would mean that additions beyond the proposed and accepted system would be considered in terms of the overall impact of the total proposed additions to that system. Links within the system would necessarily be evaluated on not only benefits and costs of the project but also impact on all parts of the system. During the evaluation of other links within the system, losses were balanced by overall benefits provided by the highway system and not merely by the individual projects. Not to build a key link in a system may increase the losses absorbed by other areas and decrease the benefits.

None of my remarks should be construed to mean that, if a project is part of an approved system, it should not be subjected to a rigorous no-build alternative analysis.

Although the systems approach is more consistent with regional and community planning, many projects do not fit into that context. The analysis is no less important for those projects. The 3-stage approach set forth in the beginning of this paper appears to be the most reasonable mechanism for considering the no-build alternative on individual projects.

In summary, the no-build alternative is the essential base for considering all other alternatives and for establishing the trade-offs that the community will be required to accept if the project is built. The most practical time to evaluate the do-nothing alternate is when systems changes are anticipated. Often that is not possible, and projects must be evaluated individually.

3 preservation of recreational, natural, and historical values

case study of the milwaukee-green bay interstate corridor location

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In October 1969, the Wisconsin Division of Highways contracted with the Environmental Awareness Center of the University of Wisconsin's Department of Landscape Architecture to develop a computer program to be used in the corridor location study for the proposed Interstate highway from Milwaukee to Green Bay. The expertise of the Awareness Center was also to be an integral part of the corridor selection process carried out by the Wisconsin Division of Highways. The purpose of the computer-oriented selection process is to simultaneously weigh the social, economic, and environmental factors of a large area to determine the most acceptable corridor for a transportation facility.

The staff of the Awareness Center decided to take advantage of similar work being done by the Department of Landscape Architecture and the Laboratory of Computer Graphics at Harvard University and by Steinitz Rodgers Associates of Cambridge, Massachusetts. Grid, a computer evaluation and graphic display program, was purchased from Steinitz Rodgers as the basic component of the process.

The first step in the process was the development of a data bank capable of providing a quantitative and qualitative inventory of existing and future resources throughout the total study area of approximately 4,500 square miles shown in Figure 1.

The data bank was developed through a reference system based on the universal transverse mercator projection, the reference system employed by various federal agencies for high altitude and satellite imagery data collection. The use of this system allows for future data maintenance from the imagery of the earth's resources technical satellite, which is intended to provide data every 18 days for the entire state of Wisconsin.

The basic data storage unit, as defined by this project system, is a 1-km square or cell of which there are more than 9,000 in the study area. Each of these cells contains 247.5 acres. A list of data items to be quantified within each cell was developed by the staff of the Awareness Center. The items were intended to be general in nature and responsive to the existing Wisconsin landscape, availability of information, and

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practicality of being measured over a large study area. Other constraints were that the structure should allow for updating and revision and that each item should be maintainable. Originally, there were 130 data items basically structured as follows: (a) Natural characteristics including hydrological, ecological, physiographical, and pedological systems; and (b) cultural characteristics including existing land use, projected land use, population distribution, and communications systems. In addition to these basic items, others can be generated by the computer program. For example, the orientation or direction of a stream was determined within a cell by searching adjacent cells for the existence of the stream.

The data were extracted from various special purpose maps and aerial photographs and converted to dimensional units for computer input. This particular phase was the most time-consuming part of the entire process, and a more sophisticated data extraction process using modern remote-sensing technology would be necessary for studies of a large area and a long time period.

Once stored within the computer, the data are readily accessible and can be displayed in various formats that show the percentage of agricultural land in each cell, the type of ecological system, and the type of water.

The first step in determining the importance of each data item on a highway corridor location was categorizing the necessary social, economic, and environmental criteria to be considered. These determinants or factors affecting location were developed through the combined efforts of staff members of the Awareness Center, Wisconsin Divisions of Highways and of Planning, and the Federal Highway Administration. The members of the study group found little difficulty in consolidating their thoughts into the 9 corridor determinants listed below:

1. Least engineering difficulty,
2. Least cost of construction,
3. Least cost of acquisition,
4. Projected traffic generation,
5. Least impact on the cultural system,
6. Least impact on the ecological system,
7. Least impact on quality of agricultural lands,
8. Greatest scenic potential, and
9. Least impact on potential recreation and conservation lands.

Sufficient data were not readily available for adequately defining determinant 4. Consequently, it was not used in the final analysis. A tenth determinant, greatest potential for development of joint communication corridors, was added later in the study.

These determinants and the data items were arranged in a working matrix that was used to group the variables (a single variable will frequently be assigned to more than one determinant) into broad influences commonly used in highway location studies. Within each determinant, the variables were weighted relative to each other based on the significance of the resource indicated and the anticipated impact by the proposed facility. This grouping and weighting process was carried out by the composite study group. As anticipated, it was much easier to weigh variables within those determinants associated with dollar cost than those associated with cultural values.

To represent various viewpoints or opinions, relative weights were then assigned to each determinant; each combination of weighted determinants formed an alternative. For any alternative selected, the computer analysis resulted in a numerical expression of appropriateness for a highway corridor for each cell. This value is based on the quantity of the various resources in a cell and the weights assigned. Ten intermediate increments of the total range of the values obtained were assigned symbols varying from dark for low values (more suitable for locating a highway) to light for high values (least suitable). These symbols were then printed out providing a graphic display of suitability for highway location as shown in Figure 2, an alternative with all determinants weighted equal. The most desirable location for the proposed highway corridor, based on this methodology, is one passing through the darkest shaded cells. A computer program was developed later in the study to select the continuous series of cells between

Figure 1. Study area of Interstate between Milwaukee and Green Bay.

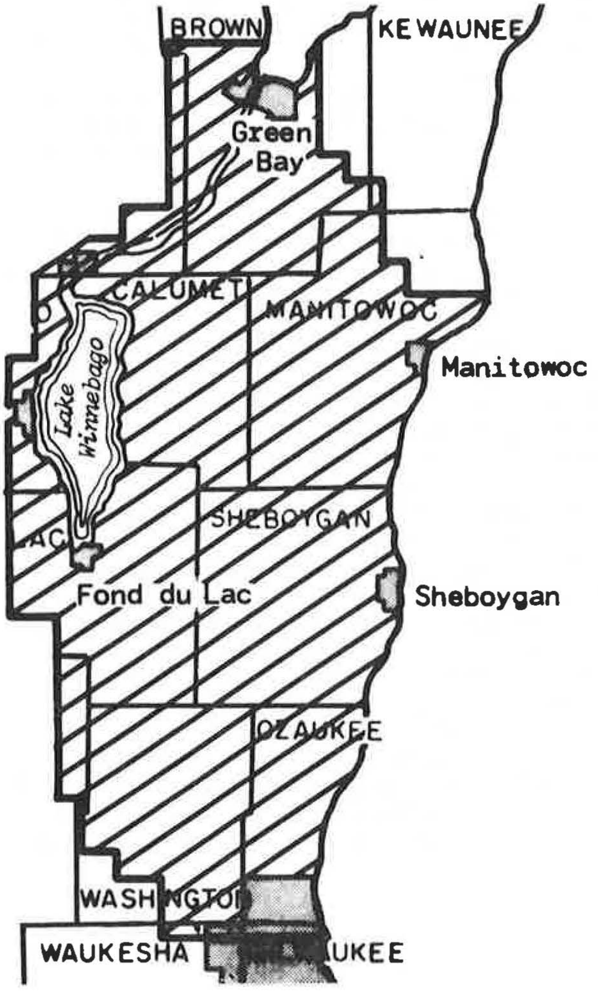
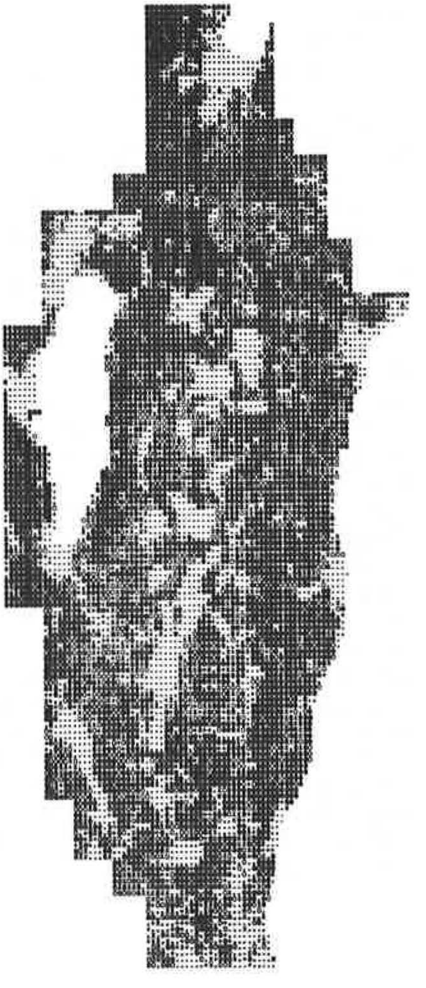


Figure 2. Equally weighted corridor determinants without demand.



termini that would minimize the potential impact based on the numerical values of the cells.

Although total acceptance of the corridor location defined by the computer is not yet practical, several incidental portions of the computer process proved valuable as input to these studies.

A computer-based storage and retrieval system is essential for handling the many data items involved. This particular data storage system provides the flexibility of obtaining a data inventory for any group of cells within the entire study area. This means that many varied data comparisons are possible. The quantity of any resource within a particular corridor can be compared with that of the entire corridor area or with that of any other corridor or area. A particular corridor can also be subdivided by political boundaries, making possible a separate analysis of the corridor by county or city.

The process of determining the proper location for an Interstate highway involves considerable input to the corridor study. Added emphasis to the depth, diversification, and documentation of the study was necessitated by considerable public interest and anticipation of the preparation of an environmental impact statement. The data-handling ability of the computer program proved to be a useful tool in the corridor studies. Computer printouts were readily available for inventorying resources throughout the study area, and their formats were useful in presenting data in the environmental statement. General areas of incompatibility were quickly identified, thus limiting the areas where more detailed studies might be made.

The application of the computer also provides the capability of simultaneously considering many variables as location parameters. This ability is becoming increasingly important as the highway location process becomes more complex and is influenced by interdisciplinary studies. It is only as good, however, as the weights that are assigned to the variables. Proper weights can only be assigned by individuals who have an understanding of the nature of the data items, the format by which they are input to the program (such as predominant type or percentage of cell), and the program itself. If they do not have this understanding, the values intended will not be reflected in the final output.

The use of this process for providing an indication of the environmental impact is also dependent on the assigned weights. This system is not a vehicle for determining how a highway affects the various resources in its vicinity. Studies and research on these effects are a necessary input to the weighting process. Even then, the indication provided is only that of the potential impact because the data are at a 1-km scale. The existence of a resource within a cell is not specific enough with respect to the final highway location to completely define the impact. This would indicate that additional studies are required to better define the actual anticipated impact.

The use of advanced remote-sensing techniques would greatly simplify the most time-consuming portion of this type of corridor selection process: data gathering. If an acceptable and efficient remote-sensing system were developed, the data bank could realistically be expanded to include the entire state of Wisconsin and would make the use of this process for any proposed land use relatively simple. Quick computer-oriented data inventories and area comparisons could be produced for all agencies attempting to determine the impact of a proposed land use on the environment.

The use of this computer-oriented selection program has proved to be an effective tool in the corridor location process. Additional flexibility and program development will substantially enhance its effectiveness. Practicality can be realized, however, only when large-scale application is employed through the effort of many agencies on a joint basis.

computer-aided transportation corridor selection in the guelph-dundas area of ontario

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Society, at least a considerable segment of it, has changed its views concerning the role of transportation in determining the quality of daily life. For example, an ideal highway location was defined recently as "a path of maximum social benefit at least social cost" (3). Professional planners and engineers must respond to these concerns. They must be able to present and defend their proposals not only in terms of the traditional cost-benefit studies but also in terms of aesthetics and environmental effects. Such considerations add complexity to the traditional techniques. Time and manpower limitations dictate that the traditional planning procedures be revised and improved.

A number of procedures have been developed to aid the planning engineers in handling the increasing complexity of the location problems. Graphical analysis procedures and computer-aided methods represent the two most widely applied methods.

GRAPHICAL METHODS

The graphical procedures have some considerable attraction. A by-product of the techniques is the production of several map overlays that can be exhibited during public hearings and that will explain to the public the reasoning used by the planning agencies. Production of the map overlays is a manual operation that can be handled with equipment and personnel in many engineering offices (1, 3, 4, 5).

On the other hand, production of the overlays is a time-consuming and expensive process. In cases where large numbers of factors are involved, large numbers of overlays are required. The graphical technique may not speed up the planning process in such cases. Bias is possible, for it is rarely practical to revise the overlays and test the effects of these changed concepts on the selection of the corridors. Subjectivity seems certain to enter into the analysis, during either the combining of the overlays or the weighting of the routes chosen. Finally, to emphasize the importance of one factor or group of factors in any certain or consistent way is seemingly impossible.

Sponsored by Committee on Photogrammetry and Aerial Surveys.

COMPUTER-AIDED METHODS

Computer-aided regional location methods contain greater flexibility than the graphical methods. Rather than the values of a series of factors being mapped manually in gray scales or color scales, the models are stored in numerical form as matrices within the computer. If the models are described in terms of codes that represent natural or cultural conditions, values can be assigned and numerical "cost models" can be constructed that correspond to the graphical gray scales. However, these numerical models can be rapidly and economically modified by simply changing the values assigned to the various condition codes. The engineer is thus free to modify the various factor overlays as often as he desires. This is the first major advantage of the computer-aided procedures.

The computer-aided methods also have additional advantages. For example, the various factor models represent data banks that can be used for any number of purposes for which information on the environment of an area is required. The data banks can be revised and updated as new information becomes available, probably more easily than can the graphical overlays. Furthermore, the various numerical cost models can be analyzed, by minimum path techniques, for example, to produce a ranked series of alternatives. Although these rankings must be reviewed by the engineer in charge of the project, they are a valuable source of information on the alternatives generated. Finally, numerical models allow the engineer to combine them in known proportions, by means of weighting factors, so as to emphasize certain factors or groups of factors. This capability is not available in the graphical methods. For these reasons, the computer-aided methods are the subject of this report (2, 6, 7, 8, 9).

USE OF GCARS IN THE GUELPH-DUNDAS STUDY

An operational computer-aided corridor selection system, the Generalized Computer-Aided Route Selection System (GCARS), was available. The Canadian government had initiated the Canada land inventory program in 1961, and preliminary results were available for several areas in Ontario. Increasing demands for more sophisticated data analysis in route selection were becoming evident.

Thus, it seemed appropriate to apply GCARS to new data sources in a southern Ontario test area in order to evaluate and test the capabilities of such types of analysis. The Guelph-Dundas area was chosen because it was accessible, was representative of much of rural southern Ontario, contained a good variety of conditions within a compact area, and was an area of current interest to the Ontario Department of Transportation and Communications.

GCARS was developed at Purdue University between 1966 and 1969 as a research and teaching tool to analyze and demonstrate the potential role of the computer in the regional planning field (7, 8, 9). The early concepts and experiments were based on the premise that transportation corridor selection includes some operations that involve judgment and some that are merely routine. Therefore, it seemed that a man-machine interactive system would allow the engineer to exercise his judgment to its fullest and the machine to perform all the necessary calculations. The results of these early experiments were sufficiently promising to cause the development of more sophisticated versions used in this study.

Figure 1 shows the basic concepts of the system. Appropriate mathematical and statistical methods are applied to some basic information for each factor in order to develop numerical cost models. These models are shown as solid 3-dimensional surfaces in Figure 1, whereas in actual practice they are stored as matrices within the computer.

Desirable routes will follow the valleys across such cost models. The most desirable combines directness and low elevations so as to obtain the lowest total cost. Less desirable routes follow other valleys and pass over the intervening high cost areas. Sometimes such alternatives are shorter than the first choice and, although they have a higher cost per unit length, may be more desirable. Thus, the various choices should be compared in terms of overall length and total cost.

If a grid network is laid on such cost models such that each link in the network is assigned the cost of traversing it, minimum path analysis will discover the optimal path. Preventing the further use of the links forming central portions of the chosen path and reanalyzing the revised network will produce a second minimum—a second best alternative. Repeating the process will allow the generation of a ranked series of alternatives.

Figure 1 also shows that models for several factors can be superimposed and summed to produce cost models for any desired combination of factors. Before summation, each model can be multiplied by a weighting factor and thus be enhanced to any desired degree. Repeated minimum path analysis on networks derived from such combined models will generate a series of ranked alternatives in terms of combinations of factors.

GUELPH-DUNDAS AREA

The Guelph-Dundas area is approximately 7½ miles wide and 20 miles long and is oriented northwest-southeast. It lies northwest of the city of Hamilton in southern Ontario and extends from the lip of the Niagara escarpment just north of the town of Dundas in Wentworth County to southwest of the city of Guelph in Wellington County. Figure 2 shows the location of the test area.

The area has a variety of topography, geology, soils, and land uses. It was extensively glaciated in the recent geologic past.

In the southern portions of the area (in this discussion the Dundas end of the test area is the southern end, and the Guelph end is the northern end), the topography is quite flat; silty and sandy soils were formed from glacial lakes overlying the dolomite bedrock at shallow depths. These are interspersed with some silty glacial till that forms a series of low terminal moraines. Farther north, the soil becomes extremely thin so that over many areas the bedrock is essentially exposed at the surface. In the same area there are several groups of drumlins. Their axes lie almost true east-west at about 45 deg to the long direction of the test area. They range between 25 and 100 ft high.

Beverly Swamp, an extensive swampy area, lies between the drumlins and the first of a series of glacial moraines that cross the test area. The swamp is caused mostly by poor drainage into the near-surface bedrock. Peat and muck materials are rarely more than 6 ft deep and do not pose a major obstacle to construction. However, the area is valuable for wildlife breeding, and its preservation is of considerable concern to many persons in the region.

Three moraines that cross the area are, from south to north, Moffat, Galt, and Paris. The Galt and Paris moraines essentially merge around Puslinch Lake and to the east are separated by an outwash plain (composed of sand and gravel), which ranges up to about 2 miles wide. Another outwash plain lies to the north of the Paris moraine and extends to the Speed River, which lies just outside the limits of the test area. Many eskers and kames and several kettle lakes and minor muck pockets are associated with these moraines. Most of the moraines are sandy till, but several sections are sandy or gravelly.

The area was developed for agriculture by settlers around 1800, but much of the area is not ideal for farming because the soils are too thin or the topography is too rough. Only about 50 percent of the area is currently being farmed. Most of the farmland is used for beef and dairy cattle pasture, but important acreages are used for raising hay and corn ensilage for winter feed.

Some quarrying of the dolomite for construction materials has been undertaken in the southern part of the area. Sections near the edge of the Niagara escarpment and around some newly constructed or proposed reservoirs have been designated as recreational sites. Wildlife refuges and conservation areas have been set up or are proposed for several sections. The largest of these surrounds Beverly Swamp. Figures 3, 4, 5, and 6 summarize some of the conditions in the area. The data used for building the GCARS models were obtained from much more detailed maps as discussed in the following sections.

Figure 1. Basic concept of GCARS.

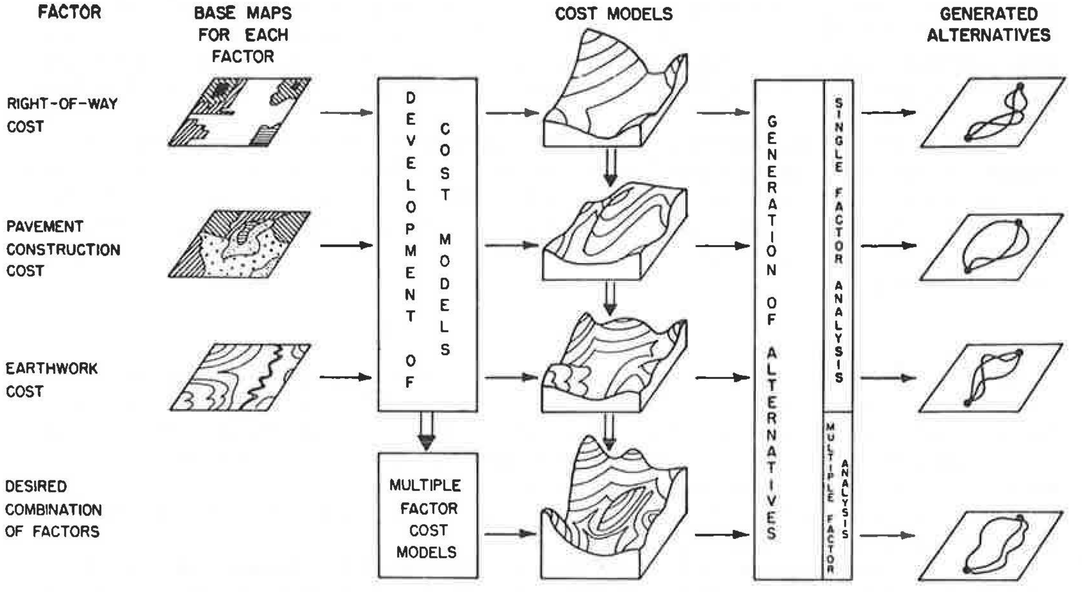


Figure 2. Guelph-Dundas test area.

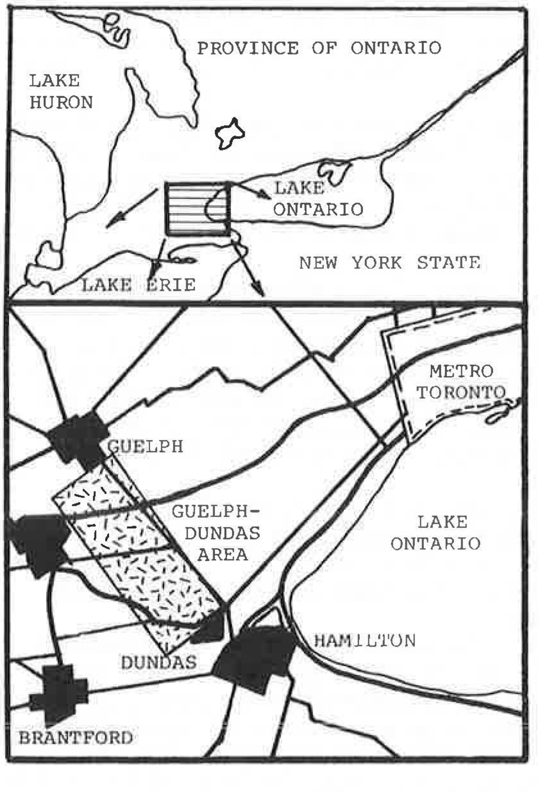
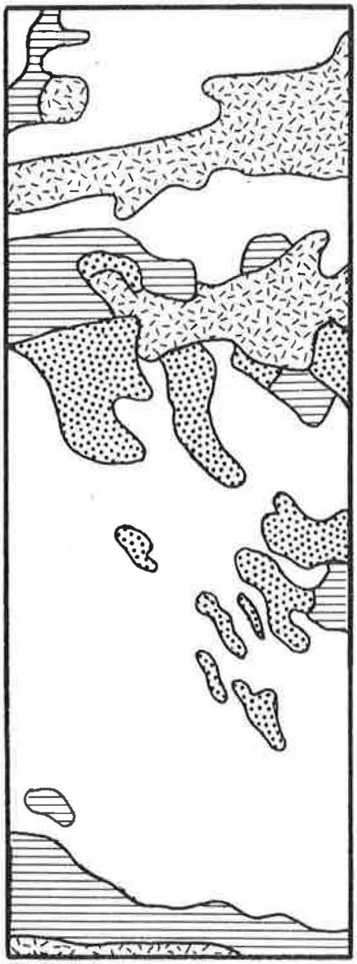


Figure 3. Topographic conditions.



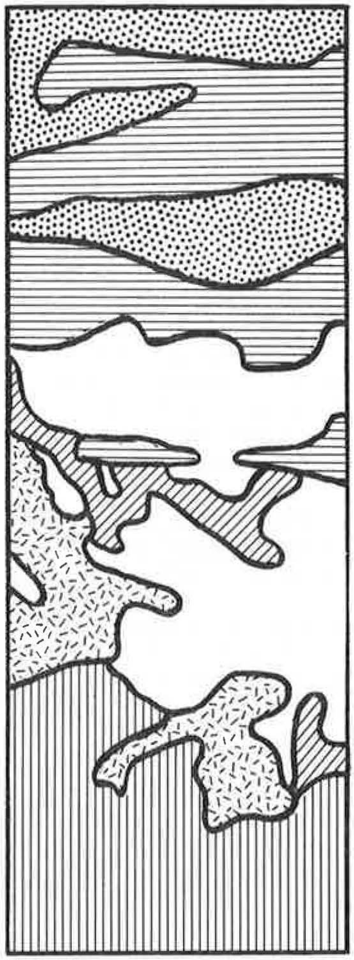
Broken Topography

Hilly Topography

Rolling Topography

Flat Topography

Figure 4. Surficial materials.



Outwash Sand and Gravel

Sandy Moraines

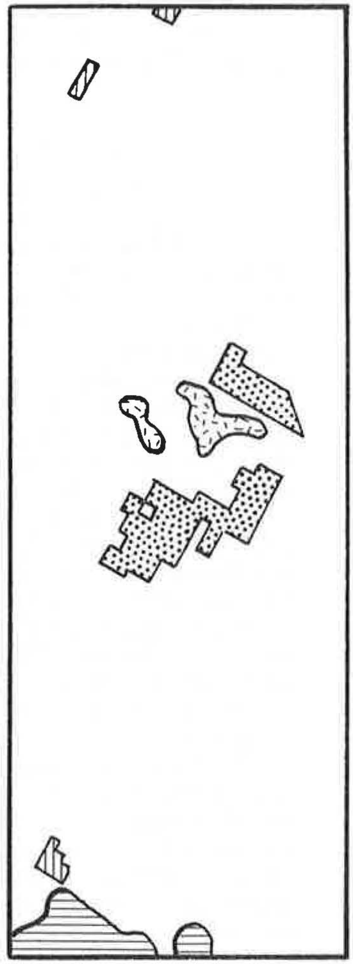
Till Plain and Drumlins

Thin Materials on Bedrock

Lacustrine sands, silts, and clays

Swamps

Figure 5. Recreation capabilities.



Present Park Areas

Potential Parks

Present and Proposed Reservoirs

Areas Classified as having high Recreation Potential

DEVELOPMENT OF GCARS FACTOR MODELS

A primary goal of the Guelph-Dundas study was the evaluation of environmental and social factors. The choice of factors was governed to some degree by the availability of data. It was decided to investigate a new potential data source: the Canada land inventory.

Canada Land Inventory

In 1961 the Canadian government passed the Agricultural Rehabilitation and Development Act that initiated a cooperative federal-provincial program to develop the Canada land inventory, a comprehensive survey of land capability and use. It includes information on present land use and assessments of land capability for agriculture, forestry, recreation, and wildlife (11, 12, 13).

Data are collected by provincial personnel and are generally recorded on 1:50,000 topographic base maps. The federal administration is responsible for overall coordination, establishment of national classification standards, and publication of final results. Data shown on 1:50,000 maps will ultimately be replotted on 1:250,000 scale colored regional maps, which will be sold to the general public. However, it is possible to obtain, by special request, copies of the more detailed 1:50,000 maps for use in highway location studies.

On occasion the provincial authorities expand their classification schemes to make them more detailed than the national classifications. For example, the Ontario wildlife classification uses 13 animal categories, and the national classification uses only 2 animal categories (13).

The capability inventories belonging to the Canada land inventory have certain standards in common. All utilize a 7-class rating scheme, where class 1 represents the ideal, class 7 the worst, and class 4 the average conditions. An area mapped as a single class includes those regions having "the same relative degree of limitation or hazard" (12).

Subclasses represent those regions having "similar kinds of limitations or hazards" (12) and by their letter codes are intended to convey the reason for an area being classified as less than ideal. Class 1 areas by definition do not need subclasses. The Ontario wildlife inventory shows the ultimate wildlife capability of each area according to class and natural limitations (subclass). It also shows a degree-of-effort rating, which represents the amount of effort and cost required to bring the area from its present state to its ultimate capacity (13).

The highway engineer is responsible for identifying and avoiding as much as possible those areas having superior capabilities for any resource and environmental factor. Construction of a highway inevitably causes some changes to preexisting conditions. If the road can be located on land marginally useful for agriculture, recreation, forestry, or wildlife, the improved accessibility may serve to improve the utility of this land for other purposes while protecting the more desirable areas. Thus models of the resource and environmental factors for use by GCARS need only identify and classify those areas having above-average capabilities. Accordingly, some simplification of the Canada land inventory classifications was possible.

Chosen Models

In addition to the Canada land inventory, topographic, geologic, and agricultural soil maps and air photographs were available for the entire area. It was ultimately decided to develop and evaluate the following 7 factor models: earthwork costs, foundation costs, right-of-way acquisition costs, recreation potential, wildlife potential—deer, wildlife potential—waterfowl, and wildlife potential—upland birds. Models 1 and 2 measured the construction costs of earthwork and pavement and subgrade support. The right-of-way costs model included not only costs of acquisition but consideration of the land's suitability for other uses, chiefly agriculture. Thus, this model to some extent measured environmental and social considerations as well as economics. Models 4 through 7 were used to analyze some of the important environmental concerns expressed by area residents.

Methods of Model Development

Data for each model were first compiled in map form at 1:25,000 scale. A grid was prepared on a transparent overlay, and the conditions at each mesh point were recorded on a coding form according to a predetermined 2-digit numeric code. Data from the coding forms were keypunched onto computer cards, and the cards were error-checked. Each grid was ¼ square mile, and the digitized data on the computer cards described conditions within $^1/_{16}$ square mile cell.

This system represents probably the simplest possible method of preparing data for machine computation. It is effective, rapid, and economical. All 7 models were converted to computer card form and error-checked in 1 week by 2 laboratory technicians. The original manuscript maps were saved and used during the analysis phases of the project.

Earthwork Cost Model

Aerial photographs and topographic maps were used in classifying and coding the terrain (Table 1). The value scheme to convert the codes to values before the minimum path analysis was attempted represents but one of many that might be used. A computer-aided system makes it possible to use different value schemes without having to recompile the basic topographic data.

Foundation Cost Model

A surficial geology map was developed by air-photo interpretation and checked against published geological reports and agricultural soils reports. Table 1 also gives the 14 categories mapped and coded.

The weights used to convert the codes to values for analysis are based on Ulbricht's methods (10). By utilizing 160 pavement sections, traffic records, and a panel of 6 experienced engineers to rate each section, he developed a mean soil rating based on a 10-point scale. He was able to show that these mean soil ratings were proportional to the soil support factors required by the AASHO design equations. Thus, larger ratings meant larger soil support factors, greater equivalent pavement thicknesses, and longer pavement life for any pavement design under a given traffic condition. Alternatively, if a standardized useful pavement life is desired, cheaper, thinner pavements can be built on soils having higher ratings.

The ratings proposed for the Guelph-Dundas test area were developed by comparing local soils with the soils studied by Ulbricht. However, they were computed on a 10-point scale so that high values represent soils on which high construction costs can be expected.

Right-of-Way Acquisition Cost Model

Information for the right-of-way costs model was obtained from the Canada land inventory and agriculture maps. The suggested ratings give high values to land uses that should not be disrupted (Table 1). Use of minimum path analysis procedures will produce routes that avoid the high-cost areas as much as possible while remaining reasonably direct.

Recreation Potential Model

Information was gathered on existing and proposed parks and conservation areas from local authorities and on areas having high recreation potential or historical interest from the Canada land inventory.

Canada land inventory capability classes 5 through 7 were ignored, for they are the least likely to be developed if other more suitable sites with greater potential are available. However, parks or conservation areas could be developed in such low capability areas just to provide open space. Accordingly, all existing or proposed sites have to be indicated regardless of their classification in the Canada land inventory. Table 1 gives the recreation model classifications, codes, and ratings.

Figure 6. Land use.

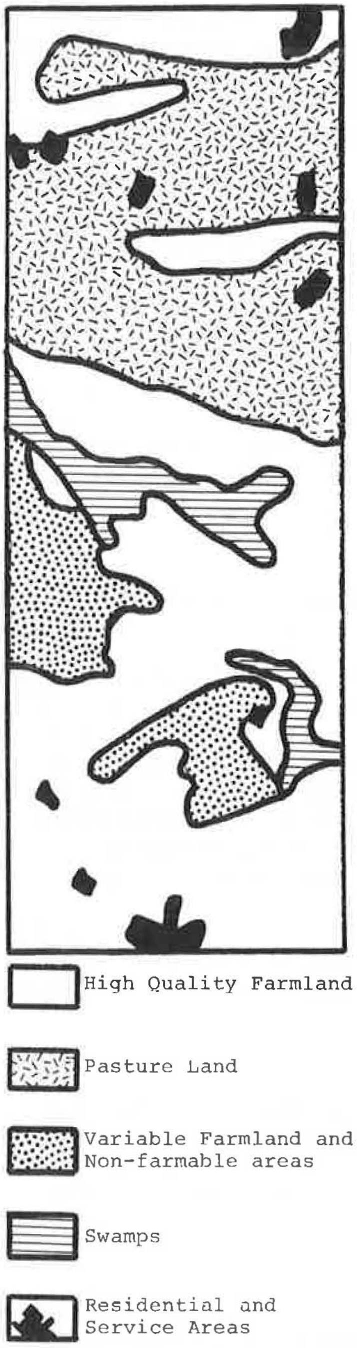


Table 1. Cost model codes and ratings.

Classification	Code	Proposed Rating	
Earthwork model			
Flat terrain	10	0	
Flat terrain on bedrock	11	2	
Rolling terrain	20	4	
Hilly terrain	30	8	
Rough and broken terrain	40	10	
Water bodies	90	12	
Foundation model			
Glacial till			
Drumlins	01	5.2	
Sandy till	02	5.3	
Kame moraines, kames	03	2.5	
Sands and till	04	5.3	
Silt and clay till	08	5.5	
Glacio-fluvial materials			
Sands	05	1.5	
Outwash gravels	06	1.5	
Eskers	07	1.5	
Thin material on bedrock	09	4.9	
Swamp	10	9.7	
Quarry	20	6.3	
Gravel pit	30	6.3	
Alluvium	80	7.0	
Water bodies	90	10.0	
Right-of-way model			
Urban and urban-related	01	10	
Cemeteries	02	8	
High-quality farmland	10	6	
Good farmland	20	4	
Pasture	30	2	
Nonfarmland	40	1	
Swamps	50	1	
Water bodies	09	10	
Recreation model			
Recreation sites			
Parks			
Existing	01	10	
Proposed	02	4	
Other areas[a]			
Existing	03	10	
Proposed	04	6	
Reservoirs			
Existing	05	10	
Proposed	06	8	
Historical sites			
Existing	07	10	
Proposed	08	8	
Lakes	09	10	
Recreation capability			
Class 1	10	10	
Class 2	20	8	
Class 3	30	6	
Class 4	40	4	
Wildlife model		Primary Species	Additional Species
Wildlife capability[b]			
Class 1A	1	10.0	1.00
Class 1B	2	9.5	0.75
Class 1C	3	7.0	0.50
Class 2A	4	8.0	0.75
Class 2B	5	7.5	0.50
Class 2C	6	5.0	0.25
Class 3A	7	6.0	0.50
Class 3B	8	5.5	0.25
Class 3C	9	3.0	0.00

[a] Animal sanctuaries and conservation and reforestation areas.
[b] Alphabetic suffix is degree-of-effort rating.

Wildlife Potential Models

Wildlife data from the Ontario land inventory were analyzed on 3 separate models. The first showed the distribution of deer; the second, waterfowl (geese and ducks); and the third, upland birds (partridge and grouse).

Only the best capability classes—highest, high, and above-average production—were considered at all. Areas belonging to these classes were given only the best 3 degree-of-effort ratings, for it was pointless to be unduly concerned about areas of high ultimate potential that would be very expensive to bring to that potential.

Although models were constructed for deer, waterfowl, and upland birds, it quickly became apparent that a single wildlife potential model was desirable because any particular area could support a variety of species at various capability levels. Thus, a more complex ranking system was developed incorporating 2 ratings for each class and degree-of-effort combination (Table 1). These double ratings were analyzed in a special computer program as follows:

1. Designate a series of importance weighting factors for all animal species (species to be ignored were weighted 0);
2. Find species having highest type A rating;
3. If more than one species have equally high type A ratings, select species having largest importance weighting factor as primary species; and
4. Compute final rating as $W_p + W_2 + \ldots + W_N$, where W_p is type A rating for primary species and W_2 and W_N are type B ratings for species 2 and N.

The final set of importance weighting factors used in the study are as follows:

Category	Factor
Deer	5
Geese	4
Ducks	3
Partridge	3
Grouse	2

Obviously, different wildlife models can be built by varying these factors. The resulting combined model can be weighted and combined with other models to produce corridor selections.

GENERATION AND ANALYSIS OF ALTERNATIVES

Single-Factor Analyses

The first step in a route-location study is the analysis of alternatives generated by individual highway location factors. These analyses indicate the minimum path or best locations for the route in terms of each location factor. The engineer thus gains an appreciation of the effects of each factor on route locations within the study area and also an appreciation of the conflicts among the factors.

Before minimum path analysis can begin, a suitable origin and destination must be selected and defined by the nearest nodes. For the Guelph-Dundas test area, the route origin is the terminus of the Guelph Bypass. Although 3 destinations for the route at the Dundas end were proposed and studied, this report shows examples of the eastern terminus only.

Figure 7 shows the 5 corridors developed for the earthwork cost model. Choices 1 and 2 follow predominantly western routes, and 3, 4, and 5 follow central routes. Considerable crisscrossing of the region is caused by moraines, drumlins, and steep terrain.

Corridors minimizing foundation costs are shown in Figure 8. A 13 percent spread in the relative path values of choices 2 through 5 and a 26 percent difference between those of choices 1 and 2 can be attributed to the good foundation conditions provided by the predominantly granular materials along the eastern boundary of the test area.

Figure 7. Corridors minimizing earthwork costs.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
EARTHWORKS	1.0	1	1,000	124
		2	1,246	138
		3	1,443	126
		4	1,656	144
		5	1,918	126

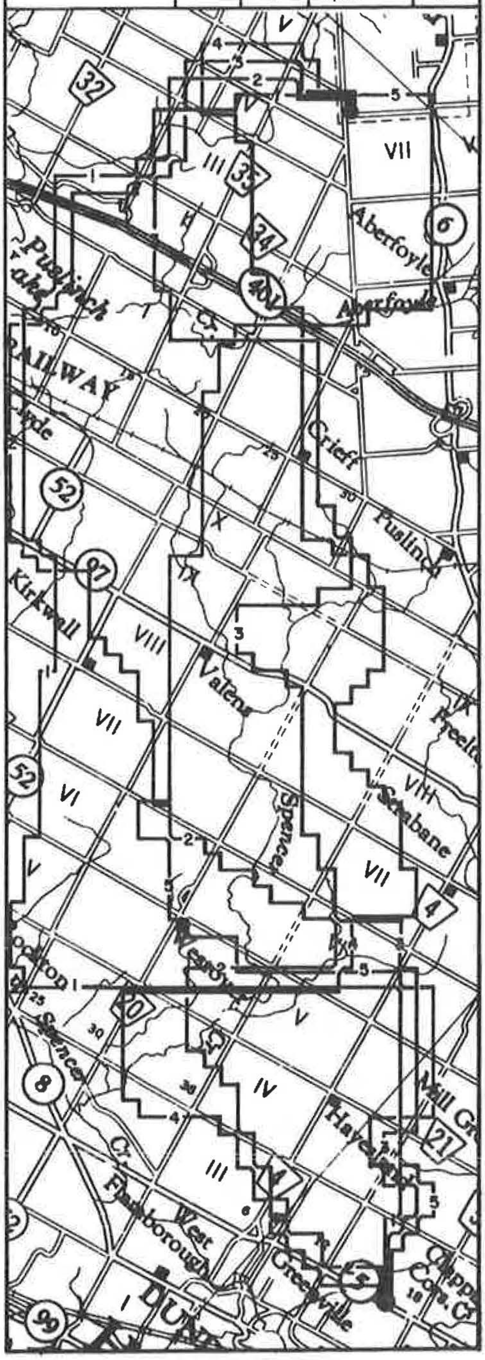


Figure 8. Corridors minimizing foundation problems.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
FOUNDATIONS	1.00	1	1,000	96
		2	1,260	90
		3	1,311	134
		4	1,337	112
		5	1,387	132

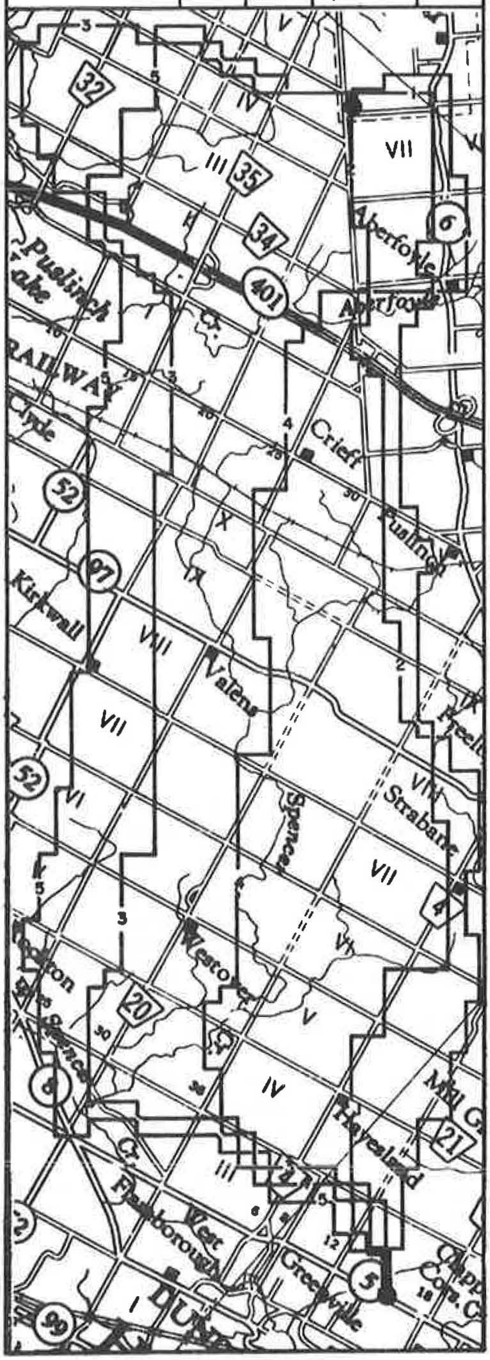


Figure 9 shows the corridors that minimize impact on valuable agricultural land. Choice 5 along the eastern boundary is the shortest of all the routes but is 90 percent more expensive than choice 1. The wide variety in route lengths and route costs reflects the varying land values and prime agricultural land locations in the test area.

Figure 10 shows the corridors that minimize disruption to potential and existing recreation areas. The relative path values of all choices are the same because none actually crosses a potential or existing recreation site.

Figure 11 shows the corridors that minimize the disruption to wildlife habitats. All are located in the western portions of the area to avoid passing through Beverly Swamp.

Multiple-Factor Analyses

Fourteen multiple-factor combinations were studied. The 2-factor analyses of earthwork and foundation cost factors allow the engineer to investigate route-independent construction costs. Adding the land use (right-of-way acquisition) cost factor produces a closer approximation of the true construction costs that include grading, paving, and land. Adding the recreation and wildlife factors minimizes the route's effect on the environmental and ecological conditions in the area and thus can be considered as benefit factors. Thus, by weighting the 5 factors in varying proportions, alternatives can be generated for certain chosen balances of economic costs and environmental benefits.

Figure 12 shows the alternatives generated by a 2-factor analysis. More clearly defined corridors are produced by the combination of earthwork and foundation costs than by either factor alone (Figs. 7 and 8).

Figure 13 shows the results of a 3-factor analysis. Land acquisition costs and the impact of the route on prime agricultural land modify the construction costs. Increasing the importance of the land use model increases the attractiveness of the eastern corridor because the land use considerations tend to overwhelm the more expensive construction in the eastern area.

The recreation factor is added to generate the corridors shown in Figure 14. All choices avoid Beverly Swamp. The recreation factor thus helps increase the separation of the 2 general alternative corridors (Figs. 13 and 14).

Figure 15 shows the corridors generated for an 80 percent cost and a 20 percent benefit weighting. Earthwork, foundation, and land use factors are considered costs, and recreation and wildlife factors are considered benefits. Two main corridors are generated. Total cost difference among the corridors is only 11.9 percent, and route length varies by 35 percent.

Figure 16 shows the corridors generated for a 50-50 costs-benefits ratio. The western corridor is strengthened and the eastern corridor is weakened as the environmental considerations are increased in importance.

A number of other factor-weighting combinations were examined, and for all 80-20 and 50-50 costs-benefits ratios, the western corridor was preferred. It becomes more strongly preferred as benefits are increased in importance, but choice 1 is always in a midwestern position.

CONCLUSIONS

For this study, GCARS was used in approximately 30 analyses in which factors had different weightings. The conclusions developed from these analyses were presented to a larger planning team that had used manual methods to study the area.

The conclusions developed by the GCARS analyses agreed closely with those developed by the manual analyses. However, the GCARS analysis was completed in about one-quarter of the time. Each GCARS run took only about 3 min of computer time at a cost of about $20; total analysis cost was approximately $500. This compared favorably with the cost of the manual analysis because lower manpower costs compensated for computer costs.

The preparation of data for computer analysis need cost no more and take no longer than that for manual analysis. Thus, the use of the computer in route selection can be justified economically. In addition, computer-aided analyses yield 2 valuable additional benefits: (a) a much more rapid analysis period and (b) a more comprehensive and

Figure 9. Corridors minimizing impact on agricultural land.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
AGLAND CAPABILITY	1.00	1	1,000	130
		2	1,411	124
		3	1,589	126
		4	1,781	146
		5	1,904	96

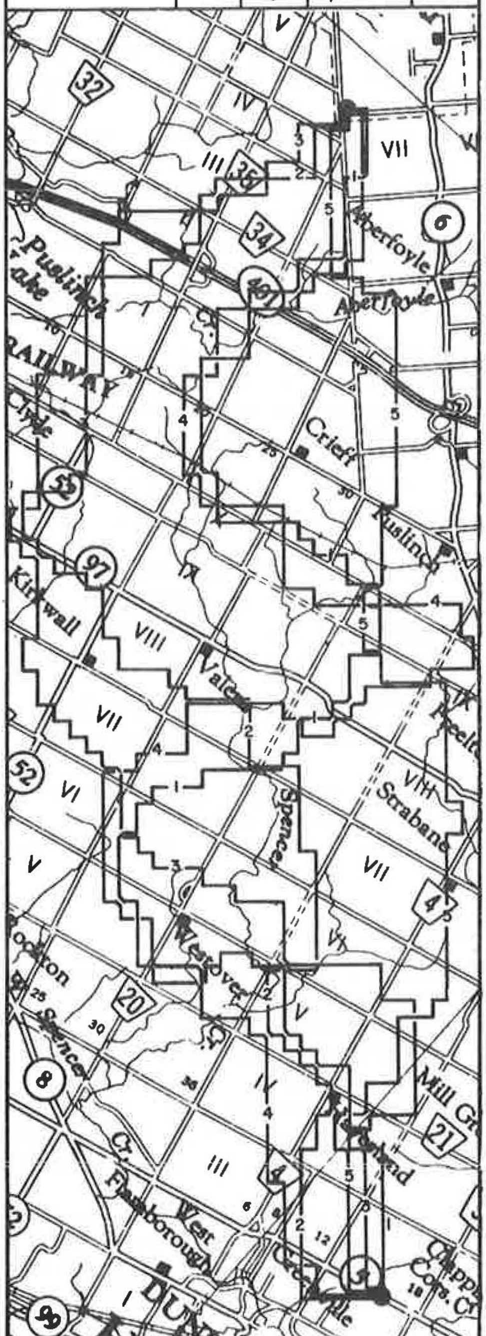


Figure 10. Corridors minimizing impact on recreation areas.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
RECREATION	1.0	1	1,000	82
		2	1,000	84
		3	1,000	86
		4	1,000	98
		5	1,000	100

Figure 11. Corridors minimizing impact on wildlife habitats.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
WILDLIFE	1.0	1	1,000	124
		2	1,046	126
		3	1,159	130
		4	1,181	122
		5	1,198	128

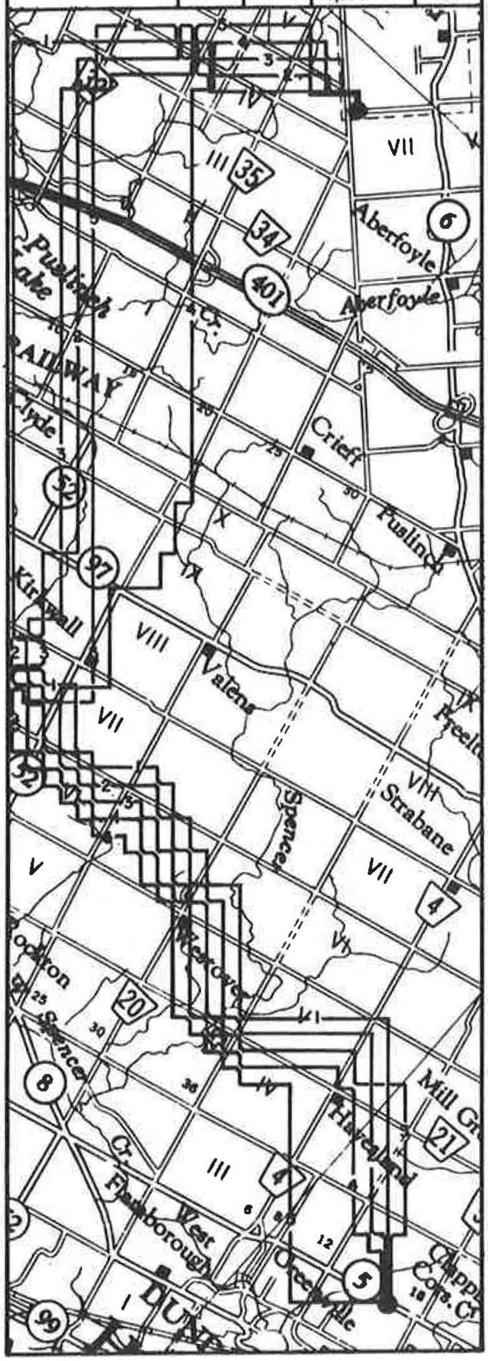


Figure 12. Corridors generated by 2-factor analysis.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
EARTHWORKS	2.0	1	1,000	118
FOUNDATIONS	1.0	2	1,136	108
		3	1,199	134
		4	1,303	124
		5	1,324	96

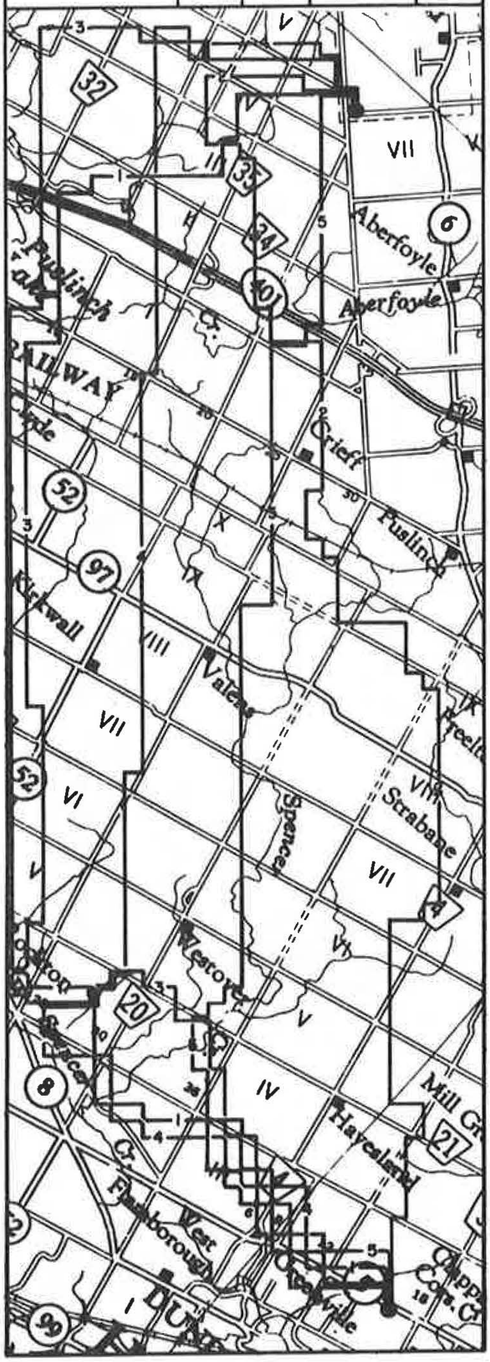


Figure 13. Corridors generated by 3-factor analysis.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
EARTHWORKS	1	1	1.000	80
FOUNDATIONS	1	2	1.080	88
LAND USE	2	3	1.081	102
		4	1.134	112
		5	1.160	90

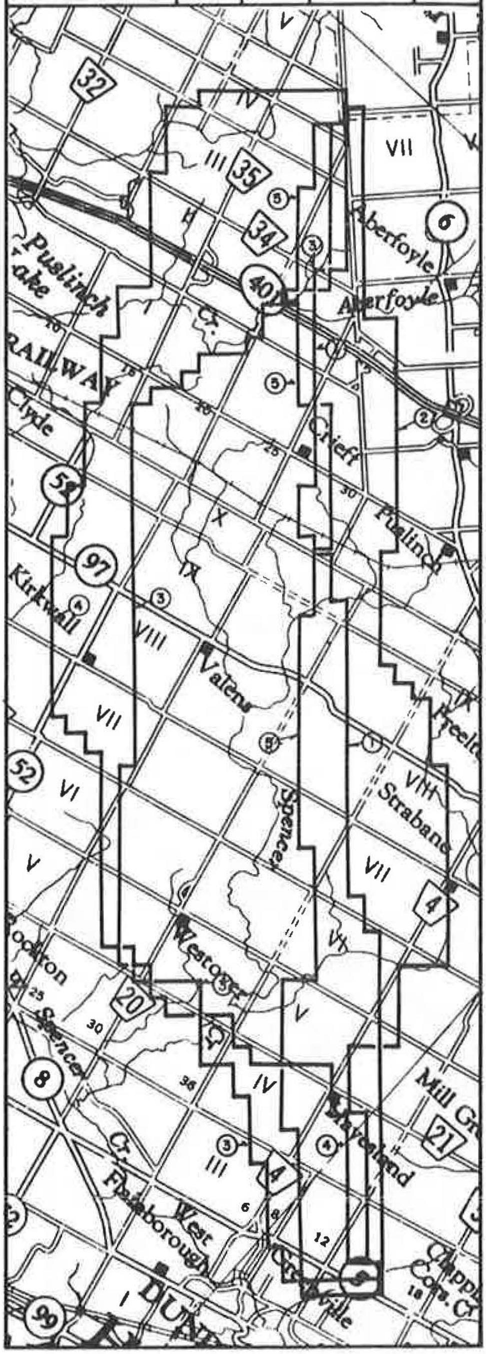


Figure 14. Corridors generated by 4-factor analysis.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS – SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
EARTHWORKS	1	1	1,000	86
FOUNDATIONS	1	2	1.007	104
LAND USE	1	3	1.100	86
RECREATION	1	4	1.125	118
		5	1.177	104

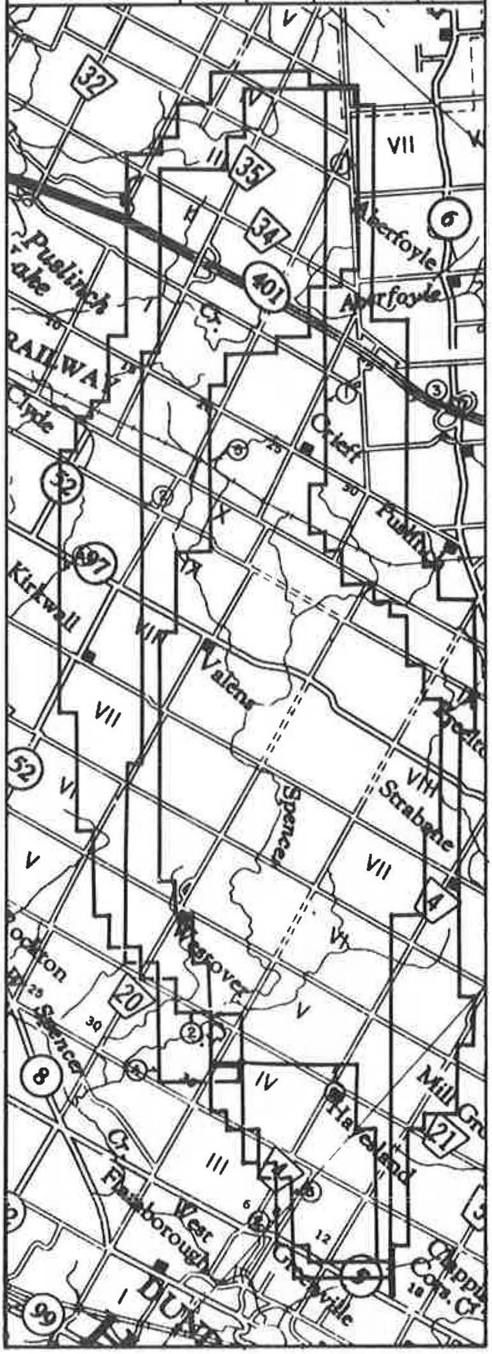


Figure 15. Corridors generated for cost-benefit ratio of 80/20.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS - SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
EARTHWORKS	2	1	1.000	104
FOUNDATIONS	2	2	1.053	82
LAND USE	4	3	1.075	76
RECREATION	1	4	1.076	114
WILDLIFE	1	5	1.119	98

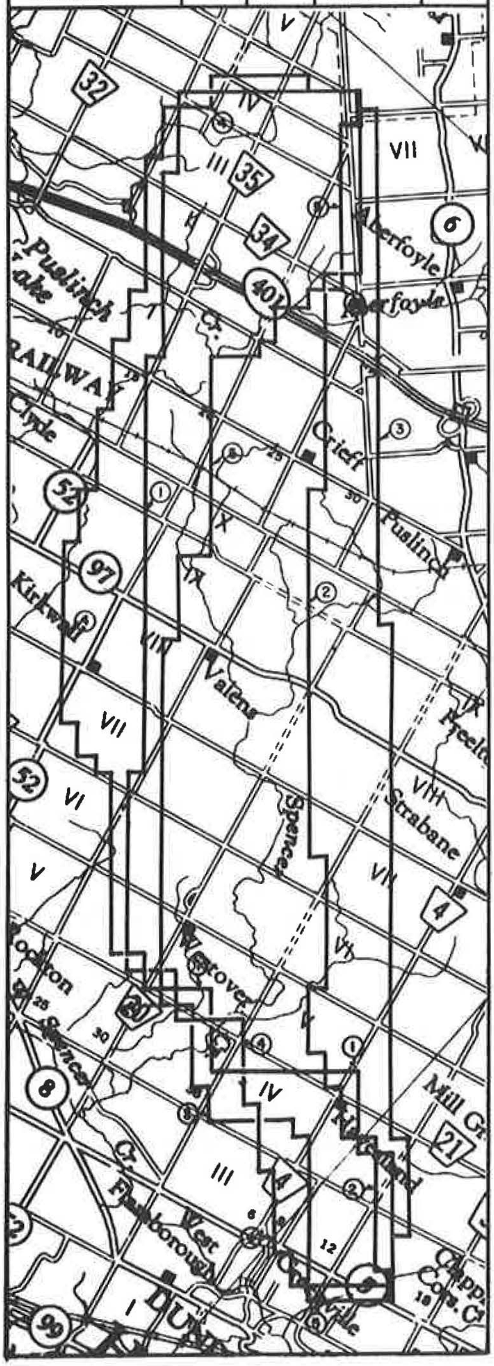
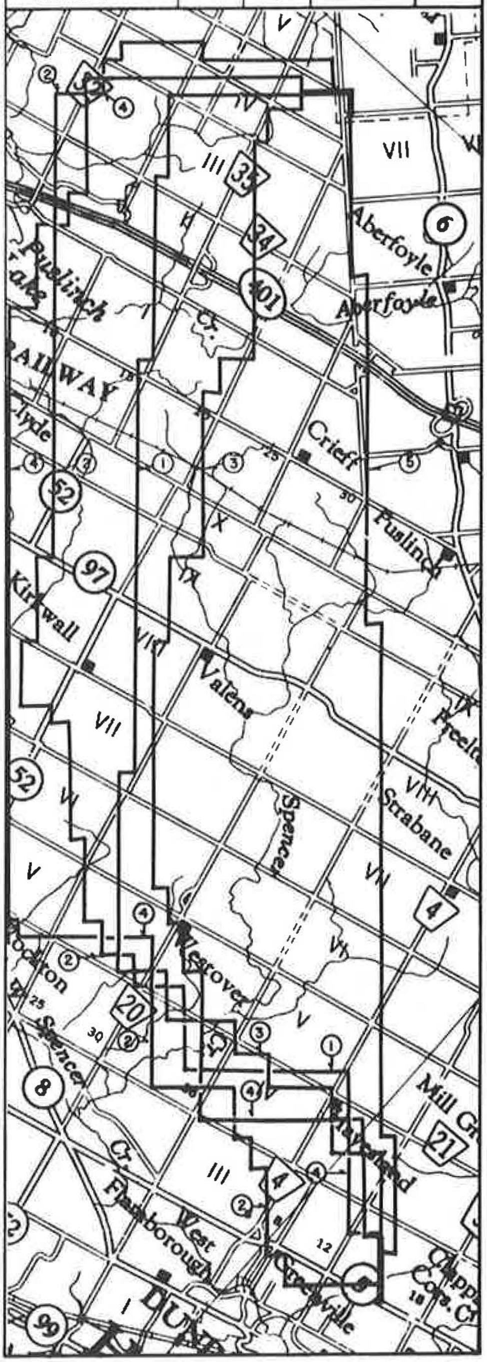


Figure 16. Corridors generated for cost-benefit ratio of 50/50.

GUELPH-DUNDAS TEST AREA

ANALYSIS OF CORRIDOR		ANALYSIS - SUMMARY		
FACTOR UTILIZED	WEIGHT	CHOICE NUMBER	RELATIVE PATH VALUE	NUMBER OF LINKS
EARTHWORKS	2	1	1,000	104
FOUNDATIONS	2	2	1.045	118
LAND USE	2	3	1.099	100
RECREATION	3	4	1.110	124
WILDLIFE	3	5	1.141	76



more quantifiable analysis providing both deeper insight into factor interactions and a ranked series of alternatives.

During this study, the Canada land inventory, used in conjunction with air photographs for checking purposes, was a useful data source. We also found that simple data digitization processes could be used economically to produce numerical models of the various factors that could be computer processed.

The study revealed some desirable additions to the basic GCARS system. Several of these are under active development and testing. Methods are being developed to allow some quantitative measure of the costs involved in increasing the environmental benefits so that rational, economically justifiable alternatives can be presented to the public for discussion.

As a consequence of this study, the Ontario Department of Transportation and Communications is actively reviewing the GCARS system and other computer-aided techniques for possible inclusion into its planning procedures.

ACKNOWLEDGMENTS

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the moanalua corridor: environmental problems along the proposed route of hawaii interstate h-3

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University of Hawaii

Even in the "Paradise of the Pacific," Honolulu and the island of Oahu have not escaped traffic congestion. Eighty percent of the population of Hawaii, or 650,000 people, live in the 600-square-mile area of Oahu and create a traffic problem of major magnitude. Following the precedent set by mainland cities, we have attempted to cope by planning and building freeways. Three have been scheduled so far; H-1 is operational, and H-2 is under construction. The peripheral parts of H-3 are already under construction, and construction of the major part will probably begin within the year (Fig. 1).

Although H-1 and H-2 were favorably accepted, H-3, planned to link the windward and leeward sides of Oahu by crossing the Koolau Range through the relatively undeveloped Moanalua corridor, has generated considerable opposition. The sources of this opposition and the less than enthusiastic response to the upcoming freeway construction illustrate not only some interesting, although somewhat confusing, contrasts but also some serious deficiencies in the traditional transportation planning process. Planning for H-1 began in 1959. Similar planning techniques were used for H-2 and H-3. It appears now that the time lag between the planning of H-1 and the construction of H-3 coupled with the aroused concern that has developed for the environment is the reason for the opposition to H-3. In any event, looking back on the events as they occurred is an educational experience.

IN THE BEGINNING

The first automobile come to Oahu in 1898 and, as elsewhere, was immediately popular. Even though there were few reliable roads, automobile ownership continued to increase, and the demand for road construction had generated enough pressures that Hawaii finally won approval to receive funds legislated in the Federal-Aid Highway Act of 1916. This participation established a significant precedent for later highway funding.

Sponsored by Task Force on Highways and the Environment.

By 1959, as shown below, vehicle ownership had grown to the point that the transit system, which had been operating profitably since 1921, began to feel the effects. In fact the number of annual transit revenue-passengers dropped by a third between 1945 and 1950 (and is still dropping even today). Urban expansion, which got off to a faltering start prior to World War II, picked up momentum during the 1950's, and traffic problems increased proportionately.

Year	Vehicles
1920	6,000
1925	17,000
1950	82,000
1958	135,000

Because of the precedent established earlier, the Territory of Hawaii was eligible for inclusion in the Federal-Aid Highway Act of 1956. This new money available for construction coupled with the mounting traffic problems made the need for transportation planning quite obvious. So, planning for an Interstate Highway System on Oahu was begun.

OAHU TRANSPORTATION STUDY

The Oahu Transportation Study (OTS), an island-wide transportation study, was authorized in 1962, and work was actually initiated on March 1, 1963, as a joint project of the state and the City and County of Honolulu (the majority of the people on Oahu live in the district of Honolulu, and the entire island is under one city-county government). The study's findings, based on traditional transportation planning procedures of the Federal Highway Administration, were published in 1967.

Unfortunately, because of mounting pressures to ease the traffic congestion problem, freeway planning began prior to island-wide transportation planning, and the corridors for all 3 freeways were selected before OTS was completed. In fact by the time OTS was completed, H-1 was under construction, the final design for H-2 was accepted, and the preliminary design for H-3 had been completed.

The island-wide transportation plan prepared by OTS was essentially a highway-oriented plan. Rapid transit was proposed only along a corridor passing through the central portion of Honolulu, approximately paralleling H-1. The lack of emphasis on transit was based on modal-split characteristics observed during the early 1960's and on forecast vehicle ownership characteristics. Minimal transit usage was forecast along the H-2 and H-3 corridors.

H-3 CORRIDOR STUDY

To a certain extent, the need for the 3 transportation corridors, which have become freeway corridors, really could have been located without the aid of sophisticated models because the need to serve the 3 distinct sectors of the island was obvious. Most of H-1 is now open and actual use has proved its utility. The structures on H-2 are complete and paving will begin in the fall of 1972, so worrying about the suitability of its location is an exercise in futility. But construction of H-3 has not reached the point of no return. Because of this, a review of the H-3 corridor location process is appropriate.

Major determinants of route selection for highways linking the windward and leeward sides of Oahu are the deep valleys curved into the leeward slope of the Koolau Range. Studies were made of 5 potential corridors that take advantage of the valleys of Moanalua, North Halawa, Kalihi, Nuuanu, and Manoa (Fig. 2). At a public hearing in January 1965, the state discussed these potential corridors and explained that the North Halawa corridor was not receiving further consideration because it failed to provide the required traffic service. The Nuuanu corridor and the Manoa corridor presented multiple difficulties: displacement of families, additional congestion of existing connecting highways, and great disruption of existing facilities during

Figure 1. Proposed freeways for Oahu.

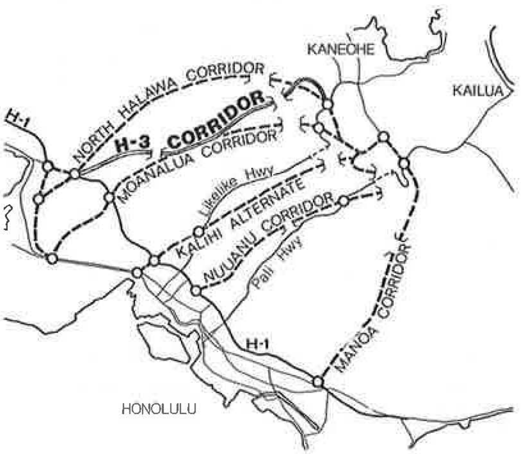
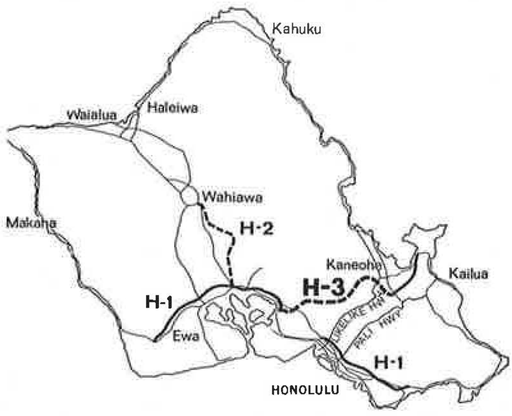


Figure 2. Corridors considered for H-3 route.



construction; hence, both of these corridors were also dropped from consideration. During the public hearing, the state indicated that it favored the Kalihi corridor. However, at the public hearing the community opposed the Kalihi corridor for reasons similar to those the state posed for Manoa and Nuuanu and strongly supported the Moanalua corridor. For example, the Chamber of Commerce of Honolulu stated (1), "The Moanalua corridor would open a completely new scenic area which would be a tremendous asset to the state." The Oahu Development Conference stated (1), "The ODC believes that the state has a rare opportunity to design and construct through Moanalua Valley a scenic freeway that could be one of the most dramatic in the nation."

In response to the opposition generated by the Kalihi corridor proposal, the state changed its plans and came back to community meetings in May 1965 with the Moanalua corridor design. This corridor concept received substantial support at the May meeting and little or no opposition. The state continued further development of the Moanalua corridor; and, when the OTS plan was adopted in 1967, the state felt it had satisfied most interested parties, and the Moanalua corridor design was adopted. During October and November 1969, the state published notification of the opportunity for public hearings to discuss the design. No requests for public hearing were received. Following this, the state requested the Federal Highway Administration's approval of the design, and in August 1970 the approval was received.

The approved proposal involves a 9.4-mile, divided 6-lane freeway designed to Interstate standards. The construction cost is estimated to be $260 million. The cost is high primarily because the design entails 2 tunnels, the 0.4-mile Red Hill Tunnel and the 0.9-mile Trans-Koolau Tunnel. Except for a 1-mile portion of the facility that drops down the Pali cliff on a viaduct, the freeway will be at-grade. There will be only 2 interchanges plus the connector to H-1.

H-3 ENVIRONMENTAL IMPACT STATEMENT

It is questionable that the requirements of the National Environmental Policy Act for the preparation of an environmental impact statement applied to a project for which planning and design had proceeded as far as they had for H-3. However, in similar cases, the courts have tended to hold that the projects are not exempt from the act (2). Perhaps for this reason, and certainly because the Hawaii Department of Transportation wanted to have H-3 built quickly and openly with as few interruptions as possible, it arranged for the preparation of an environmental impact statement.

The first draft of the environmental impact statement was issued in June 1971, 9 months after FHWA had approved the design. The statement, prepared by a consulting firm, which was to have a contract to finalize certain aspects of the H-3 design after the project passed the environmental review, was, on the surface, an extensive document. It contained a justification of the need for H-3, the alternatives, a project description, and a discussion of the environmental impact of the route including visual impact and aesthetics, noise, air quality, water supply, stream flow, erosion and siltation, displacement of families, business and employment, agriculture, schools and religious institutions, public recreation facilities, vegetation, wild life, historical and natural features, and public transportation.

The draft was mailed to the appropriate city and state agencies, to the Environmental Center of the University of Hawaii, and to a number of environmental community organizations. The response to the draft provided local planners with a fresh insight into the changeable nature of planning goals as perceived by the more vocal community groups. Community groups that had come out in favor of the H-3 design 5 years before were now violently opposed. Whereas no one was concerned enough in 1969 to attend a public hearing to learn about the design, by July 1971 officials of the transportation department were asked to attend as many as 3 public meetings on the same night. Groups were formed to "Stop H-3," and other groups were formed to "Save H-3"—usually the groups opposed were more vociferous than those in favor.

RESPONSE TO THE DRAFT STATEMENT

Responses to the draft statement were collated by the Hawaii Department of Planning and Economic Development. Most of the responses from city or state agencies approved the impact statement or at least did not disapprove. Most of the responses from community groups that engaged in critical review disapproved of the draft and questioned the state's assessment of the environmental impact that would result. Analyzing a summary of the response prepared by the University of Hawaii Environmental Center provides a more or less moderate view of criticism of the draft. The university's critique stated (3), "If the H-3 route could be justified, the justification would require much more understanding and evaluation of the environmental impact of the project than was displayed in the impact statement under review which was in some respects inaccurate or misleading and which is in important aspects incomplete." The major points subject to argument can be divided into 7 categories detailed below.

Relation of Freeway Width to Valley Width

The project description did not disclose the exact alignment or configuration of the road. From the discussion, it was not clear whether the highway was at-grade or elevated or whether the centerline followed or was displaced from the axis of Moanalua Valley. A route map showed the highway crossing the Moanalua Stream at least 20 times. The estimated effects of the highway on water, soil, and aesthetics obviously depended critically on whether construction within the valley was to be primarily cut-and-fill with extensive stream relocation effectively reducing the number of stream crossings or primarily a viaduct with limited cuts and fills.

The Moanalua Valley ranges from 2,500 to 6,000 ft in width, yet no note of the width of the highway in relation to the width of the valley was made. Thus, the freeway could have occupied from 10 percent to 50 percent of the valley floor depending on the design, but exactly how much of the valley would be covered and what the effects would be were never discussed.

Effects on Vegetation and Wildlife

The portion of the impact statement dealing with vegetation and wildlife hardly hinted at major questions such as the degree of disruption of the various ecosystems traversed by the route and the value of preserving those ecosystems. The ecosystem problem is complex because there is often an enormous range in ecological conditions in Moanalua Valley related especially to variation in rainfall. Moderately dry-land vegetation predominates in the lower part of the valley and rain forest vegetation in the crest area. Evidence could be found that many botanists do not put a high value on preserving the existing vegetation in the valley, but the question was not discussed specifically in the draft.

There was no discussion of the effects on fauna except the claim that the highway will have negligible effect on land animals and birds. Ignorance was very likely the major reason for the slight degree of concern with faunal effects.

The statement indicated little concern with the effects on agriculture. It recognized that attempts would be made to relocate banana farms displaced by the highway but did not recognize the great difficulty of finding other lands with the necessary combination of soil, climate, terrain, access, and ownership.

Effects on Water

In its proposed route through Moanalua Valley and through the Koolau ridge, the proposed H-3 freeway would or could have many effects on water—influencing groundwater recharge, groundwater storage, floods, dry-weather stream flows, and surface-water quality. The draft impact statement mentioned only 2 effects: those having to do with groundwater recharge and low-water stream flow. The effects on flood flows and water quality, certainly the most significant expectable, were not even mentioned.

Construction of the highway will prevent infiltration of precipitation through the pavement, perhaps restrict infiltration of precipitation on the shoulders and the steep slopes of cuts and fills, and prevent seepage from those parts of the stream confined to lined channels. The naturally occurring infiltration and seepage recharge dike compartments in and windward of the Koolau ridge and, to leeward, the basal groundwater transitional between the Honolulu and Pearl Harbor areas. The dike water infiltration from the vicinity of the proposed highway may supply part of the discharge of a Board of Water Supply tunnel as well as provide low flows of windward streams and recharge to the leeward basal groundwater body. The leeward basal groundwater body is the main source of water for the Honolulu-Pearl Harbor area. The effects of the reduction in infiltration on water supply did not seem likely to be important, but their appraisal seemed essential in the impact statement.

The effects on flood flows in the Moanalua Stream are likely to be very great, especially if the 1967 plans are followed. These plans call for the construction of a flood control reservoir, which was only hinted at in the statement in its reference to a request made by the Damon Estate trustees "that the state reexamine its plans to construct a reservoir at the South Branch of Moanalua Stream" (3), a request to which the state agreed, subject to determination of feasibility. It appeared that this reservoir, not elsewhere discussed in the statement, has been designed to reduce the flood-carrying capacity necessary in bridges, culverts, and channels downstream, including already existing structures below that part of the valley to be occupied by the highway. Obviously the effects of this reservoir needed discussion in a comprehensive environmental impact statement. So, too, should have been included the possible effects of grading and paving on flood flows.

Very likely the most profound effects of the proposed highway construction on water will be on the quality of the water delivered by Moanalua Stream through its channelized lower course to Keehi Lagoon. During floods, Moanalua already carries enough sediments to run red. The source of the red soil it carries is uncertain because the soils of the upper valley are brown and gray. With the extensive cut-and-fill work proposed by the 1967 plans for the proposed highway, the additional burden of soil that will be carried by the stream will be very great. The resulting increase in water pollution, which warranted thorough examination in the light of the state's water quality standards, was not mentioned in the impact statement.

The flood control reservoir in the 1967 plans would reduce sediment yield from the southern branch of the valley but at the expense of loss of useful life. Quite probably this reduction would be offset by the increase in erosion resulting from increased flood flows from the paved and graded areas and the greater rates of flood discharge produced by straightening and shortening the stream channel. In particular, the cuts and fills will be extremely susceptible to erosion during construction. Stilling basins shown in the 1967 plans are obviously designed only for dissipation of hydraulic energy and not for sediment trapping. Limitations to the effectiveness of revegetation of cuts and fills are discussed in connection with effects on flora; and, even with extraordinary controls on sediment production and transport, not indicated in the statement, acceleration of erosion and the transport downstream of sediments and turbidity should be expected.

Effects on Air

The possible deleterious effects of automobile emissions produced along the proposed H-3 corridor were passed over lightly in the environmental impact statement in discussions of the Red Hill Tunnel, the Trans-Koolau Tunnel, and in a brief section on air quality.

Automobile emissions generated within the Red Hill and Trans-Koolau tunnels are to be exhausted through ventilation structures from which, according to the draft, the trade winds were expected to dissipate air pollutants rapidly. How rapidly was not stated. Qualitative observations concerning the air quality of the existing Likelike Tunnel seemed pertinent. That tunnel, located at approximately the same elevation and near the proposed Trans-Koolau Tunnel, utilizes, as far as could be determined, the same mechanism for ventilation. The air quality of the present tunnel is often poor at least in terms of objectionable odor. The possibility of adverse health effects due to carbon monoxide buildup if automobile traffic were stalled within the tunnel is also of concern.

According to the draft, the northeast trade winds are expected to dissipate quickly and effectively the pollutants emitted by automobiles within Moanalua Valley. Again there was no quantitative estimation of the rate of dispersion. It should be recognized, however, that moderate to strong trade winds blow only about 70 percent of the time. During the other 30 percent of the time there are either kona (south to southwest winds) or relatively calm conditions—what would happen then?

There was in the draft no mention of the damaging effects to vegetation of ozone, PAN, and oxides of nitrogen or of the concentration of lead in vegetation and soil that might be expected near the highway. Besides these effects on the natural vegetation, there should have been discussion of the effects on the banana farms through which the highway will pass on the windward side of the Koolau Range and on the plantings in the planned botanical gardens in Moanalua Valley.

Effects on Archaeological Sites

The draft impact statement indicated a commendable concern with possible effects on archaeological sites in Moanalua Valley and referred to a report on such sites resulting from a Bishop Museum study supported in part by Department of Transportation funds (1). The statement concluded that the effects would be slight. It was, however, difficult to reconcile details in the statement with the museum report. According to the report, 20 sites are included within the highway right-of-way. All but 4 of the sites will remain unaffected by the highway, and these 4 will be relocated. But, the 4 sites are not identified.

Noise Effects

The draft statement indicated (1), "The Department of Transportation anticipates a substantial reduction in noise from motor vehicles. A special acoustics consultant is being engaged, and it is expected that the state's program of noise minimization will be effective." This statement was questioned for a number of reasons.

Experiments have shown that sound can be attenuated if the path of propagation passes through extended areas of dense planting. The required thickness of planting varies with the density of plant material and the frequency of the sound. A given thickness is more effective at the high end of the audio frequency spectrum than at the low end. Generally speaking, a thickness of dense planting of the order of several hundred feet is required to have an appreciable effect.

The planting is effective only when the sound passes through it, for the attenuation results primarily from a combination of reflection, refraction, and absorption of the sound energy by the plant material. Where a highway is elevated, or surrounding land areas are elevated, the sound energy often can follow a direct path from the source to an observer. In addition, in steep-walled valleys, sound may be reflected from rock faces.

With respect to Moanalua Valley, it seemed doubtful that planting alone will allow retention of the valley's present noise-free quality. Large diesel trucks create significant amounts of acoustic energy at the very low frequencies on which planting has the least effect. The high walls of the valley, on the other hand, are likely to be efficient reflectors of this same energy. It is probable that truck exhaust noise will be audible throughout most of the valley region, and it is likely to be distinctly intrusive within approximately 1,000 ft of the highway. Almost the entire bottom area of Moanalua Valley lies within approximately 500 ft of the proposed H-3 route, and the slopes, which are to be included in the proposed park, cannot be shielded effectively from noise by any plantings.

Another potential problem area is the windward-viaduct section of the proposed route. The buildings of the Kaneohe State Hospital, a mental hospital, are located between 500 and 2,500 ft of the windward viaduct. Unless precautions are taken in the design of this viaduct, the patients at the hospital can be exposed to a psychological stress caused by traffic noise. Because of the nature of the patients at this hospital, the additional stress could have an important effect on their treatment.

Visual Effects

The draft indicated that the transportation department was concerned with both views of the surroundings from the highway and views of the highway from its surroundings. To quote from the Environmental Center review (3): "Without question, the highway, even designed to defense highway specifications rather than to truly scenic highway specifications, will afford a scenic ride to the motorist in both Moanalua and windward portions." Doubtless, too, detriments to the scenic characteristics would be minimized by skillful architectural treatment and landscaping as suggested by the statement. However, the scale relation between the highway and Moanalua discussed earlier, and probably the similar relation between the windward viaduct and the pali along which it is built, are such that it is extremely doubtful that the obtrusiveness of the highway in its surroundings can be obscured to viewers either on or at a distance from the highway. To visitors in the proposed park in Moanalua Valley, especially, even with the maximum care in design and planting, the field of view will be that of a major highway in a pleasing setting and not that of a beautiful valley incidentally containing a roadway. In particular, it is difficult to imagine how, in either the narrow valley or on the windward pali, the opposing roadways can be obscured from each other as suggested.

Recreational Effects

The draft statement recognized very little impact of the highway on recreational opportunities in the area it will traverse. It overlooked a unique aspect of Moanalua Valley that should have been considered in connection with the plan to develop a park in the valley. The valley had a significant pre-Cook traditional background, as well as some historical importance during the period extending through the periods of the Kingdom and the Republic and into the early period of the Territory. These give special significance to the historic zoning proposal for the park in the valley, which is intended to be not merely recreational but educational. The traditional and historical significance of the valley and the historical zoning concepts embodied in the park plan were nowhere discussed in the environmental impact statement.

The statement declared that the park development and the proposed highway will be compatible and, indeed, that the highway will be advantageous in providing access to the park. Because the highway will occupy so large a part of the valley (most of the valley bottom), because of the traffic noise it will produce, and because of its overwhelming visual impact, it cannot appropriately be considered compatible with the park.

COMMUNITY REACTION

The deficiencies in the draft environmental impact statement as well as a number of points of questionable validity were mentioned by many of the groups that reviewed the statement. Accusations were made, with some justification, that the statement read more like a rationalization for the H-3 project than a critical analysis of environmental effects. However, the major focus of the reviews of community groups was on alternatives to the construction of a new freeway rather than on its environmental impact. There were questions whether the capacity of the 2 existing highways across the Koolau Range could be increased through the application of traffic engineering concepts such as the use of 1-way routes, reversible lanes, and the widening of the existing roadways so as to eliminate the need for the H-3. There were also questions as to the extent to which the transport needs might be met by public transit. It was pointed out that the modal split between individual automobile transportation and transit that was used to justify the highway was based on characteristics of the early 1960's that might not still be valid, more travelers being willing to consider using transit now than in the past.

Nearly all of the opponents to H-3 came out in favor of transit as an alternative approach to highway construction. However, it was clear that they were thinking in terms not of bus transit but of rapid transit such as subway or monorail. Yet, with a population of 40,000 now on the windward side and of no more than 100,000 within 20 years and most employment opportunities in Honolulu, nearly everyone in this bedroom community would have to take a daily trip on the rapid transit line in order to make it a feasible operation. Bus transit on an exclusive freeway lane is a viable alternative that was not seriously considered in the original draft and gained moderate acceptance during the fall as the controversy continued.

THE PREFINAL DRAFT

Probably had the Department of Transportation foreseen the extent of adverse criticism that was generated by the first draft of its H-3 environmental impact statement, it would have made a strong case for bypassing preparation of the impact statement. Having begun the impact statement process, however, there could be no backing out, and the department had its consultants prepare a new draft. This "prefinal draft" was issued in December 1971.

As contrasted with the 22-page first draft, the new version ran to 5 volumes. The first 96-page volume comprised the statement itself; the second, about 400 pages, contained criticisms to the first draft and responses from the department; and the remaining 3 volumes contained 9 appended reports on special studies. This new draft clearly represented not just more bulk but a much more thorough attempt to identify and where possible to quantify the environmental effects of the proposed highway.

Effects on Erosion and Sedimentation

The new draft recognized that special pains would have to be taken to control erosion from cuts and fills on the highway and to control the resulting turbidity and sedimentation in the waters downstream; it cited controls being used at the Halawa interchange, which was already under construction at the leeward end of the H-3 route, as evidence of successful methodology. With the onset of the kona season rains, however, limitations on the success of the controls at Halawa were becoming apparent. At the opposite end of the highway, on the windward side, special stringency of control is justified because of the special conservation classification of waters of Kaneohe Bay into which the area drains. Effective control cannot be expected from conventional methods in that area or in the upper part of Moanalua Valley because of the high rainfall in those areas. Completely effective control cannot be expected with any practicable measures, and a significant impact of the highway on erosion and sedimentation should be regarded as inescapable.

Effect on Air Quality

Concern over air quality in the tunnels was reduced by a clarification in the prefinal draft of the impact statement that one of the tunnels would be served by a semitransverse ventilation system and the other by a full-transverse system distributing air inflow over each traffic lane.

The new draft concluded that the effects of the highway and tunnels on open air quality would be insignificant. This conclusion was based on a special consultant study of air pollution, based on a quantitative diffusion model. The model has, however, been severely criticized. A full discussion of the problem is unwarranted here, but some brief notes may be of interest. The model utilizes a coordinate system moving with the vehicles, but its application to the problem involving a fixed terrain, fixed tunnel portals, and 2-way traffic flow has not yet been satisfactorily explained, although there has now been extensive discussion and correspondence between the air quality consultants and their critics.

Effects on Noise

The prefinal draft also concluded that the highway will have a great noise impact to a distance of only about 200 ft from the centerline, some impact to a distance of about 300 ft in areas with dense vegetation and about 700 ft in areas without such vegetation, and no impact in residential areas. These estimates were based on another special consultant study.

These conclusions have, like the conclusions with respect to air quality, been the subject of considerable discussion and correspondence between the consultants and their critics. The remaining disagreement is in part a function of limitations in the state of the art of noise estimation and in part the result of inclusion of noise levels that clearly have effects on activities such as sleep and recreational enjoyment within the range defined as no impact.

Traffic Alternatives

The 2 existing highways, the Pali and the Likelike, are both 4-lane divided highways. Each highway has grades as steep as 7 percent, and each passes through tunnels beneath the crest of the Koolau Range. There are a number of at-grade intersections along each route. During peak hours the split is about 85-15, and the traffic flow approaches complete congestion, occasionally going into a stop-and-go situation. The combined average daily volume on the 2 routes is about 60,000. The city-owned bus line does not extend to the windward side. A private bus line runs from the windward side to Honolulu on a 45-min headway, and usage is negligible in terms of total daily travel.

Establishing a 1-way pair on the Pali and the Likelike is impractical for a number of reasons. The primary one is traffic safety. The intersections and driveways along the routes would be hard to control. Also, for many streets that converge on these highways, there are no alternative arteries. Hence, a large number of users would be forced to go far out of their way if a 1-way pattern were in effect. Because of the observed low transit usage and the relatively high levels of congestion on the existing routes, the department concluded that no travel alternative existed and nearly all future traffic would have to be carried on a new freeway.

Indirect Effects

In its review of the prefinal draft, the Environmental Center called attention to the fact that the proposed highway, like any other major new transportation facility, would have profound effects on population dispersal and land use and those effects would lead to a host of indirect and ramifying environmental effects not discussed in the statement. The center went on to indicate that capabilities to analyze and predict those indirect effects were severely limited and that only their general recognition could be expected in the framework of an environmental impact statement.

The land use implications of H-3 became matters of general public concern; commentary on H-3 began to appear regularly in the local news media, and by the end of February 1972 the controversy reached proportions sufficient to receive the attention of the state legislature. A joint hearing on the H-3 was held by the senate and the house; no conclusions were reached, however.

In March a further critical review was received from the Environmental Protection Agency (EPA). After claiming that the estimates of damage to vegetation and wildlife in Moanalua Valley were incomplete, that the effects of stream channelization in Moanalua were not considered and the proposed erosion control measures were unsatisfactory, that the air quality model was of questionable validity, and that the effects on air quality of increased vehicle use were not considered, the EPA severely criticized the lack of analysis and long-range implications and secondary environmental effects. It concluded (5): "The Environmental Protection Agency recommends that Interstate H-3 not be constructed until the existing course of the island's development can be thoroughly examined, focusing on that course's impact on the human environment. This should include administrative and legislative mechanisms established and implemented to ensure that the direct effects of the highway construction and the secondary effects of inducing development are regulated to reduce adverse environmental effects."

While the EPA report was being prepared and distributed, a representative of a local conservation group found that H-3 had never been completely adopted on the Oahu general plan. The city council reacted by directing the city planning department to add all portions of H-3 to the general plan. The planning department responded by saying it would have to study the matter before it could form an opinion. Their study is continuing, and no action has been taken.

CONCLUSIONS

The preparation of environmental impact statements is required by the National Environmental Policy Act in the case of actions supported by federal funds and by executive order of the governor of Hawaii in the case of actions supported by state funds or affecting state lands. These joint requirements have been hailed as a great advance in planning; they have indeed forced planning agencies to take more serious cognizance of the environmental effects of their actions. The extent to which the environmental effects have been identified and analyzed by the responsible agencies or their consultants has varied a good deal from project to project. All too often when an impact appraisal is made by the agency that wants to construct the project or by a consultant hired by the agency, the statement has been a defense rather than an evaluation. This problem is compounded by the effect noted by Winfrey that many transportation planners have lost sight of the fact that transportation facilities are not and never have been ends in themselves (6).

For the H-3 freeway, the extent of the environmental identification and analysis displayed in the preparation of the prefinal draft was greatly increased over that displayed in the first draft, but even so the outcome has been severely criticized by citizen groups, other local reviewing institutions, and even by the EPA. The validity of the criticisms is open to question. Although environmental enthusiasts tend to hold out for complete descriptions of environmental effects and go to the extreme to insist that no project should be undertaken that will have negative effects on the environment, the demands of an increasing population make many public construction projects unavoidable.

If the EPA's review and criticism of the Moanalua impact statement truly reflects the all-encompassing goals of the agency, then future environmental impact statements must consider not only the typical traditional environmental consequences of new construction but also the social implications and urban design trade-offs of public facility construction. Is this all-encompassing review really the purpose of an environmental impact statement?

Public facility construction must continue. The valid points raised by those concerned with the environment must be treated adequately in future design and construction. This will cause design and construction costs to increase—a justifiable increase when one considers the costs that the community has had to bear in the past for narrowly conceived projects that only partially considered the total environmental impact problem. But how much environmental control and design improvement can be accomplished if tools to estimate environmental impacts are unavailable or yield conflicting results? One typical problem illustrated over and over again in the Moanalua example was the tendency for environmental "experts" to totally disagree on basic environmental elements such as noise control or level of air quality. The community has high environmental expectations, but available evaluation techniques and design procedures do not live up to the expectations. An intensive effort must be made to bring about improvements in the techniques of analysis and design of projects subject to environmental impact.

Is the Moanalua case just another instance of environmentalists out of control, or can a community's goals really change completely within the short span of 2 years? The development of the plans for H-3 has taken many years. Concern for environmental quality did not arrive until the end of this period. The further development of alternative plans and the analysis of the environmental effects of these alternatives would take additional time. It is seriously questionable whether the provision of additional needed transportation capacity can be deferred so long, especially if the overall advantages of the alternatives, including the environmental advantages, are uncertain.

Community goals do not change overnight, instead the process is evolutionary and should be reasonably predictable. The obstacle confronting the transportation planner so far has been that he has been so wrapped up coping with the changeable nature of land use and population distribution he has either missed or refused to accept the fact that modal-acceptance characteristics are also changing. This acceptance of transit did not show up in the travel inventories of the early 1960's, but, perhaps for reasons involving environmental impact, the trend is apparent now and growing in intensity.

One of the basic assumptions of many transportation planners is that travel patterns and characteristics inventoried in an urbanized area will remain constant for a 15- to 20-year time span. Evidence on Oahu indicates that this concept is not (or at least is no longer) valid. It appears that travel patterns and modal-acceptance characteristics do change with time.

The Moanalua situation is an example of a transportation plan caught in the midst of change. People on Oahu are not rushing to get on transit today; they have not in the past. But, their goals are changing, and all indications are that people on Oahu will accept transit more readily in the future than they do now. As the acceptance rate goes up, need for new freeways should go down. This phenomenon of changing goals and acceptance characteristics is normal and must be built into the planning process.

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action strategies and environmental values

introduction

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At the HRB Summer Meeting, a 4-member panel was given the assignment of bridging the gap between the work of compiling and analyzing data on the environment within transportation corridors and making decisions about development that will be allowed to occur in those corridors.

Their assignment does not say that models, such as those described in this report, are not beneficial in guiding decisions on location, design, and construction. Models are essential in assisting planners and administrators to organize and systematically consider the great and varied mass of data relating to transportation programs. But we do need to be reminded that the success of models depends as much on how well we have defined our values as on how we order and assign priorities to them.

This panel, therefore, was concerned with the basic values represented in 3 types of natural and man-made environments that have constituted unusual problems for highway planners and administrators: wildlife resources, parks and outdoor recreation facilities, and historic landmarks and preservation sites. Panelists were asked to describe briefly the nature and needs of the particular environmental resources with which they work and to relate these values to strategies for ensuring that these needs will be considered in transportation plans.

In a way their observations necessarily are 3 variations on the general theme—or strategy—of reconciling the demands of a modern urban industrial society with the needs of the ecosystems that the natural environment supports. This general theme, which underlies all action strategies for environmental quality, frequently is referred to as our "environmental ethic."

Vermonters are justly reputed to have refined this ethic to a fine point in both their public and private lives. It is fitting that the secretary of Vermont's Agency for En-

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Sponsored by Task Force on Highways and the Environment.

vironmental Conservation presented an overview of this general viewpoint concerning man and his environment.

conservation: an overview

Robert B. Williams
Vermont Agency of Environmental Conservation

I have been asked to perform the difficult task of providing the panelists a conceptual framework by using as a basis Vermont's landmark laws and experience with them during the past 2 years. That which is occurring in Vermont is not really much different from that which is occurring in the rest of the nation except for 2 elements:

1. We appear to be farther ahead than other states in making a realistic public commitment to environmental quality. We have action programs in all areas, most particularly in control and review of land use in both general and special categories.
2. Vermont is taking this action before major environmental catastrophe has struck and before it has become too late to do too much more than simply make a bad situation a little better.

As I see it, Vermont's commitment is attributable to 4 environmental principles. The first is a growing appreciation that for every action there is a reaction. That rule applies equally well in environmental matters as in physics. It is a new application of a common law, and it is gaining wide recognition from the public as well as from the committed professional. I need not recount the trends in public concern for the impact of highways. It is no longer simply a matter of evaluating environmental impact of the construction of a highway corridor. People want to know what the secondary effects will be: Where will development be stimulated? What kind of development will it be? What will development do to scenic quality? What will it do to the ability of a town to provide basic services such as police protection and solid waste disposal?

What is happening in Vermont is also based on Barry Commoner's environmental "law," which states "that there are no free lunches"; everything has its costs, and those costs must be weighed against the benefits. Developers in Vermont can no longer lull the apprehensions of communities by telling of the wonderful benefits that their development will bring—more taxes, more economic activity, more growth. The state has encouraged its communities to now ask developers and the towns themselves to perform this exercise of cost-benefit analysis. A good example is the recent controversy over an east-west superhighway from New York to Maine through Vermont. The consultants painted rosy pictures of the tremendous economic benefits that would accrue to Vermont from such a road. The costs were discounted or ignored at local, regional, and state levels. But, Vermont looked at some of the costs and found them too high. The proposal was rejected.

The third thing that is happening is grounded on the realization that environmental quality is not simply aesthetics or unpolluted air and water and is not simply the matter of protection of natural resources or fragile specialized areas. The environment is a composite of everything surrounding man—natural and man-made—and is not limited simply to physical things but encompasses all systems—social, governmental, and economic. And, on this matter, Vermonters are asking questions that pertain to the total environment. What will this development do to the town's fiscal condition? What will it do to the political or social characteristics of the community? How will it affect the region?

Finally, an ethic of wise stewardship for this and continuing generations is developing. Where is the community going? Where is the state going? What is it going to look like, not just tomorrow, but 30 or 40 years from now? Vermonters are looking at development projects no longer in isolation but from the perspective of the future. They are asking whether continuing development of a certain nature is consistent with community objectives for the long term. They are asking about the possibility of aggregate or serial consequences. It is not merely the presence of one gas station or drive-in stand but the continual inexorable sprawl of many that will lead to strip development and the destruction of public intent and investment in the initial highway. On this basis, development is being refused or redesigned even though it might satisfy all traditional natural resource conservation standards.

Vermont is now trying through the application of these public principles to seek balance between economic growth and the aspirations of Vermonters to maintain the state's environmental quality. We are upholding our belief in Vermont's unique environmental character through a number of environmental protection laws and a comprehensive land use control and planning law. It is somewhat of an experiment—that we have to admit. No other state has attempted such commitment in so radical and far-reaching a manner. Whether the new public ethic regarding its environment can survive the challenges of the future remains to be seen.

Perhaps it would be helpful to have an outline of some of Vermont's programs particularly as they relate to the planning, review, and approval of transportation systems.

Vermont, contrary to popular belief, has for some time exercised considerable control over many aspects of land use under state standards and administration. Since the 19th century, many types of buildings have been subject to state approval for water supplies and sewage disposal systems. Subdivisions were subject to minimum standards as early as 1965; the state has regulated water quality since 1949; and Vermont's efforts to control roadside advertising began in the early 1940's.

However, as in many other states, 1970 was indeed the year of the environment for Vermont. A concentrated legislative effort was made to modernize existing laws, to enact new laws covering previously inadequately controlled land uses, and to recognize the executive branch to enable coordinated and balanced administration.

Thus, for instance, state control was asserted over mobile-home parks and campgrounds; the water quality law was substantially revised and a permit system authorized; and the Agency of Environmental Conservation was created to which natural resource programs and their administering departments, ranging from forest land management to air quality control, were transferred.

It may be safely said that any land development of any significance—commercial and industrial developments, subdivisions, apartment buildings, or the increasingly popular condominiums—is invariably subject to state control and review under one or more regulatory programs.

To a very large extent, land use controls are related to physical capability of the natural resources to support the proposed use such as proper sewage disposal, provision of water, and prevention of soil erosion. Only in the case of projects that are very large, located in areas experiencing accelerated development trends, or that involve radical alteration of land form or existing land uses does state review involve broader considerations such as assessment of impact on schools, fire and police protection, and area capability.

The most significant and far-reaching legislative action in 1970 was the passage of Act 250 creating the state Environmental Board and district Environmental Commissions. Under this law, state control is asserted over virtually all land development activities—commercial, industrial, residential, and subdivisions—of any significance within the state. Without question, this law and the program mandated by it are the most advanced in the United States and are having significant impact on the quality and character of land development.

Because of its novelty and newness, considerable misunderstanding still prevails concerning many of its features and the administrative procedures that have been initiated for its implementation. On the other hand, except for isolated instances, Act 250 has been accepted, and responsible land developers have respected and, in fact, benefited from the program objectives and criteria.

The determination of whether a land development project is subject to Act 250 is frequently complicated, and it is impossible to summarize accurately the jurisdictional provisions of the law. In brief, the following land uses require Act 250 permits:

1. Land development for commercial or industrial purposes, other than agriculture and forestry, under 2,500 ft elevation, if on a tract of land of more than 1 acre (43,560 sq ft) or if in a municipality with permanent subdivision and zoning ordinances of more than 10 acres;
2. Any residential project involving 10 units or more including any other units owned or controlled by the developer within a 5-mile radius;
3. Subdivision of land into 10 or more parcels, each of which is less than 10 acres, including any other lots of less than 10 acres owned or controlled by the subdivider within a 5-mile radius within a continuous period of 10 years beginning April 1970;
4. Any development at 2,500 ft elevation or higher; and
5. Any project for state or municipal purposes involving more than 10 acres.

The Environmental Board has by rule declared that development occurs when the first man-made change is made to the land, and a permit is therefore required even before any site preparation, construction of access roads, and the like are undertaken. Vermont law requires that prior to recording a deed a transferor must certify on the Vermont Property Transfer Return that the subject property either complies with or is exempt from Act 250. The law provides for criminal penalties for development or subdivision of the land without a permit. If there is a dispute as to whether a proposed project is subject to Act 250, a declaratory ruling from the Environmental Board may be requested.

Act 250 specifies that no application may be denied unless it is found that the development will be detrimental to public health or general welfare. In addition, the act specifies that certain affirmative findings must be made by a commission or board before a permit may be issued. Criteria under which a project is reviewed may be divided into 3 categories: (a) natural resources capability—water and air pollution, sewage disposal, water supplies, and soil erosion; (b) long-range resource utilization—local, regional, and state plans, aesthetics, and historic and ecologically fragile areas; and (c) human resource capability—roads, municipal services, and education facilities.

For the purpose of providing evidence in these categories to support affirmative findings, the burden rests on the applicant for categories 1 and 2 and on opponents to the proposal for category 3. Although the law precludes denial of a permit for reasons based on criteria specified in the third category, reasonable conditions may be imposed.

The commission frequently finds that in order to make favorable findings on all criteria, permits must be issued with conditions. For example, permits have contained conditions such as requiring the applicant to submit landscaping plans (aesthetics); to obtain a subdivision permit from the agency (proper sewage disposal); or to phase development over a specified period of years (impact on schools).

Act 250 created the Environmental Board composed of 9 members appointed by the governor with the advice and consent of the senate. It has 5 principal functions.

1. Administrative: The board, under its general powers, has the responsibility of administering itself and its subordinate district commissions and the authority to establish rules of procedure.
2. Regulatory: The board has authority to promulgate regulations establishing standards under the 10 criteria specified in the act. So far, the board has promulgated no regulations other than administrative rules and procedures and standards pertaining to distribution lines. In practice, the board and its commissions have accepted the standards of the various state agencies administering categorical programs such as the subdivision regulations for sewage disposal and water and air quality standards of the Agency of Environmental Conservation.
3. Quasi-judicial: The board by statute is empowered to hear appeals from the decisions on land use permit applications of district environmental commissions. By statute, appeal hearings before the board are de novo, and therefore any issues relevant to the application may be reheard. Proceedings before the board are of record, and consequently formal administrative rules of procedure pertain. Appeals from board action are to the Vermont supreme court.
4. Planning: Under the act, the Environmental Board is mandated to prepare an interim land use capability plan. This plan was officially approved by the governor on

February 9, 1972, and is effective until July 1, 1972. However, board policy enunciated in that plan will continue to be used as a guide in evaluating land use proposals. Two other plans are called for by 1973: a state capability and development plan and a state land use plan. Both plans must be approved by the governor and the Vermont general assembly.

5. Enforcement: Act 250 empowers the Environmental Board to institute legal action to prevent or abate violations of the act or of board regulations. In addition, the Agency of Environmental Conservation in conjunction with the board is empowered to institute suits for restraining orders and civil penalties. So far, most of the proceedings against violators have been handled administratively without court action.

There are 8 district environmental commissions that are subject to the control of the Environmental Board. Each commission has jurisdiction in specified counties. District commissions are composed of 3 members appointed by the governor. The chairman has a 2-year term, and the other 2 members have 4-year terms. Other than accountability to the Environmental Board, commissions are autonomous administrative hearing bodies subject to no control by any state agency. Their principal function is to entertain applications for land use permits under Act 250 and hold hearings. They must hold hearings on applications if requested by the applicant or any other party authorized under statute to do so. Since parties have a right to appeal to the Environmental Board, district commissions customarily permit considerable latitude in receiving evidence and testimony.

District commissions are served by full-time, paid environmental coordinators, who are responsible for commission administration, provide assistance to applicants, keep commission records, schedule hearings, and the like.

Act 250 is specific as to who has the right to be heard before district commissions. A district commission may, however, designate as parties other persons or agencies it feels appropriate or necessary. Statutory parties are the applicant, any unit of local government such as the board of selectmen or planning commission, regional planning commission, any state agency directly affected, and persons owning property adjoining that to be developed.

The Agency of Environmental Conservation plays an important role in Act 250 procedures, most particularly because it administers regulatory programs that overlap or complement Act 250, e.g., regulation of subdivisions. However, neither the agency nor any other state agency exercises control over commissions or the Environmental Board or participates in making final decisions or rulings on Act 250 applications.

To date many applicants have considered the agency to be an adversary. However, it is agency policy to provide assistance to applicants at any time it is requested. Preapplication review with agency staff frequently results in agreement between the state and the developer on project character and specifications. This obviously facilitates processing of applications through a district environmental commission or at least clarifies the issues that a commission will have to resolve. Many developers have benefited from consultations with state personnel even to the point of determining that their proposals as originally conceived were not feasible.

The agency has the same status and acts in the same capacity as any other party entitled to appear before a district commission or the board. It makes recommendations and comments and offers supportive evidence. Illustrative of the relation is the fact that district commissions have issued permits over agency opposition; in several instances, the agency has appealed from commission action to the board, and in at least one instance the board itself rejected agency recommendations.

The agency reviews applications in cooperation with other state agencies having expertise or jurisdiction by way of a review committee that meets biweekly. In most cases a consolidated state position is communicated to the applicant, other parties, and the commissions by filing agency prehearing statements. However, other departments do, from time to time, represent their own interests, most particularly the Department of Health and the Department of Highways.

If an application is of particular interest or presents special problems, state personnel, such as the agency's environmental advisor, may appear before the commissions as witnesses or advocates. In highly controversial cases, the agency prepares and presents a formal case under the direction of an attorney.

The state has attempted to stay clear of purely local issues and to confine itself to aspects of a project over which it has specific regulatory control such as water and air quality. However, where it appears that a development will have effects reaching beyond the locality, the agency may intervene and has done so when it was felt that a development would have serious adverse impact on a state road, scenic area, or stream. Usually the agency simply raises issues to alert the community and other parties of interest that an application may present problems that should be considered such as effect on local roads or school facilities. There have been a number of instances where towns have actively participated in the evaluation of land use proposals after having an issue raised by the state.

In addition to an Act 250 permit, a developer or subdivider usually has to obtain permits from other state agencies that have specific statutory jurisdiction. Although technically these agencies' jurisdictions overlap with those of the Act 250 agency, in practice, as mentioned above, district commissions have accepted their reviews as evidence of satisfactory compliance with Act 250 criteria pertaining to the same subject matter. Thus, for instance, if a subdivider obtains a subdivision permit from the agency under the subdivision regulations, commissions have found that the applicant has satisfied the sewage disposal and water supply requirements of the act; and if a subdivision permit has not been obtained, an Act 250 permit may be issued conditioned upon the applicant's obtaining a subdivision permit. Except in unusual instances, the agency does not have any position on whether Act 250 permits should proceed or follow other permits as long as the applicant clearly understands and accepts that they must be applied for and the applicable standards satisfied.

Act 250 has been in effect a little more than 2 years. As of June 1, 1972, 812 applications had been filed with district environmental commissions, and 682 had been acted on. Of these, 27 were denied, mostly for technical deficiencies such as inability to dispose of sewage adequately. The other denials are largely attributable to poor planning or application preparation that could be or has been remedied by modification of the proposed project or development of more comprehensive engineering analysis.

I would like to cite several observations relative to our Vermont experience. The course we have embarked upon is not easy; there are many levels of perception among the citizens of our state. All do not wholeheartedly agree with the primary environmental ethic. Many applaud the principles and decry the programs that bring them into practice. Government itself resists some of the organizational changes necessary to administer these programs. Fair, equitable, and competent administration requires time-consuming dedication and patience from our staff members. Our role is by necessity educational as well as administrative; the innovative nature of our programs means that the latter cannot proceed without the former. In reaching for these novel solutions, we have created some problems, and now we are in the process of rectifying mistakes, upgrading our techniques, and refining our input.

But through it all, Vermonters, from the executive level down to the municipal, believe that their environment deserves a higher priority than it has ever received. Our commitment to a quality environment demands no less than vigilance, energy, creativity, and consistency of belief that is exemplary and forward-thinking. I believe we have put this ethic into practice in Vermont, and I hope this will serve as inspiration to the rest of the country.

biological values

Lewis A. Posekany
Wisconsin Department of Natural Resources

Since 1953 Wisconsin has had something akin in principle to Vermont's Act 250. At that time the legislature modified existing (state, county, and local) road statutes to include the then Conservation Department in the agencies to receive formal notice of actions. It quickly became apparent that a specifically designated means of contact between both agencies was necessary, so we designated a highway liaison team of a district engineer and an experienced conservationist who was acquainted with and worked within the district. The district engineer's charge was to protect the environment while building and upgrading the road system. The conservationist's charge was to prevent material damage to fish and wildlife. When the field team was unable to agree on a plan, matters were to be referred to me. In the course of some 15 years, only 3 cases were not resolved in the field, and during that time the entire Interstate System in Wisconsin was planned, designed, and built—in some cases through very fragile environments. For example, any stream that is crossed by I-94 and is less than 30 ft wide is a trout stream of as high a caliber after construction as it was before.

How do we protect these fragile units? We could do so through our many laws. Wisconsin adheres strongly to the trust doctrine for navigable waters, and we could probably arrest contractors or enjoin the Department of Transportation. But you will note my charge was to prevent material damage to fish and wildlife. I have yet to see a roadway built that did not do some damage to some habitat, but in Wisconsin that damage is minimal because the transportation and natural resources departments at the local level planned it that way.

Sometimes plans go awry, of course, and occasionally the game warden may have rather firm words with a contractor or even the project engineer. And occasionally the conservation member of the liaison team leans too heavily on the design expertise of his highway counterpart without really spelling out how a particular niche could be damaged, and then we lose something valuable.

About 3 years ago, the 2 departments by agreement formed an environmental liaison committee consisting of members of their top-level administrative staffs. This group is designed to prevent trouble, discord, and dissension at both field and staff levels and to air problems at an early date. To date it has worked remarkably well.

The Department of Natural Resources found the correlation, collating, and integration of its numerous and sometimes rather separate (or independent) disciplines into one position required the creation of a district impact coordinator. That coordinator consults with all appropriate agencies before commenting on an environmental impact statement for a proposed project.

In addition, the legislature created special statewide integrators. A prime example is the Natural Resources Committee of State Agencies, which handles research on runoff nutrients and salts, special procedures to minimize construction damage in colloidal "red clay" areas, weed and brush control, and statewide interests in matters such as the rather rare projects of the U. S. Corps of Engineers.

Also, local individuals and groups such as the elected Conservation Congress look to our district staff for advice and counsel on proposals ranging from dam construction to highway development. In addition, the Scientific Area Preservation Council has a trained staff of botanists and ecologists who look with jaundiced eye on those types of proposals. Similarly various independent organizations such as the Southeastern Wisconsin Wetlands Association, Nature Conservancy, Trout Unlimited, and many others look to the Department of Natural Resources for information and counsel.

Thus, our highway liaison team, having learned sometimes by bitter experience and hindsight and always by team appraisal, is in a position to weigh and evaluate most of the probable effects on the environment of any proposal to change the physical characteristics of a particular environmental niche. In turn, the district highway engineer and his staff have learned that their counterparts are there not to stop them but to keep things from going wrong.

Something one must see to believe is a district engineer proposing a new corridor through a heavily wooded area and finding that his natural resource counterpart heartily endorses extensive cutting because an overage stand of poplar is involved. Similarly, one should see the shock the district engineer exhibits when he proposes borrow pit lakes and is asked what he is trying to produce—boating ponds, reflecting pools, or fishing lakes? To him a lake is a lake! He is horrified to find that Wisconsin's fertile waters will not keep a reflecting pond reflecting long because a crop of aquatic plants will develop or that our harsh winters require a fishing lake to be 20 ft deep if winterkill is not to be a problem or that lakes that produce duck habitat will not necessarily produce fish. But after working with the conservationist for a number of years, the highway engineer learns either by his own experience or by advice from his predecessor that "these people" know what they are talking about.

In addition, they are backed by an experienced technical staff and top administrators who are prepared to go to court if necessary. Thus, for the past 17 years Wisconsin has in effect carried out the spirit if not the letter of the National Environmental Policy Act long before that act existed.

recreational values

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U.S. Department of the Interior

The human need for recreational areas is a function of many factors such as population density, health, amount of leisure time available, and individual genetic makeup and social values. The specific motivations for recreation can be a social occasion, a need to escape from pressures, an attraction to an outstanding resource, or a desire to learn or relearn about nature. Whatever the motivation or the type of activity or area, our increase in numbers and our ever-urbanizing life style create an urgent need for establishing and preserving recreational amenities so that people—especially those in cities—can recreate (more properly pronounced re-create) and maintain a sense of balance and well-being away from surroundings that are increasingly artificial and in which they are less and less self-sufficient.

Highway planners are involved with recreation values in both positive and negative ways. The positive aspects include provision of reasonable and necessary access to recreation areas or of highways for pleasure driving. The negative aspects arise primarily from situations where someone took too little care to avoid imposing the physical presence of a highway in or near an area that should have been kept in a more natural state or where too much access caused an area to deteriorate from overuse.

I would like to propose three action strategies relating to recreational and aesthetic values. Two involve areas of conflict between those values and highway programs, and the third involves an area of more common goals.

1. The first and most straightforward strategy is simply to avoid highway alignments that degrade recreation resource areas. The Federal Highway Administration has within the past year or two developed administrative procedures to carry out the intent of the National Environmental Policy Act of 1969 and Section 4(f) (as amended) of the Transportation Act of 1966. The impacts of those pieces of legislation and pertinent court decisions are just beginning to be felt, and it is hoped that the incidence of highway projects affecting publicly owned recreation, wildlife, and historic areas will drop significantly. The values of recreation areas cannot be quantified in monetary or other terms that allow one to numerically balance them with highways in a benefit-cost ratio or other mathematical mechanism. Recreational resource values must be judged subjectively on the basis of their social merits and the degree to which retention of such areas is in the best public interest.

2. The second strategy concerns not recreation but aesthetics in general. It is that aesthetics and geometrics often do not mix, and aesthetics should occasionally take precedence. Examples of situations I have in mind are (a) projects in which a row of trees or some other natural feature must be removed or degraded not so that a roadway can be built or widened but that requirements for obtaining federal-aid funding can be met or (b) projects in which deep cuts must be made so that an existing roadway can be replaced by one having a higher design speed.

I understand that the geometric standards used for federal-aid funding and other purposes are contained in a publication of the American Association of State Highway

Officials called the AASHO Blue Book. If I may be permitted a small sacrilege, I would like to question the breadth of thought that has gone into the Blue Book and geometric standards in general. It is a rather sensitive area, for highway safety has been awarded sainthood by so many. My views involve the question of how far society is obligated to go to protect the individual against his own negligent conduct or that of others. Drivers impaired by alcohol or by other conditions, speeding, and inadequately maintained vehicles are nonhighway factors leading to accidents. Is it because of those factors that geometric standards are as rigid and inflexible as they now are? Could there be situations where we should tolerate that row of trees or that winding road because the retention of desirable aesthetic values outweighs the lower safety factor? I think there are. I would encourage highway engineers to mull over that idea when they put on their AASHO hats and sit in session. I cannot speak for the Department of the Interior on the question of balancing accident potentials against aesthetics, but my own answer is, "Yes, I am willing to live with the knowledge that compromising geometric standards without altering other factors such as degree of speed enforcement or vehicle design will cost in terms of accidents and human suffering. But the retention of aesthetic values affects a vastly larger number of people and is worth that price."

I do not mean to be arbitrary on this point at all or to give you the impression that I have gone off the deep end for "poor" highways. I do urge, though, that highway engineers give thought to the degree to which they pursue geometric standards and consider whether in a wider view more discretionary latitude should exist in providing for natural beauty and aesthetic values. It seems to me that an undue share of the burden for highway safety is being assumed by highway planners, with the result that geometrics has been pursued beyond a reasonable point.

3. My third strategy relates to pleasure driving—the use of highways and byways for recreational purposes. Driving for pleasure is one of the forms of outdoor recreation in greatest demand today. The Outdoor Recreation Resources Review Commission, which was established by Congress in 1958, reported that in 1960 driving for pleasure was the most popular outdoor recreation activity in the nation. We can say with reasonable certainty that it will probably be among the most popular outdoor activities through the year 2000. The preliminary results of the Federal Highway Administration's nationwide personal transportation survey showed that 33.3 percent of automotive travel is for social and recreational purposes, including vacations, visiting friends and relatives, and pleasure rides. Even after mileage by persons wishing to "make time" is discounted, there remains an appreciable amount that is driven each year by people who are not in a hurry and who view their drives in whole or in part as recreational experiences. So the third action strategy I offer is to consider what should be done to provide greater pleasure driving opportunities.

During the years 1965-67 the then Bureau of Public Roads conducted a study of scenic roads and parkways. The proposed scenic road system was not implemented; it was expensive and placed too much emphasis on road construction and not enough on scenic enhancement. In the Department of the Interior, we view pleasure driving as a recreation activity and are more concerned with the scenic corridor through which travelers pass than with the roadway itself; the roadway is simply a means to an end. Why not shift the emphasis in meeting pleasure driving needs from road-building to preserving and enhancing the corridor that travelers see and to emphasizing the natural and historic values of the area? We can all think of some pleasant secondary or possibly even primary roads we have traveled that would be worth preserving for such use.

Aspects to be considered in planning such leisure driving facilities—which would have to be limited to only a few of America's byways in each state—include preserving scenic corridors through easement or other means, developing complementary facilities such as trails and picnic sites, documenting historic or other heritage areas, and controlling traffic volume and speed. As indicated earlier, the engineer would have to leave intact that row of trees or that winding roadway and to rely on speed limit enforcement as the means of safety control.

To summarize, I propose action strategies with respect to recreation and aesthetic values:

1. Avoid highway alignments that would degrade recreation resource areas;
2. When aesthetics and geometrics do not mix, occasionally give precedence to aesthetics; and
3. Consider what should be done to provide greater pleasure driving opportunities.

historic and prehistoric values

Joan E. Freeman
State Historical Society of Wisconsin

Interest in preserving historic and prehistoric sites has been increasing in recent years. That may be partially due to increased mobility of the population. More people visit restored historic sites throughout the country and become more interested in local history. Urban sprawl also increases concern for both the physical and cultural environment. People in urban areas are more vocal about destruction than those in rural areas simply because change is more rapid in the urban areas.

It is impossible to establish guidelines as to which sites need protection because personal views vary. Local people may be concerned about the destruction of Indian mounds, for they feel that the mounds are a local asset. A study of all mounds in the state may show that a particular mound group is not highly significant. However, both state and local views must be considered before changes are made in the land.

For environmental impact statements that must now be written for federal-aid highways, historic and prehistoric sites must be evaluated if they are in the path of a highway. Sites listed in the National Register of Historic Places have prime consideration because they have been declared to be of national, state, or local significance.

All states are working as fast as possible to list and evaluate sites for possible inclusion in the National Register. There are many types of historic sites ranging from houses that are still standing and Indian burial mounds to historic and prehistoric sites that have long since disappeared beneath the farmer's plow. As an archeologist I am more attuned to those sites that now appear as a corn field, a pasture, or fallow land. I feel that those nonvisible sites are more easily neglected than others. There are no written records by Indians as to the location of prehistoric sites and often few written records on historic sites that are now partially destroyed.

Archeologists are hesitant to evaluate sites. They can make a few statements about a prehistoric site from surface collections of pottery and arrowheads, but only full-scale excavation can tell the significance of a site. Because archeological excavation actually destroys a site, we archeologists are perhaps more concerned about destruction by other means than are most people.

Another problem is that archeologists do not know the location of every prehistoric site in a state. In Wisconsin we have records of site locations, but only an exhaustive field survey will reveal the location of every site. Last summer we initiated the first survey for prehistoric sites for evaluation for the National Register. In 5 weeks, about 55 miles along the Mississippi and Wisconsin rivers in Crawford County were covered. About 70 burial mound groups and some 50 camp or village sites were located. Of these, 3 were felt to be of such significance as to be nominated for the National Register.

Although only 3 sites may be placed in the Register, there are many sites in the area that could be destroyed by construction. Archeologists are concerned about all sites because each site has a unique combination of artifacts that show the unique human activities that were carried on.

When there is highway construction and a site cannot be preserved we do have a backup plan in the highway salvage program, which makes it possible for data to be collected through excavation. Although the Federal-Aid Highway Acts of 1956 and 1966 provide for the highway salvage program, it has not been established by all states.

Those who are concerned with environmental impact statements should check at an early date in planning with agencies and people who are knowledgeable about the state's history. Important sites can thus be preserved, and many last-minute objections can be avoided. In each state there is a state liaison office appointed under the National Historic Preservation Act. Usually the liaison officer has channels of communication already set up. Many states have a state archeologist or someone who serves a like function. In each state there is an archeologist who is a member of the Society for American Archeology's Committee for Public Understanding of Archeology. That society, the Society for Historic Archeology, or local historical societies can be contacted about sites. Public Archeology, a book by Charles R. McGimsey, III, has a summary of archeological programs in each state and summary of state and federal laws concerning protection of archeological sites.

Many agencies and many individuals may have to be contacted by those preparing an environmental impact statement in order to protect those aspects of our culture that people value. Highway planners must find out who the experts are in their states and contact them early in the planning of each highway.

4 visual quality in highway design

preservation of landscape features

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Preservation of landscape features is not a new notion. "Roadside development must conserve, enhance, and effectively display the natural beauty of the landscape through which the highway passes." That statement was issued 40 years ago by a joint committee of the Highway Research Board and the American Association of State Highway Officials to define the subject of the committee's concern.

Although preservation of landscape features is not a new idea, it is certainly a more important consideration today then it ever was before. Why? For one reason, we have denuded the earth and reworked natural features in an unnatural way to the point that landscape features are so scarce that they must be given more than token consideration. They must be given an increasingly higher weight among the various considerations in locating and designing highways.

It is one thing to be aware of landscape features; it is another thing to do something about their preservation. What are some specific landscape features? What is the first step toward their preservation when a highway is planned?

An inventory of all natural and scenic features should be made during the early planning and location phases of highway development. If an existing highway is to be improved, the inventory should be made before design starts. The inventory should gather available data from other agencies and field check and expand those data as necessary. Field trips with natural resource personnel may also be necessary.

The landscape features to be inventoried will vary depending on the region of the country. Features may be large or small areas including individual features such as specimen trees or rock outcrops.

Woodland is important because it takes several generations to create. Once destroyed, it may never be reestablished. Not only do woodlands provide scenic beauty but they also aid highway drainage and abate, screen, or reduce air, visual, and noise pollutants. Farmland and changes in types of vegetation should also be noted in the inventory, and existing species of plants should be recorded for future reference.

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Every effort must be made to minimize any alteration to the natural state of streams, rivers, and other surface water features. They should be treated as inviolable features that are either preserved in their natural state or disturbed only with utmost care. Retaining the natural habitat for fish and wildlife in and along such waters is extremely important. Shortening the length of a meandering stream steepens the stream gradient, increases water velocity, and causes downstream troubles.

More consideration should be given to maintaining water courses in their natural channels rather than to placing them in man-made structures or channels. Bridges and in special cases viaducts may be required to retain streams and stream valleys in their natural state and to ensure the highway's compatibility with the natural environment. Artificial channels have been constructed for great distances in the past, and that action has resulted in immediate destruction of the natural ecology of streams. Such artificiality is in no way compatible with life systems and must be avoided as much as possible. Instead of solidly paving stream beds, vegetation, gabions, riprap, and other natural or near natural liners should be used. We must find ways to expand the use of vegetation in drainage courses. By not using natural means, we forego great absorption and energy-dissipation benefits that are provided by vegetation (grass, trees, and shrubs).

Wetlands, one of the most important natural resources, should be included in the inventory. In the past, some people thought of wetlands as wasteland and considered them to be of value only if they were filled in for some man-made use. Today we realize their great value as habitats for basic flora and fauna systems and as nature's aquifer. Their preservation is paramount.

Floodplains must also be respected as never before. As man continues to pave so many natural water-absorbing areas, the floodplains are needed more than ever. If a highway must pass through a floodplain, high viaduct sections should be used so that harmful effects on the water table will be minimized and plant and animal growth can occur beneath the structure. Permitting some sunlight and rain beneath the structure is beneficial and can be accomplished with separate structures for each direction of traffic. Along a section of Interstate highway in Baltimore, we are also placing viaduct structures at different elevations.

Special attention should be given to inventorying urban and suburban landscape features such as vegetation and near or distant views of lakes, rivers, or ocean fronts. Urban highways are usually thought of solely as hard-surfaced routes along which buildings are placed. But those highways provide a great opportunity to protect the environment and to provide open and green spaces so desperately needed in urban and suburban areas.

Adequate and generous acquisition of land is required to preserve landscape features and to create necessary buffer and transition zones between the highway and adjacent areas. Wherever possible, right-of-way acquisition, particularly in wooded areas, should not be limited by the requirements of construction but should include a natural buffer strip. Too often, the policy is to acquire only the construction area—a policy that may be detrimental to the environment and the environmental compatibility of the highway. We should think of highways as a means to provide open space and greenery and not just paths on which motor vehicles travel. Land acquired along highways should serve a dual purpose: scenic beauty to motorists and open space or greenbelts for the communities traversed. Costs for acquiring those scenic lands are a logical highway construction cost and should be treated as such.

The toll section of Interstate 95 in Maryland traversed scenic woodlands, but the state owned only a narrow band of land beyond the construction area. Very little of the natural beauty lay within that band. Five years ago, the state, realizing that some day the area between Baltimore and Philadelphia would be developed, started using toll funds to acquire scenic lands along the entire expressway. I am sure the public will appreciate the natural beauty along this road in future years and will realize the wisdom of that action.

Highway alignments often sever properties, resulting in remnants of land that the state is compelled to acquire in the initial taking. Those parcels may have little value to the original owner but may be very valuable to the highway department because they have scenic qualities, may be excellent buffers between the traveled lanes and adjacent properties, and may be good sites for future rest areas or overlooks.

In Maryland, a procedure was established several years ago to ensure the retention of any such land parcels until the Bureau of Landscape Architecture inspected the land and determined whether it has any existing or future landscape or scenic value. If it has, the parcels are included as part of the highway right-of-way. We have acquired several hundred acres of scenic land each year by this method.

The landscape features preserved during location and design must be protected during construction. That means protecting existing growth from excessive clearing or fire and protecting stream beds from equipment damage, pollutants, and sediment.

Sediment from highway construction can destroy streams, woodland, wetlands, and wildlife habitat. That destruction is unnecessary, for we have the technical capability to prevent it. Sediment control should not be the sole responsibility of construction personnel. In Maryland, we consider it to be a design and not a construction problem. The designer prepares the plans with control measures clearly shown and addressed in the specifications. In this way, we have done most of the job in advance so that it will be a relatively routine matter during construction.

Landscape features preserved during location, design, and construction should be given proper care during maintenance. Scenic views should be kept open by selective thinning, stream debris should be removed, and other maintenance should be performed to encourage or help nature.

Preservation of landscape features is not limited to highways on new locations. As time goes on, we will be providing fewer highways on new locations and upgrading more highways on existing locations. We must make every effort to preserve landscape features in the upgrading process. That may mean building of retaining walls, acquisition of additional right-of-way, or restoration.

We must maintain continual contact with all state and local planners and natural resource agencies so that we are aware of their plans and they are aware of ours. Only through such an awareness can we see beyond the roadway right-of-way to the entire environmental picture. We should be ready to give our expertise and to receive theirs. We often hear about the use of a team of various disciplines within a highway organization to develop a highway; we now have an opportunity to be part of a team to preserve the environment.

the environmental impact statement and visual quality

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Vollmer Associates

The environmental impact statement (EIS), which is required by law as a step in every federal construction undertaking and now in many state and local projects, shows signs of developing into one of the most misunderstood, misused, and inhibiting requirements in the history of public works. The EIS procedure was, unfortunately, needed to cure some very real ills. But as so often happens, the cure threatens to be more painful than the disease. That should not be the case.

The EIS is looked upon by a great many people today as a monster—a bureaucratic contrivance designed only to delay, block, impede, and frustrate progress. Admittedly the mandated procedure is a nuisance; and the tendency of a large part of our society to judge the worth of a book by its bulk leads to unnecessarily windy, turgid, jargon-filled prose works, the reading of which becomes a Sisyphean task. But the worst-tasting medicine at times does a great deal of good. Anything as tedious as the EIS procedure cannot be all bad.

It should hardly have come as startling news to anyone in the field of planning that any of man's works has a complex influence on his environment. Although we are generally confident that the change effected by our work will be for the better, there is always some gamble. I, for one, confess that a little element of risk adds spice to life. When we have the means of completely controlling the genetic character of our offspring, will we be willing to take full advantage of this godlike power? As a father, I feel that half the fun derived from the very uncertainty of the undertaking. Who wants to stay in a card game where every player can count on being dealt a royal flush each hand?

Creative genius has, more often than not, been characterized by an arrogant disregard of both natural and social history. Bernini, Michaelangelo, Wren, and many others ruthlessly scavenged the works of antiquity to obtain their own building blocks. They changed their environments with a bold and virile self-assurance. Although we may deplore their callous lack of regard for their predecessors, we must at the same

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time recognize that the Ice Age and Krakatoa—to say nothing of the deceptively gentle forces of wind and rain—have done more to change the face of the globe than have all of man's activities, planned or inadvertent.

Nonetheless, man's tools are becoming so powerful that a thoughtless use of them could lead to disaster—particularly if those tools get into the wrong hands. We must make every effort to prevent bunglers from exercising any measure of control, and in this connection the EIS may well prove to be an effectively restraining influence. The EIS procedure has the same sort of insane logic as those law-enforcement procedures that achieve the jailing of thieves and murderers on income tax evasion charges. The EIS may well turn out to be a blessing for all of the wrong reasons.

The planning process is immensely complex. It requires not only carrying water on both shoulders but juggling apples and bananas at the same time. It is characterized by involution and convolution. There are inevitably many false starts; wrong turnings are a constant peril of the road. There is little profit in the single-minded, straight-arrow approach. Effective planning demands talent and training, dedication and experience. It demands a high measure of professionalism and, despite some current misconceptions, is not to be undertaken lightly by amateurs. Unfortunately, there will always be the cooks who, when they fail to achieve a palatably grilled hamburger, cheerfully and hopefully turn their hands to Boeuf Wellington.

Cute analogies are, however, deceptive. They suggest a simplicity that is uncharacteristic of the demands of planning. The considerations that must be borne in mind from the outset defy enumeration. Each problem is different and involves different components of varying character and in varying degrees. No single formula of whatever complexity can be relied on to chart the solution. Every engineer, architect, or landscape architect maintains checklists in an effort to remind himself of the myraid influences that must be considered in the course of his work. These lists can never be all-inclusive. They are, at best, rough guides.

The environmental impact statement is, properly, nothing more than a documentatio of the process by which a plan has been devised. It is a history of each of the steps taken by the planner—a record of what his reactions were to the influences on his work as he perceived them. It is a design diary, not simply of events but of the philosophy and analysis that shaped the end product. It is an amplified checklist—a record of the questions and the answers.

The integrity of a finished structure cannot be evaluated solely on the basis of a final inspection. We need the inspector's records and certifications and the construction photos to reassure us as to the proper proportioning of the concrete mix and the presence of the invisible reinforcing steel. Even those precautions do not always prove adequate, but an occasional failure does not invalidate the whole process. Similarly, the EIS carries no enforceable guarantee. It simply documents the fact that we have tried.

Thus, to the experienced and qualified designer the EIS may be a bit of a nuisance, but it is hardly a major impediment to ultimate achievement. If our work has been properly done, there should be little difficulty in articulating simply and clearly the steps we took—however faltering and indirect they may have been from time to time—toward the final goal.

On the other hand, if the proper thought has not gone into the design process, no amount of ex post facto rationalization, couched in even the most eloquent prose, is going to disguise the essentially meritricious character of the end result. The need to make an EIS should serve to unveil the fakers.

In a famous little book on literary style, its perceptive author had the following advice for writers, and it also applies to engineers and architects.

> Young writers often suppose that style is a garnish for the meat of prose, a sauce by which a dull dish is made palatable. Style has no such separate entity; it is nondetachable, unfilterable. The beginner should approach style warily, realizing that it is himself he is approaching, no other; and he should begin by turning resolutely away from all devices that are popularly believed to indicate style—all mannerisms, tricks, adornments. The approach to style is by way of plainness, simplicity, orderliness, sincerity.

In highway design, as in writing, the visual quality derives from the integrity of the design. If the design is logical, straightforward, and professional, it will be successful. The environmental impact statement will have written itself.

The negative effect of the EIS procedure—the policing and the prevention of outrage—is important. But there are positive implications that far transcend its statement of immediate purpose. The EIS requirement constitutes a clear affirmation that a public works project is meant to satisfy more than just a basic function and emphasizes aspects of the design process that are too often thought of as only of peripheral importance.

Incidentally, at the risk of being accused of nitpicking, semanticism, and bearing in mind that a rose is supposed to be a rose regardless of its name, I wish that another title had been given the EIS. The word "impact" has generally an opprobrious connotation, e.g., the impact of a bullet, the impact of fist on flesh, of an automobile on a traveler. Perhaps "consequences" or "influence" or even "benefits" would have been better.

Because we should not undertake any work unless it does promise to provide clear benefits in terms not only of its stated functional objective but also of the environment, temporary disruptions are always to be expected. But even those eggs that do have to be broken first will show up, we hope, as a nourishing and palatable omelet.

I will wager without any fear of contradiction that the reason any of us discarded a suit of clothes the last time and bought a new one was not that the old one no longer gave us physical protection but that we no longer liked the style, fit, or general appearance and condition—all essentially aesthetic rather than purely functional reasons. The purchase of a new house is as likely to be inspired by considerations of comfort, looks, spaciousness, neighborhood, and outlook—all environmental and aesthetic qualities rather than functional.

Is it possible that we will consider relocating or reconstructing a highway not solely because it does not satisfactorily fulfill its traffic function but rather because it is an offense to the neighborhood it traverses?

Most of the highways we build are essentially replacements for older ones along time-honored travel routes. It may not be too much to hope that the day is not far off when we will consider reconstructing an existing highway not because it is unsafe, not because its physical condition is unsatisfactory, not because its capacity is inadequate to current and anticipated traffic demand, but because either it is of itself an offense to our aesthetic standards or because it relates in a less than harmonious way to its environs.

The idea is not a new one. I must confess that I have resented the shrill young voices that have so recently joined our old-timers' chorus. With a shocking lack of a sense of history, they believed they were singing a very new song and all but drowned out the rest of us. I have, however, come around to feeling gratitude for their aid. If the time for the idea of the highway beautiful has really come, the EIS is a small price to pay for it, and the smug self-righteousness of the young will be quite bearable.

aesthetics in structures

Arthur L. Elliott
California Division of Highways

Aesthetics of any kind is so subjective that we probably should have some ground rules before starting a discussion. There is truth to the cliché "Beauty is in the eye of the beholder." If you say something is beautiful, there is no guarantee at all that your listeners will agree. One hippopotamus looks beautiful to another hippopotamus. What is beautiful to you depends entirely on your taste.

During the Great Depression, there was the feeling that limited highway and bridge budgets could not afford aesthetic considerations. That situation has changed, and aesthetics has now become a design prerequisite for any kind of public structure. If it is worth building, it is agreed now that it is worth building aesthetically for it may endure a hundred years or so.

We still have, however, those who feel that it costs more to give attention to aesthetics. I get irritated when someone asks, "How much extra did it cost to make it attractive?" My answer is, Compared to what? The question assumes that there must have been some other cheaper, starkly plain, utilitarian design that would also have been satisfactory.

We should not try to put a price tag on aesthetics. A design that does not properly consider aesthetics is an acceptable solution to a design problem. How much extra does it cost to design a good-looking structure? In most cases the answer should be, Nothing. As proof that many engineers find it impossible to think aesthetically, the Federal Highway Administration sent out a questionnaire on June 5, 1972, that included a question on the cost of aesthetics and what percentage that was of the total cost. With due respect for the alleged superior intelligence in Washington, I think that is silly.

Let us realize that aesthetics is one of the prime design requirements ranking right along with adequate load capacity and safe geometrics. You should not seek to save a few dollars by skimping on the aesthetics any more than you would skimp on the load capacity. In facing a design problem, we start with the assumption that, as we design each part or as we lay out the whole, we are seeking to make everything look as good as we can.

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Of course, we now find ourselves right back where we started. Each of us has a different picture of what is good-looking. Back around the turn of the century, making a bridge look good meant adding fancy decorations, spires, big pylons, fancy benches built into the rail, or statuary on the rail posts. During that period, we also loaded our houses with jigsawed frills and decorations. That is not what I am talking about. Only on rare occasions do we put decoration on the structures. I am talking about a clean, simple, well-proportioned design. It may not be easy, but neither is it expensive. It is a matter of having everything fit and look well together so that the overall effect is pleasing.

The remainder of this paper does not concern huge or monumental bridges but the small, garden-variety stream crossings and separation structures and what can be done with them. Those small bridges really present greater aesthetic problems because one has so little to work with.

PIERS AND BENTS

First, let us consider what is going to hold up the bridge. Of course, there is nothing wrong with round or square columns or piers. But consider how much extra interest can get into a structure by using other shapes, for instance, tapered or wishbone columns. In creating new types, though, one should consider that special shapes cost more to form. If you can arrange to use the special forms several times on one job or on subsequent jobs, then the extra cost of making the special design will be minimized to the point that it becomes practical. We have already had some of our contractors renting and swapping column forms, and we hope to encourage a lot more of that. To do so, it is necessary to develop form shapes that can be easily adapted to various heights and widths.

Of course, columns must be the right size. If they are too small, they look like toothpicks. If they are to big, they look like feet on a St. Bernard puppy. You must consider how they look from all angles. Thin wall piers will practically disappear when looked at from the end and give one an odd, uncomfortable feeling of having inadequate support. The intangible feeling of rightness or comfort is an essential part of an aesthetic design.

If the height of the structure varies, you can use a sort of a golf-tee pier that can be raised or lowered and still retain its similarity. If there are going to be substantial width variations, a pier can be used that has a center panel or stripe running up the face that can be made wider or narrower.

As the columns get wider and taller, shadow, texture, or color can be used to break up the large flat faces and to make the columns more interesting. But you should consider carefully who will be able to see them. If the only person who can see the effort is the motorist who is going by at 70 mph, you might as well forget it. To benefit him, you have to apply your efforts to the end view of the piers so he can see them as he approaches. However, if there are people who live nearby and can see the piers every time they look out at the freeway, it will pay to make them attractive.

Special designs can be used to ensure that the supports and the superstructure are a pleasant combination. That was accomplished in our Old Miramar Road overcrossing just north of San Diego (Fig. 1).

Tall piers can be sculptured or they can be quite plain depending on the surroundings and the desired effect. In rustic settings the thin plain look is often desirable. The Caspar Creek Bridge (Fig. 2) on the California coast is one example. Another well-known example is the Europa Bridge at Innsbruck. If piers are high and have to be wide at the top, an attractive flare with a bit of sculpturing can be added. Some of the pier designs that look best are rather scaleless. In other words, you can build them 250 ft high on a grand scale for an 8-lane freeway or build them only 50 ft high close down over a creek for a 2-lane highway.

GENERAL CONFIGURATION

Sometimes the overall configuration of a bridge can be a problem. Through the years, tastes have changed. Years ago people did not worry too much about what a bridge looked like. At first bridges saved time that would have been spent fording the creek or waiting for a ferry or driving miles around. Later, bridges were considered to be monuments, either to their designers or to the politicians who claimed sponsorship. During this period the idea was to make them so big and overpowering that people would be impressed. Now bridges are designed so that people do not even notice that the bridge is there. When people cannot remember seeing a bridge, then you have succeeded. The basic principle is to make a structure compatible with its surroundings.

In California we have tried about every form of superstructure. We build mostly concrete box girders because they are cheaper than anything else. The most obvious form is a square-cornered rectangular box. It has a certain unattractive utilitarian appearance, so we have sloped the sides to decrease the apparent depth effect. Then we built some with round bottoms—one continuous curve clear across like a shallow bathtub (Fig. 3). They are expensive to build, however, and there are other forms easier to build that look just as good. For instance, if you slope the sides and then use large-radius fillets on the corners, you get almost all the advantages of the bathtub shape without the cost. All of these things help to make the superstructure look thinner. Most of our present-day box girders are prestressed, which in general takes about 25 percent out of their depth and makes them thinner and better looking.

There is one comparatively small touch that can be given where the superstructure meets the abutment to make a design more dynamic. The normal thing is to bring the girders into an abutment that has a vertical face (Fig. 4, top). We have been doing it for years; it is neat, but it does not say much. Now, try sloping the face of the abutment back at the bottom (Fig. 4, bottom). It need not be the whole abutment; it can be just a facia pilaster on each end. The span has a take-off point and seems to leap across. I think that one sloping line can do a lot for the structure, and it really takes very little extra effort.

RAILINGS

Railings are the visible part of the normal bridge and, in the past, represented the only place where a designer thought he could express his individuality. As a result we got some pretty fancy railings—designs, lamp posts, sometimes even benches where one could sit and watch the cars go by. Unfortunately, they were very costly, and many of them were not strong enough to stop a speeding bicycle. Now the principal function of a rail is to keep vehicles on bridges. Today, the chief complaint about railings is that they are too high and they obstruct the view. People want protection, but they also want to see. Each year cars get closer to the ground, and providing both a view and protection is harder and harder to do.

Because it saves fenders and prevents a lot of minor accidents, we are using the sloped-face or New Jersey rail on bridges and also as a center divider on bridges and closely spaced roadways. A car hitting that railing at a flat angle will be redirected without being damaged at all.

The railings still offer the designer some opportunity for individual design such as breaking up the smooth face with some interesting form or texture or a limited use of color. The end treatment of a rail is always a problem. We strive for something that looks good but that will not act as a battering ram should a vehicle run into it. Some sort of a bent-down or ramp-like treatment seems the best so far even though in certain cases a car might hit it on one side, run up onto it, and flip over.

It pains the aesthetically minded designer, who has tried to build a beautiful bridge, when we have to add a fence on each side to keep both young and old irresponsible people from dropping things on the cars passing underneath.

PEDESTRIAN STRUCTURES

We wrestled with the problem of pedestrian structures for a long time. Those bridges are narrow and should appear to be light and airy. Some of the early ones looked horrible, but they were utilitarian and worked in spite of their looks.

At first, we used stairways as access, but they could not accommodate shopping carts, baby strollers, and bicycles. Then we used ramps, but long straight ramps are not very attractive. Now we use a simple spiral, which can look very light and attractive when it is tastefully done.

Figure 1. Miramar Road overcrossing near San Diego.

Figure 2. Bridge over Caspar Creek ravine near the ocean.

Figure 3. Superstructure with continuous curve from edge to edge.

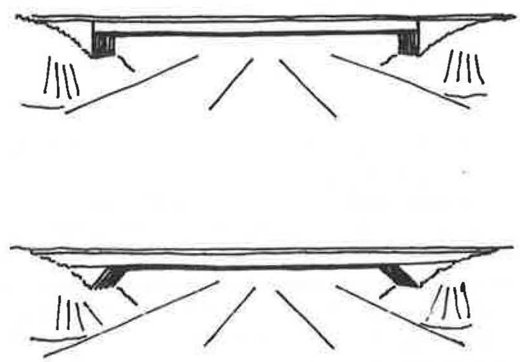

Figure 4. More dynamic design created by sloping front faces of abutments.

But, as with some bridges, we have to put a cage over the walkway, and we have been striving for some way to build a good-looking cage. The conventional approach to use heavy pipes and fittings as supports looks very institutional. We are developing a light wishbone support, and we hope it will look better. You have to round the upper corners of the cage and leave the center of the top open or the kids will climb up and walk across on top of the cage and use it as a trampoline.

WALLS

In connection with building structures, we must frequently build walls that are sometimes high and long. A huge face of concrete is unattractive and hard to hide. We have tried a number of things: striping, texturing, and checkerboarding; we have even built in recesses for planting (to the horror of the safety experts). But the cheapest, simplest, and satisfactory approach is just to use a few abstract designs scattered along to break up the big concrete faces.

SLOPE PAVING

Although not strictly a structural element, slope paving used around a bridge is certainly a factor in its design and appearance. The early tendencies were to pave the slopes entirely. That is costly and has a sterile appearance. Planting along the edges and leaving recesses in the paving for planting helped some. Next we pulled the paving in until it was right under the structure drip lines. Precast blocks and slabs and fancy textures were used, but still it was expensive and looked contrived.

Then we asked, What is it for, and why do we need it? Actually its function is to preserve the slope and prevent the earth from washing or slipping out from under the abutments. But for that, you do not need a lot of slope paving. So we went to a minimum of slope paving (we call it a bib) and paved only that portion of the slope in front of the abutment generally not reached by the sun and not suitable for plants. The rest of the area is used for planting. The appearance is much better than anything we have tried so far.

visual quality and the motorist

Larry Isaacson
Federal Highway Administration

This paper presents a framework that can be used by either a specialist or a nonspecialist to achieve better decisions concerning visual quality. It brings together the major elements of visual quality and their relation to the highway program. The implementing procedures and techniques used by various organizations will vary, but I feel that all will have some common ground.

This paper suggests that, if we can define the elements of visual quality, define the goals for desired visual values, and adopt the procedure normally followed by a highway agency to develop and advance a highway project, then we can use our resources to implement a program that provides visual quality at the correct time and to the degree necessary.

ELEMENTS

The elements include the motorist, who perceives and evaluates visual quality, the object, which imparts visual quality, and the context or environment, which surrounds or conditions both.

Because all cars have drivers but not necessarily passengers, it is the driver, performing his task, to whom primary consideration of visual quality will be directed. The health, welfare, and cultural bias of the driver and his reasons for driving are so diverse that it is unrealistic to attempt to consider them except in the most general fashion.

Objects within his range of vision include the highway, the roadside, and the views beyond the right-of-way. The most important object is the highway. All others should be subdued so that the highway remains visible, obvious, and primary. Some of those other objects we can control, and some we cannot. The objects that can be controlled are of greatest concern to highway professionals. Controllable objects include the highway, the roadside, and other elements located within the right-of-way. We cannot control the weather, the design of the vehicle, or objects located on lands beyond the right-of-way. However, the visual quality of the objects beyond the right-of-way can often be controlled by the way the highway is placed in relation to them. One can vary

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the motorists' visual access to environmental objects through many combinations of line and grade.

GOALS

I believe that the most important goal is the proper and safe behavior of the driver. Any development that conflicts with that goal, regardless of its independent visual quality, should be discarded in favor of the necessary requirements of the driver. A secondary goal is the enjoyment of the environment by the driver.

PROCEDURE

This discussion covers the general area of highway planning and provides an example of the type of visual quality information that should be gathered and evaluated at the planning stage of highway development. A similar framework can easily be developed for the functions of location, design, construction, maintenance, and operations.

The consideration of visual quality for the driver must begin concurrently with other highway planning efforts. Planning, in this context, is intended to include system and segment planning in a regional context. Usually the highway planning process produces corridors within which certain types of highway facilities will satisfy certain types of transportation needs. Obviously, the visual quality of minute details such as concrete scoring patterns are not of concern at the planning stage. What are elements of concern to the visual specialist at this time?

Motorist

The system proposed will give clues to the general characteristics of the drivers. Interstate users travel at high speeds and for long distances and look for directional information in an unfamiliar environment. An analysis of a particular highway in a particular state can give information necessary to make a rough analysis of characteristics and needs of primary highway drivers. Urban highways have high traffic levels and drivers need clear, concise information from signs. Distractions from the driving task should be minimized. Scenic views should be carefully selected to prevent dangerous driving conditions.

Objects

Lakes, mountains, rivers, cities, and forests are among the types of objects that should be identified and evaluated, if only in the most elementary fashion, in terms of their relative visual quality. Those resources, often regional in nature, have great value to the planner. A highway corridor can often take advantage of several regional visual resources if they have been identified and evaluated during the planning process.

Context

Mt. Shasta, in California, and the Atlantic Ocean along the eastern coast are examples of visual context. Mt. Shasta, in geographical spread, is small, yet its elevation makes it visually powerful from great distances. If the highway planner were to map the area within which sight of the mountain were possible, he would have identified a large geographic area. The object and the broad area from which it may be viewed, taken together, would provide several possible highway corridors. The Atlantic Ocean, on the other hand, is a vast eye-catching resource in terms of surface area covered. However, because a great portion of the eastern coastline supports either barrier dunes or cottages, both visually disruptive, the areas from which this large resource can be seen are extremely limited in number. The highway planner should recognize those problems as early as possible so that, if a solution is not possible during planning, they can be given attention by the location and design teams.

IMPLEMENTATION

In the past we have had to rely altogether on people to evaluate subjects. We now have an additional tool—the computer. Many things that a computer can do in terms of visual quality evaluation, especially in the areas of information storage, retrieval, and display, have only recently begun to be recognized. I believe it will take an expanded level of creativity on the part of all professionals in this field to properly blend the mechanical and the human systems.

Human System

People must be selected to do or to supervise the work related to visual quality. From the conceptual and managerial level, I do not believe that whether they are landscape architects, planners, engineers, or other professionals is as important a consideration as whether they are generalists or specialists.

The generalist should be able to relate the various degrees and levels of visual quality opportunity to other determinants in the highway planning process. When should the view from the road give way to the view from the community? When should visual quality be given a lower priority than community disruption? But more important, how can we achieve the highest level of visual quality for each facility on any location? These concerns require persons who have the broadest possible outlook and who do not become sidetracked with details. Such a person does not need to be recruited from a single professional background. That may be a heretical statement from a landscape architect, but I can support neither the proposal that visual quality as determined by any one professional group must dominate nor the proposal that visual quality itself is a more desirable goal than other economic, social, or cultural goals. Visual goals must be adequately considered, but decisions need not be made by one professional group.

Specialists who are capable of exploring all of the detailed visual alternatives are, however, absolutely necessary. Operating under guidelines pertinent to a phase or level of concern, they can thoroughly and expertly deal with the many opportunities offered by variation in line, grade, shape, color, texture, and other elements of visual design.

Neither generalists nor specialists operating alone can be expected to produce the product quality that is possible when they work together. That should not be interpreted as a recommendation for different people for different functions. Most people deal with both general and specific aspects of visual problems. It is important, however, that the correct role be played at the proper time.

Mechanical System

The mechanical system includes the aids that are necessary to present material for visual analysis and decision-making. Drawings, sketches, maps, and photographs may be supplemented today with various elements of computer science, cathode ray tube display, and gaming simulation. Many of these newer techniques will have to be modified to fit goals, organizations, and budgets, but I am confident that this can be done by creative people with a minimum of effort.

SUMMARY

The elements include the motorist, who interprets visual quality, the object, which imparts visual information, and the context or environment, which surrounds both in a given situation. The motorist is identified as a driver.

The development of visual quality goals is essential. The primary goal is to maximize and focus on safe driver behavior. The secondary goal is to provide visual enjoyment when that has not been considered in the primary goal.

Combining the elements and goals of visual quality with highway development practice can provide a rational visual quality procedure. During each activity phase, including planning, location, design, construction, maintenance, and operations, the applicable and appropriate characteristics of each element should be inventoried and evaluated.

All activities should be developed in anticipation of their actual implementation. Both a human and a mechanical system are needed in the evaluation of visual quality.

I believe this program is adequate to incorporate the necessary elements of visual quality into highway design for the benefit and enjoyment of the motorist. There are undoubtedly other approaches and more sophisticated methodologies for accomplishing visual quality. In any case, a clear, understandable, and implementable process must be established throughout the highway process by each highway agency to ensure an adequate level of visual quality for the motorist.

achievements in the visual quality of roadway design

B. H. Rottinghaus
Howard, Needles, Tammen and Bergendoff

There was a time in history when the occupations of the artist, the engineer, and the architect were combined into a single profession. Leonardo da Vinci and Michelangelo were not only painters and sculptors; they were also designers of bridges, plazas, and buildings. In those days a bridge or a plaza not only was functional but often served as an identifying feature and focal point of a community. There are numerous modern-day counterparts to the ancient achievements, such as the Golden Gate Bridge in San Francisco or the Papago Freeway in Phoenix, but it is most difficult to provide such examples of scenic splendor when one is designing, for instance, a rural highway connecting several farming communities.

During recent years, there have been criticisms of the visual quality of today's roads. Highway engineers have been described as individuals incapable of communicating in terms other than those of cubic yards of dirt. In response to such criticisms, highway designers have in the past decade implemented many innovative and attractive elements to enhance the visual quality of roadways. It is interesting, however, to compare what the engineering professors were teaching and writing years ago to what is being taught today. Most modern textbooks do speak favorably of the use of aesthetic design features in horizontal alignment; a surprising paragraph is found, however, in a textbook by Hickerson (1):

> More attention should be given to roadside improvement, beautification, and scenic effects. Unsightly objects should be removed, and ugly banks or slopes should be sodded or covered with evergreen vines, such as wild honeysuckle. Large and rare trees and shrubs found in their natural state on the right-of-way should be preserved; and along barren stretches of the road, trees should be planted. All shrubbery plantings along the inside edge of the highway should be limited to the dwarf varieties in order not to obstruct safe visibility.

Hickerson then suggests concepts such as the acquisition of extra right-of-way to preserve dramatic and scenic terrain for roadside development. What is surprising about

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Hickerson's statements is that they were written nearly 40 years ago! Indeed, in some ways his language is stronger than that found in today's textbooks.

It is difficult to explain, then, why it has been only during the last decade that some of the most dramatic achievements have occurred in the visual quality of highway design. No doubt the appearance of divided facilities, which lend themselves more easily to landscaping treatment than do 2-lane roadways, has something to do with the increased incorporation of aesthetics as has also the increased availability of funds for such purposes or perhaps the recently increased concern for the environment. Without speculating further on the reasons behind the achievements, however, I shall discuss examples of those achievements in the sections that follow.

Perhaps the simplest way to discuss visual quality is to divide the examples of recent achievements into 3 basic categories that refer to the class of individuals whom the achievements benefit: the vehicle driver, the passenger, and the nonmotorist. Each class of beneficiary presents to the designer a different set of opportunities and constraints.

VISUAL EXPERIENCES FOR THE DRIVER

A major constraint in offering a multitude of visual experiences for the driver concerns the need to maintain safe driving conditions. For example, in certain areas a line of sight must be maintained between drivers of vehicles entering a roadway and drivers of vehicles already on the roadway. Treatments such as sparse planting of trees in the space between the ramp and the main line can enhance the attractiveness of the approach without jeopardizing the safety of merging vehicles. That type of treatment creates another constraint for designers, however, in that safe setbacks for trees and other objects must be maintained. Figure 1 shows one means of accomplishing the setback without introducing a barren look. The use of multicolored rock, varying slope gradients, and a variety of shrubbery has created an attractive setting.

Another design constraint related to safety concerns that time span in which a driver may view scenery. A vehicle driver does not have the ability to gaze for long periods of time at specific objects adjacent to the roadway; he must maintain peripheral vision to the roadway ahead, and designers have taken advantage of opportunities to provide the driver with panoramic and sweeping views that can be seen at various locations over long stretches of roadway. Figure 2 shows how a wide median enables the driver to view the landscape without being distracted by oncoming traffic. The driver's view is further improved by the differing elevations of opposing lanes.

Figure 2 also shows how the designer has made use of horizontal geometry. Traditionally, engineers have avoided the use of highway curves unless necessary to match existing topography. In older types of design, long tangents were common, and their monotony was apparent. More recently, however, engineers have tended to use long reverse curves even in areas where topography does not require such treatment, as Van Riper has pointed out (2). Figure 2 shows that the use of long and gradual reverse curves not only is pleasing to the eye but also may tend to be less fatiguing for drivers. Safety and beauty are terms that can complement each other in highway design.

VISUAL EXPERIENCES FOR PASSENGERS

Passengers, unlike drivers, have the opportunity to look at specific objects directly adjacent to the roadway for longer periods of time. The highway designer can, by preserving or by enhancing the natural beauty of original features, provide such opportunities. In many cases, a visual amenity can be created through the use of natural elements such as rock formations in the right-of-way that can be left in place.

In addition to retaining a natural setting, in some cases it can actually be enhanced and a new viewing experience created. Figure 3 shows the gradual slope and improved shoreline that increase the natural beauty of a small lake and forest without introducing elements so foreign as to give it an urban character.

Figure 1. Obstruction setbacks do not need to look barren.

Figure 2. Long reverse curves enhance the driver's view and eliminate the monotony of long tangents.

Figure 3. Existing natural features such as shorelines can often be improved.

Figure 4. Urban parkways can be aesthetically treated.

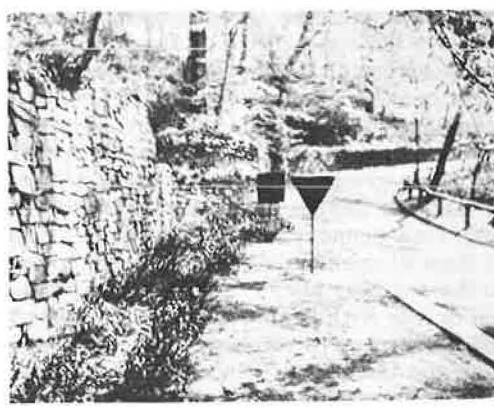

Figure 5. Attractive planting schemes and cobblestone walkways provide visual benefits to motorists and pedestrians alike.

VISUAL EXPERIENCES FOR NOMOTORISTS

Passing motorists see highway improvements for a relatively short period of time, but local residents must look at them daily. If poorly designed, they are a constant eyesore for an indefinite number of years. Designers have recognized this problem, particularly in urban areas, and have developed numerous techniques to deal with it. Figure 4 shows the preservation of the unique character of an attractive glade in an urban area; the use of a rock retaining wall, discrete signing, and the low wooden railing allow a parkway to blend easily into the natural setting.

Another example of providing attractiveness in an urban setting is shown in Figure 5; the use of cobblestones and planting refutes the notion that asphalt and concrete are the only materials engineers are capable of working with. What could have been a simple channelization project has become a desirable permanent feature of the community, and it accommodates pedestrians as well as motorists.

SUMMARY

This brief depiction of some of the achievements in visual quality during the past several years is not intended to be a comprehensive listing. I have attempted to show that highway designers have been and are capable of creating facilities that are functional in character, that retain features of the natural terrain, that introduce new and pleasant visual experiences, and that provide those experiences to drivers, passengers, and nonmotorists alike.

The noted architect Crosby pointed out that, from a distance of more than 400 ft, an object such as a building becomes part of the environment (3). To expand that thought, I would say that once a structure—building, bridge, or highway—has been built, its impact on the existing environment multiplies because it has become a part of that environment. It is a feature of the environment as permanent as a river or a forest.

That aspect of highway construction was recognized by engineers 40 years ago and continues to be recognized today. With each passing year and with each cubic yard of earth moved and replaced by concrete, the achievements of highway designers in preserving and enhancing the visual environment advance. The accomplishments of the past several years are only the beginning of a trend that will continue to improve the visual quality of transportation systems.

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5 effects of highway construction on the environment

effect of construction equipment vibration on nearby buildings

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In recent years, large-scale construction work has been increasingly carried out in built-up metropolitan areas. This construction work has entailed blasting for tunnels, demolition of obsolete structures, and activity of heavy construction machinery. When this work is carried out in the vicinity of existing structures, the ground vibration produced becomes noticeable to the inhabitants of the adjacent buildings. The question is immediately raised as to the damaging effect of these vibrations to buildings.

The question of the effect of such construction activity on buildings in general and on homes in particular became a public matter in the metropolitan Toronto area when the reconstruction of Highway 401 was begun in 1963. The necessity for this reconstruction became urgent when the tremendous economic and population growth of metropolitan Toronto caused such increased traffic loads that congestion occurred on the highways. The functional report on the proposed reconstruction (January 1963) quoted a traffic volume at peak periods of 85,000 vehicles per day, whereas the practical capacity of the highway was 48,000 vehicles per day at 45- to 50-mph operating speed. The functional report recommended expanding the existing 4-lane facility to 10 to 14 lanes throughout the section between Islington Avenue and Highway 48 (Fig. 1). In the course of the 10 years that the highway had been opened, that entire section had become heavily residential, especially from Bathurst Street, west of Yonge Street, to Warden Avenue in the East.

The widening of the road brought heavy construction equipment into residential areas and an increasing anxiety in the minds of many homeowners that vibrations resulting from operation of the equipment was causing structural damage to their homes. That anxiety was not unexpected, for individuals can feel vibrations that are a hundredth of the level required to cause structural impairment. Consequently, homeowners quite naturally attributed previously unnoticed plaster and mortar cracks to the effects of construction activity.

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The questions then raised by those events were, What level of vibration is in fact detrimental to structures? What levels of vibration are caused by heavy construction equipment operated in the vicinity of structures? Earlier vibration studies in most of the literature have been primarily concerned with the effects of blasting.

In the beginning of 1964, the Department of Transportation and Communications (then the Department of Highways) sponsored vibration studies with a view to establishing the actual level of the vibration from construction equipment. This program ran until 1968 and was extended to include measurements of vibrations from blasting operations carried out during the excavation of storm sewers. Prior to 1964, the department had already sponsored a demonstration bridge demolition project in conjunction with the National Research Council and Ontario Research Foundation. That project resulted in a study to examine criteria previously used to establish a maximum safe level of vibration that would not cause structural damage to nearby buildings.

Knowledge of those criteria and a means of measuring the vibration have been important to contractors and consultants involved in litigation resulting from damage claims; an objective assessment can be made of the situation only if measurements of vibrations have been made and critical levels have been established. Consequently, the various criteria that have been used to evaluate damage will be summarized.

VIBRATION DAMAGE LEVEL CRITERIA

Establishing a value of ground vibration at which damage occurs to nearby structures is not entirely a simple matter because there are 3 distinct types of ground waves that are generated (Fig. 2): longitudinal or compression waves in which low frequencies predominate; vertical waves in which high frequencies predominate; and transverse or shear waves that begin with high frequencies and taper off to low frequencies. Furthermore, knowledge of which is the important vibration parameter—displacement, velocity, or acceleration—had to be determined.

The first major study to establish damage criteria for residential structures was carried out by the U. S. Bureau of Mines from 1935 to 1942 (2). A damage criterion was defined as the magnitude of one or more quantities associated with the vibration impinging on the structure and, if exceeded, would result in some degree of failure within the structure. The tests undertaken by the Bureau of Mines were of two types: quarry blasting and forced vibration of actual buildings with a mechanical vibrator.

One of the objectives of the latter test was to confirm or disprove a hypothesis that is frequently advanced with regard to building vibrations: A forcing vibration at or near the resonant frequency of a floor or wall panel can cause destructive vibrations to build up, even though the level of the external vibration was not destructive in itself. The tests carried out with the mechanical vibrator were especially suited to determine that point by bringing the vibrator up to maximum speed and then cutting off the motor and allowing it to coast down to rest while signals were recorded from vibration pickups located on various panels in the structure.

The data from those tests were divided into 3 classifications, which are still used: major damage (fall of plaster, serious cracking), minor damage (fine plaster cracks, opening of old cracks), and no damage. Results of the tests are discussed in detail in another report (1). The authors of the Bureau of Mines report concluded that damage occurred if the level of vibration exceeded 1 g. Later studies (2) indicated, however, that this was rather an arbitrary figure.

Following the pioneering work of the Bureau of Mines, the next major contribution was a paper by Crandell (4), who was directly concerned, at that time, in establishing blasting limits that would enable contractors to determine a safe charge of explosives used in excavation work so that no damage was caused to adjacent structures. Crandell notes that, because a contractor may be confronted with the damaging effects on as many as 1,000 buildings during the course of a long tunnel excavation, it is not practical to measure the vibration within each structure itself, as was done by the Bureau of Mines. In that situation, the intensity of the ground vibration would be much more useful as an indicator of structural damage.

The theoretical details of Crandell's work are discussed in an earlier report (1). Crandell developed an empirical formula that gave the amount of ground energy produced by a charge of dynamite in terms of a measure of vibration level called energy ratio (ER), given by the square of the maximum acceleration divided by the square of the minimum frequency, as determined from seismograph records (units of ER are in ft^2).

Crandell's energy ratio is still widely used by the construction industry for determining upper limits for vibration from all types of construction activity. Crandell found that damage can occur to prestressed structures when an ER of 3 is reached: hence, the practice is to limit the ER to 1.

A major difficulty in establishing the energy ratio is in determining the frequency because, as Figure 2 shows, the ground wave frequency varies with time. Also, because the maximum acceleration occurs at a different time from the minimum frequency, ER is not useful in determining gradations of damage.

The most recent definite work in establishing damage criteria was that covered in two studies by Edwards and Northwood (5, 6). The first was performed in 1958 during the demolition of a number of houses in connection with the forming of a head pond for the St. Lawrence power project. Controlled blasting was carried out in increasing charge weights to determine the threshold at which damage occurred. The aim of the investigators was to find a reasonably simple vibration measurement that would provide a dependable indication of damage risk.

In that study, measurements were made of displacement, velocity, and acceleration for increasing weight of charges until the threshold points of minor and major damage were established. The conclusions reached were that there was a well-defined threshold level of vibration above which damage could occur and that peak particle velocity gave the best indication of that threshold, which occurs between 4 and 5 in./sec. The authors recommended that a safe limit of 2 in./sec peak velocity be established and that the charge equation $C^{2/3}/D = 0.1$, where C = explosive charge in lb and D = distance in ft, be used for normal blasting operations.

The most recent work has established 2 in./sec as the maximum vibration level to be permitted during blasting so that no damage should occur to nearby buildings. There is a possibility, however, that continuous vibration such as that from construction equipment has a lower damage threshold; some results from the continuous vibrator tests in the U. S. Bureau of Mines report also point to that effect. The tests sponsored by the department were designed to establish the velocity level of vibration from different types of construction equipment and to determine how the vibration varies with distance. These data can be used to made quick estimates of the effect of operating equipment at any particular locality.

Figure 3 shows the layout of the test site, a partially completed interchange at Highway 401 and Victoria Park Avenue (Fig. 1). Velocity pickups were mounted in pairs on aluminum blocks (nonmagnetic), which were located at specific distances apart and oriented to pick up vertical and longitudinal vibrations (the transverse or shear wave has been found to be usually less than those two).

Various types of equipment (Fig. 4) were run on a test path perpendicular to the line of pickups, and oscillograph recordings were made of the resulting vibrations. The data curves from those tests are shown in Figures 5 to 33. The equipment was also run at various distances from a field house, and vibration levels were measured at different locations in the house. Reference to those data curves and records enables the prediction of approximate vibration levels for almost any situation. The tabulated house vibration levels and the method of using the data are given in another report (1).

Throughout the tests, no vibrations resulting from construction activity were measured that approximated in any way the recommended maximum safe level of 2 in./sec peak particle velocity. The most severe levels encountered were produced by the vibrating compactor operated beside the field-house wall, where a peak velocity of 0.63 in./sec at 22 Hz (the vibrating frequency) was measured. Although the vibration level was only a little more than a fourth of the safe level of 2 in./sec, it was felt by the personnel conducting the investigation to be extremely unpleasant. Vibration levels

Figure 1. Reconstruction area of Highway 401.

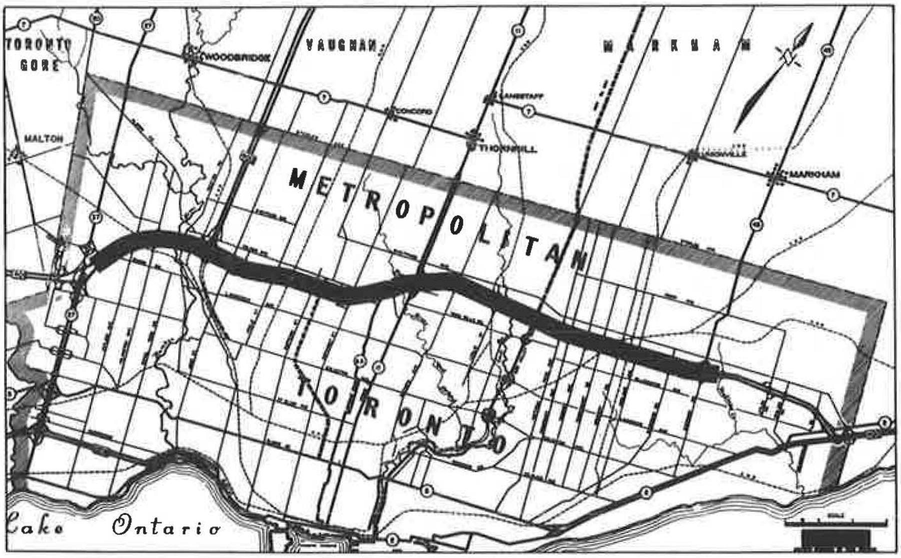


Figure 3. Field house and test area.

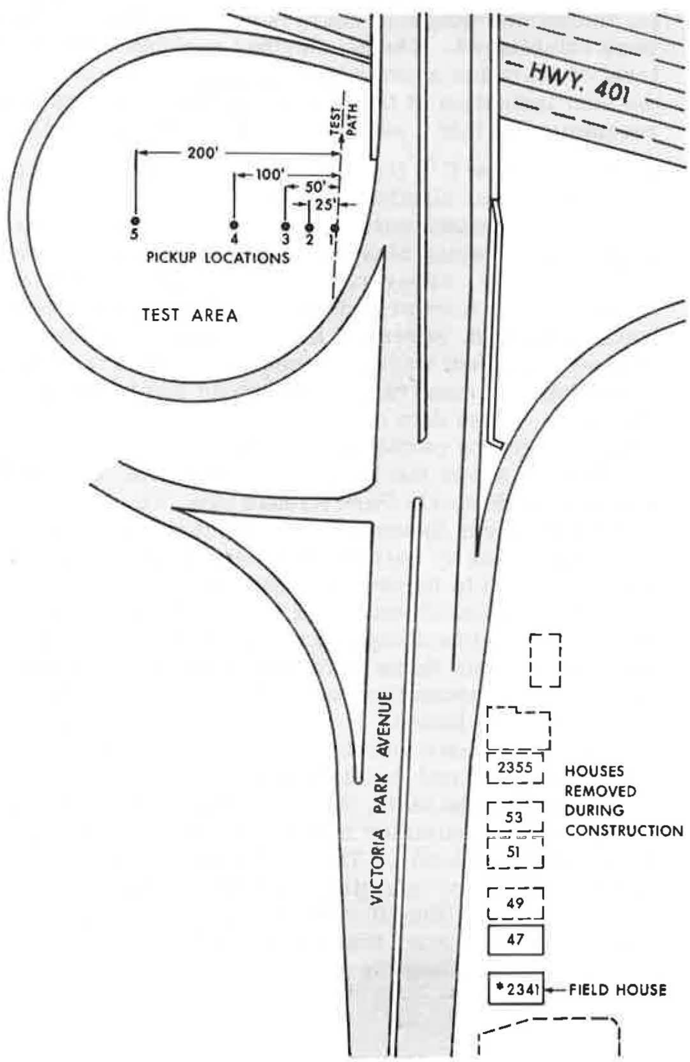


Figure 2. Ground waves resulting from vibrations and recorded simultaneously by seismograph.

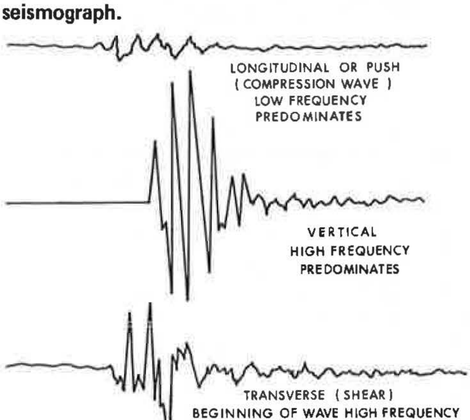


Figure 4. Construction vehicles used in vibration tests.

D8H Tractor (62,000 lb., G.W., 270 HP)

C6 Tractor (50,000 lb., G.W., 225 HP)

LW777 Grader (35,000 lb., 160 HP)

D4 Tractor and CF43 Vib., Sheepsfoot Compactor (Tractor 18,000 lb., G.W., 65 HP) (Compactor 12,000 lb., 1,400 to 1,600 vpm)

TS24 Earth Mover (91,000 lb., G.W., unloaded, 171,000 lb., loaded) (Front engine 398 HP., rear engine 207 HP.)

Figure 5. Vertical vibrations of D8H tractor passing—test 1.

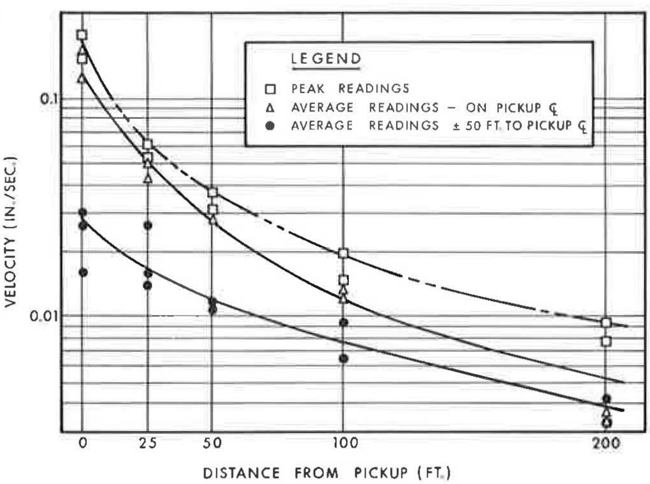


Figure 6. Longitudinal vibrations of D8H tractor passing—test 1.

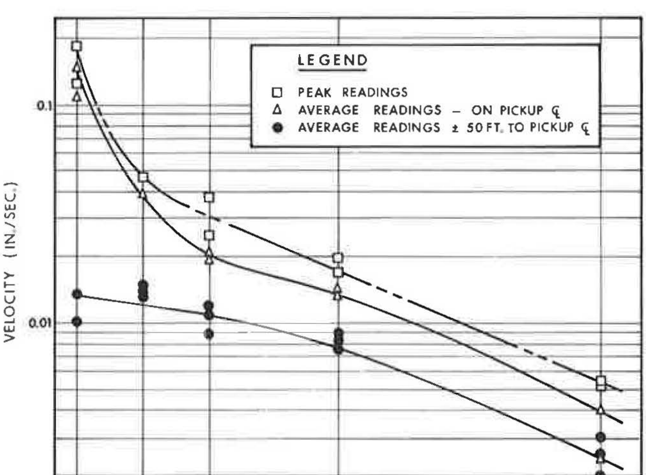


Figure 7. Vertical vibrations of TS24 earthmover slowly passing—test 2.

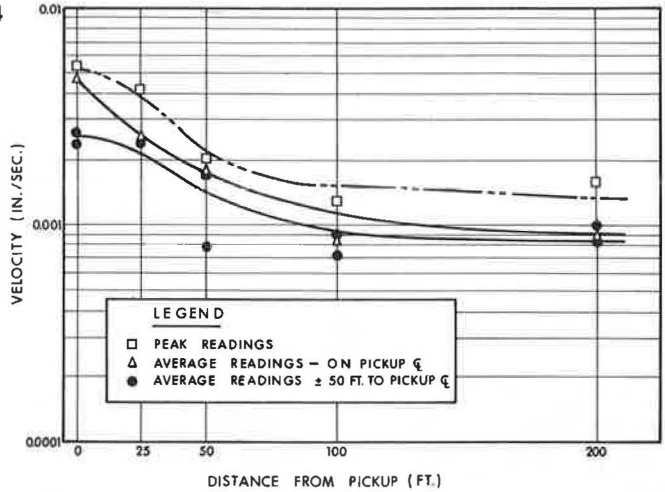


Figure 8. Longitudinal vibrations of TS24 earthmover slowly passing—test 2.

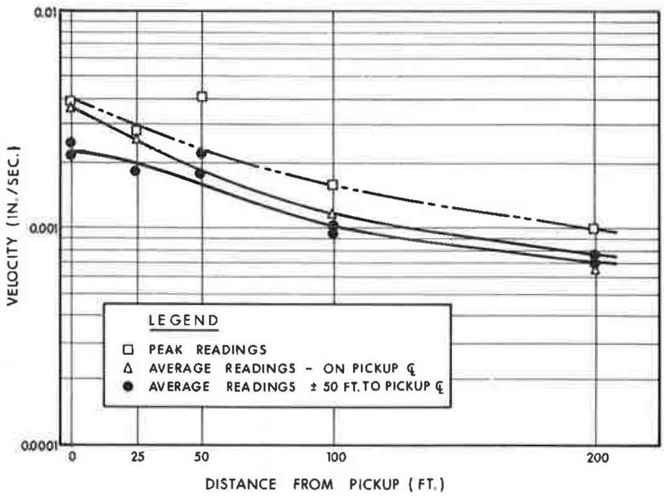


Figure 9. Vertical vibrations of TS24 earthmover rapidly passing—test 3.

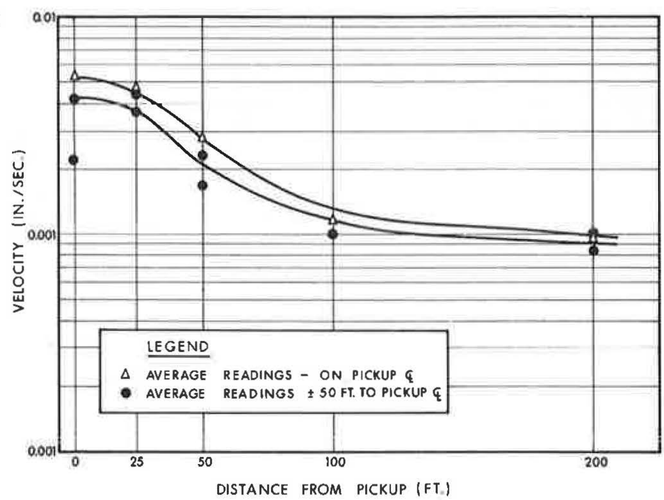


Figure 10. Longitudinal vibrations of TS24 earthmover rapidly passing—test 3.

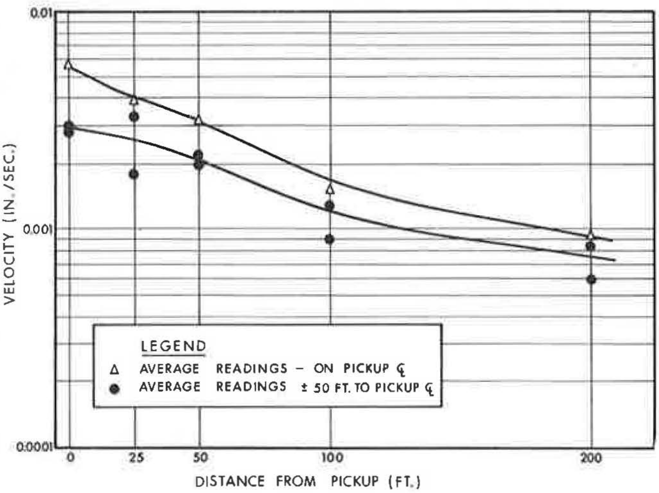


Figure 11. D8H tractor dropping blade to ground—test 4.

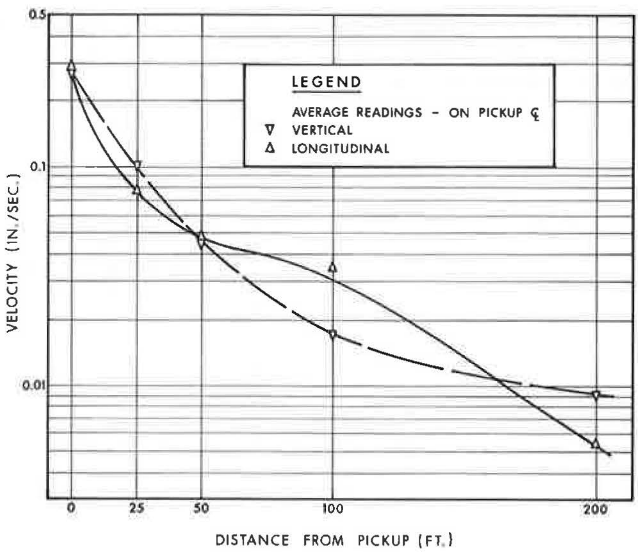


Figure 12. D8H tractor and TS24 earthmover passing but not in contact—test 5.

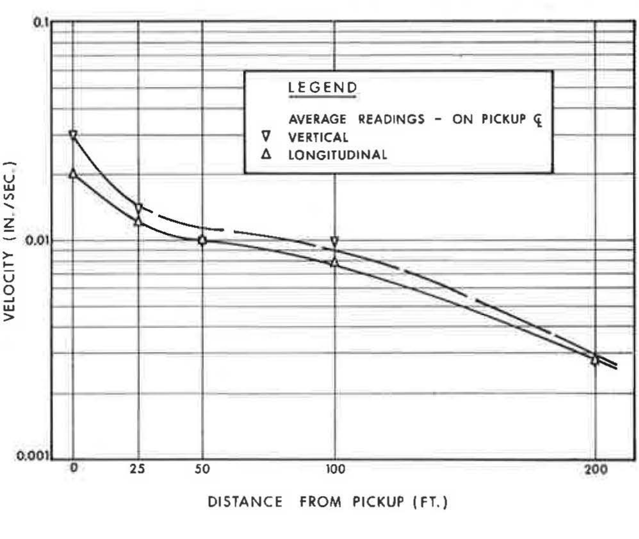


Figure 13. Vertical vibrations of D8H tractor not touching and TS24 earthmover scraping earth—test 6.

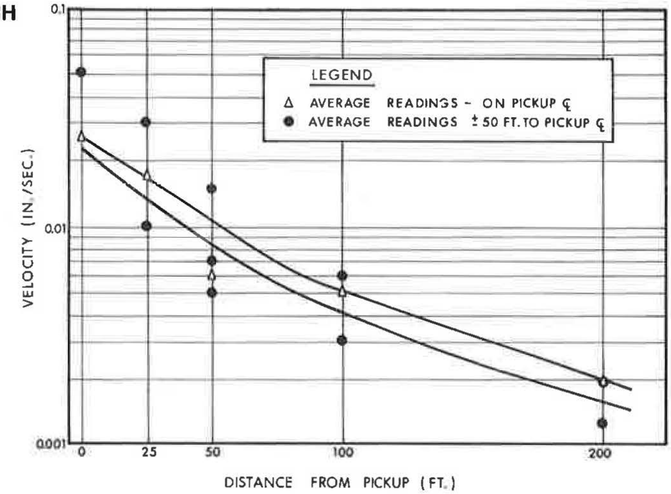


Figure 14. Longitudinal vibrations of D8H tractor not touching and TS24 earthmover scraping earth—test 6.

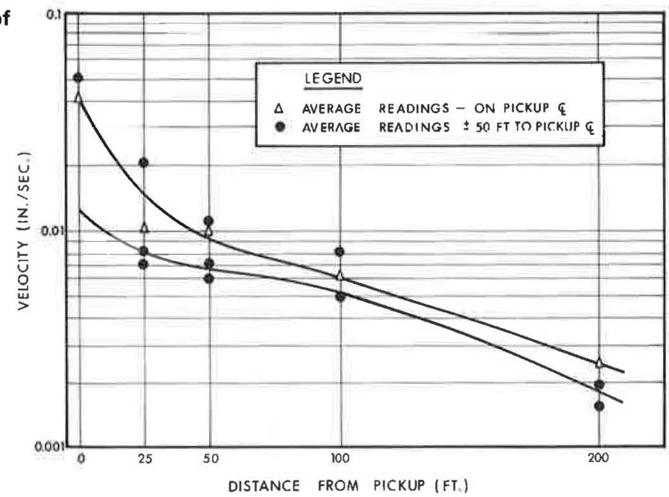


Figure 15. Vertical vibrations of LW777 passing in reverse and not cutting—test 7.

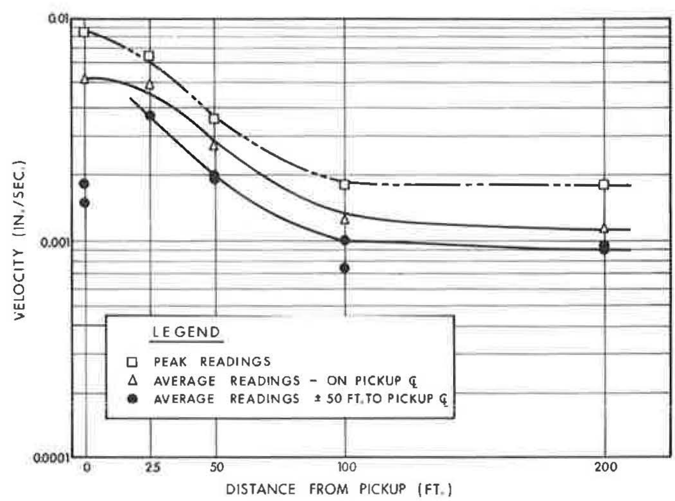


Figure 16. Longitudinal vibrations of LW777 grader passing in reverse and not cutting—test 7.

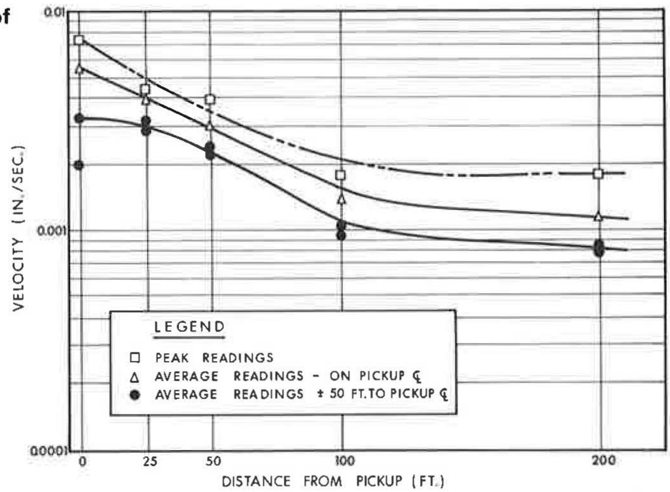


Figure 17. Vertical vibrations of LW777 passing forward and cutting—test 8.

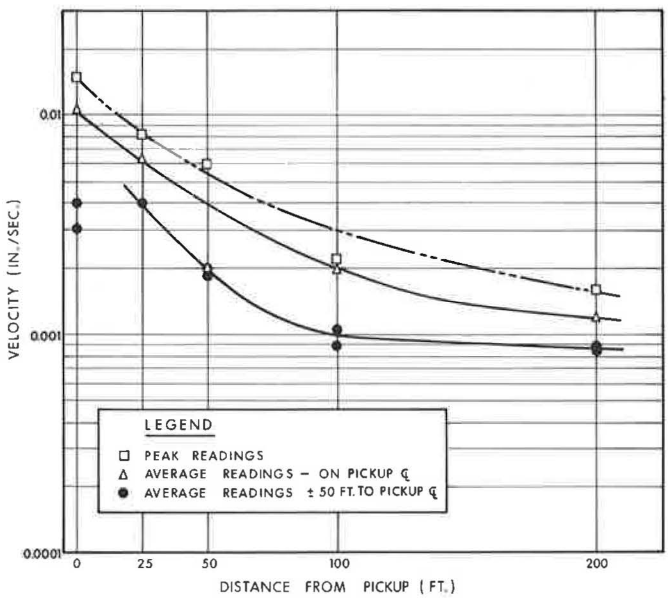


Figure 18. Longitudinal vibrations of LW777 passing forward and cutting—test 8.

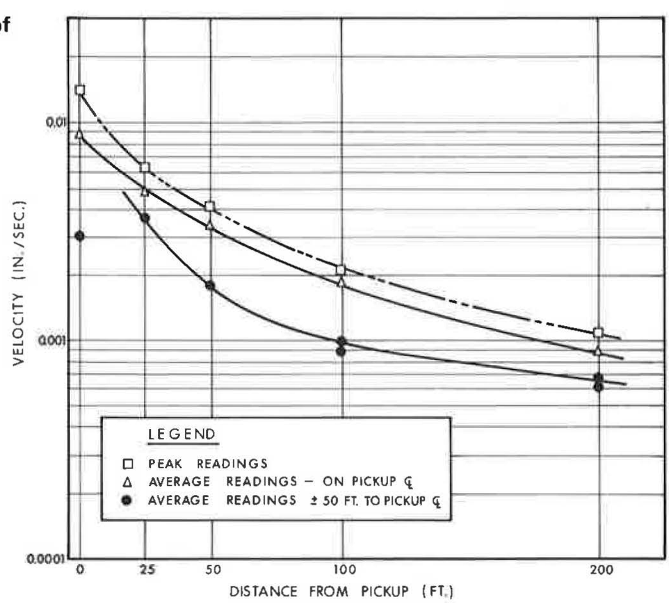


Figure 19. Vertical vibrations of C6 tractor pushing TS24 earthmover cutting earth—test 9.

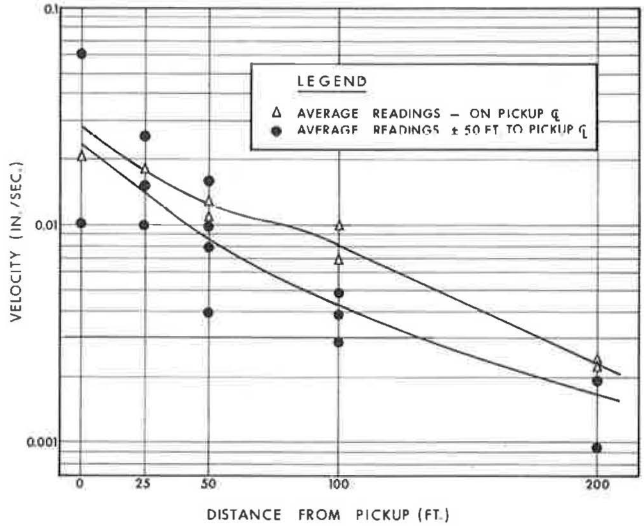


Figure 20. Longitudinal vibrations of C6 tractor pushing TS24 earthmover cutting earth—test 9.

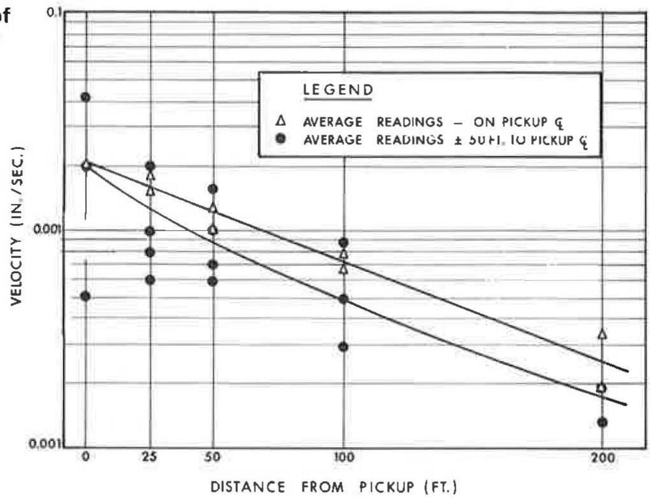


Figure 21. Vertical vibrations of C6 tractor slowly passing—test 10.

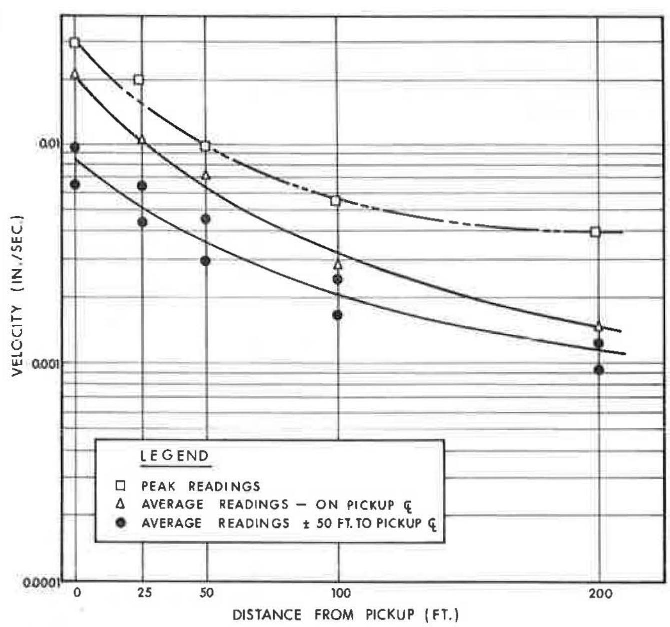


Figure 22. Longitudinal vibrations of C6 tractor slowly passing—test 10.

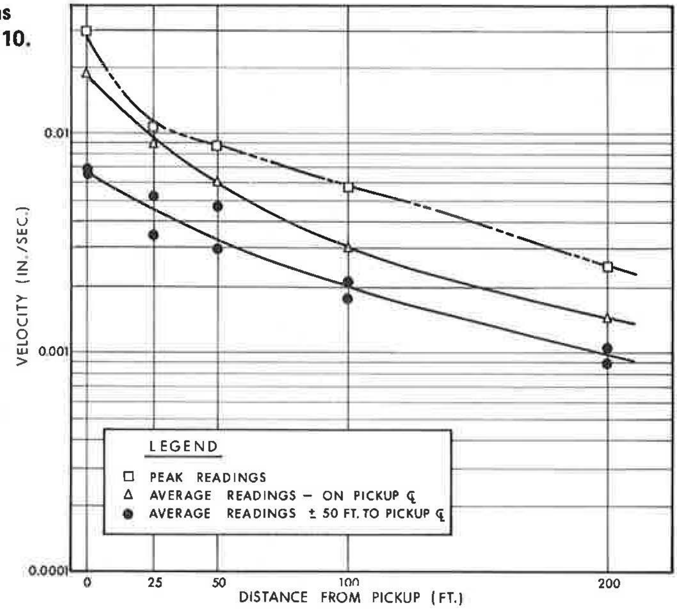


Figure 23. Vertical vibrations of C6 tractor rapidly passing—test 11.

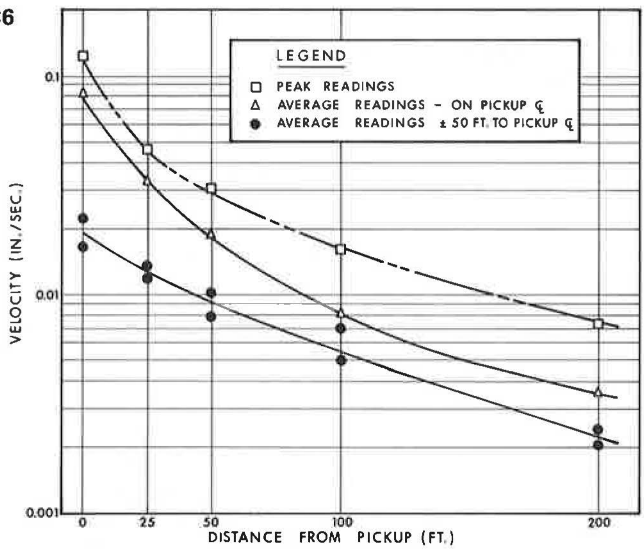


Figure 24. Longitudinal vibrations of C6 tractor rapidly passing—test 11.

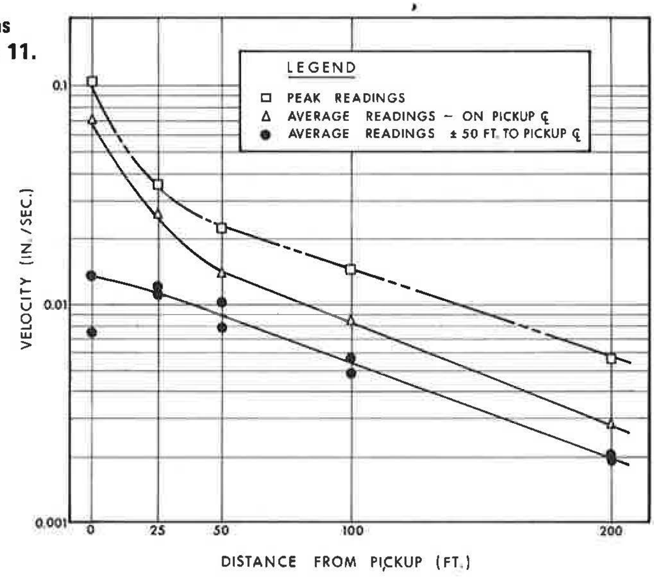


Figure 25. Vertical vibrations of D4 tractor with vibroplus sheepsfoot compactor not vibrating and slowly passing—test 12.

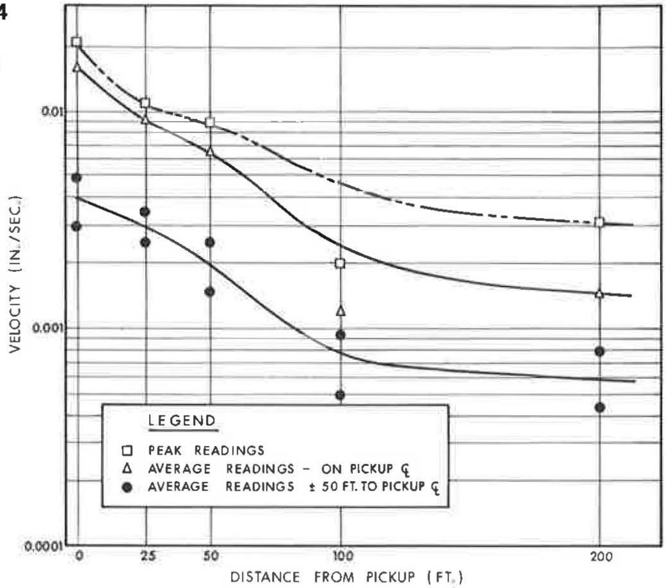


Figure 26. Longitudinal vibrations of D4 tractor with vibroplus sheepsfoot compactor not vibrating and slowly passing—test 12.

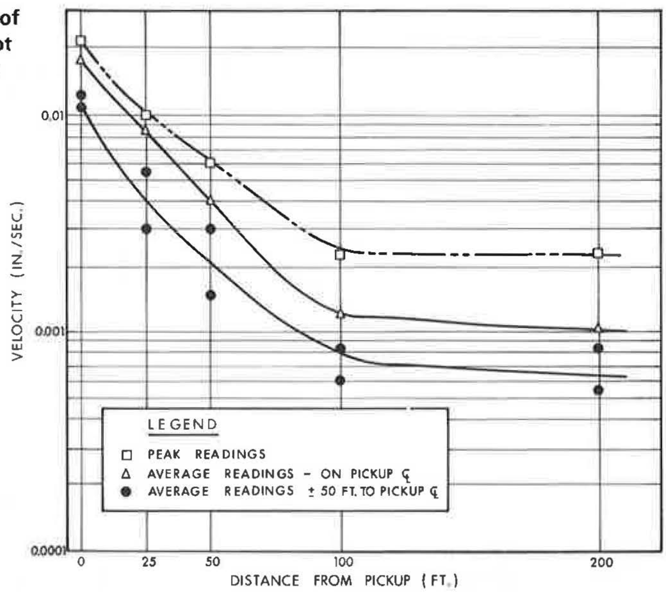


Figure 27. Vertical vibrations of D4 tractor with vibroplus sheepsfoot compactor vibrating—test 13.

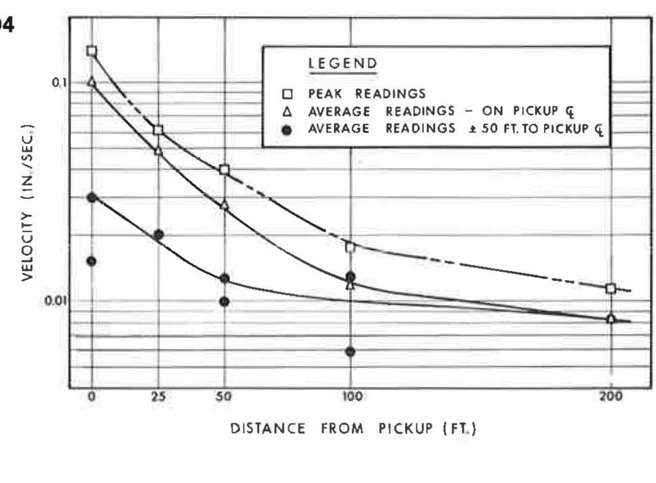


Figure 28. Longitudinal vibrations of D4 tractor with vibroplus sheepsfoot compactor vibrating—test 13.

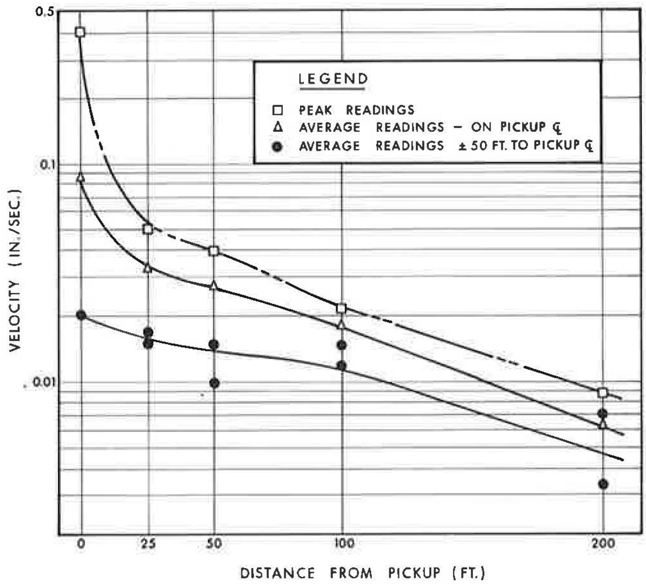


Figure 29. Stationary vibroplus sheepsfoot compactor operating opposite line of pickups—test 14.

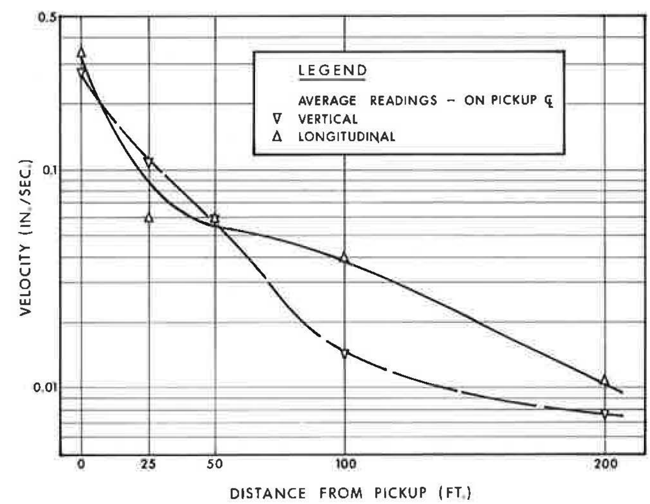


Figure 30. Vertical vibrations of D4 tractor slowly passing—test 15.

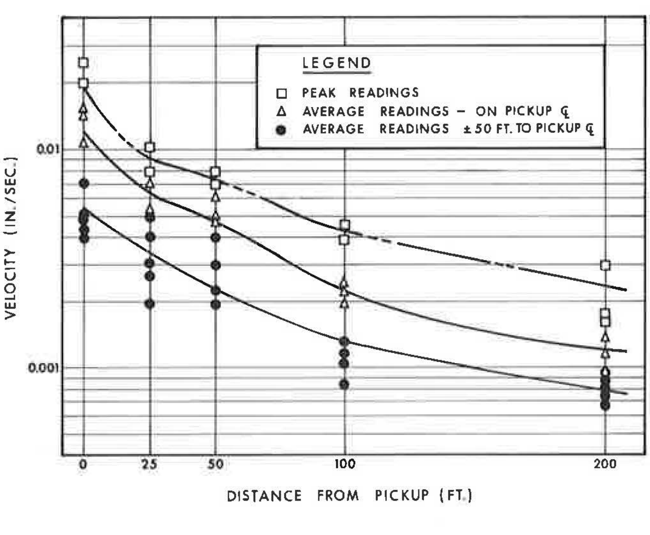


Figure 31. Longitudinal vibrations of D4 tractor slowly passing—test 15.

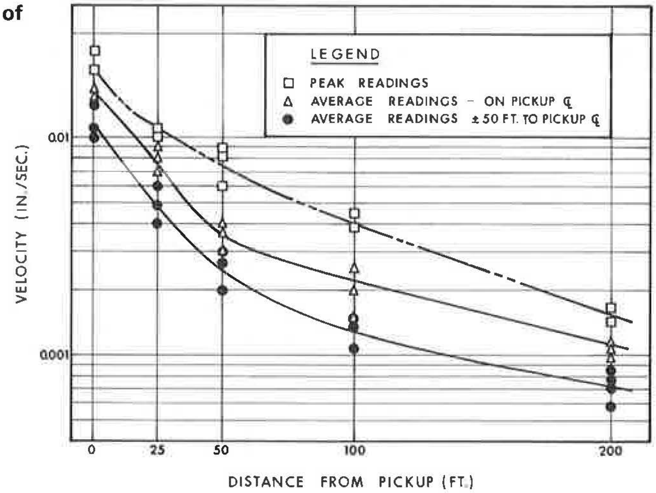


Figure 32. Vertical vibrations of D4 tractor rapidly passing—test 16.

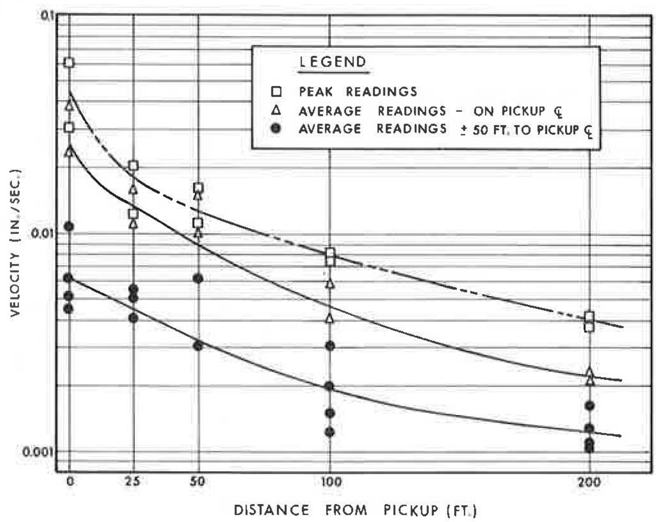
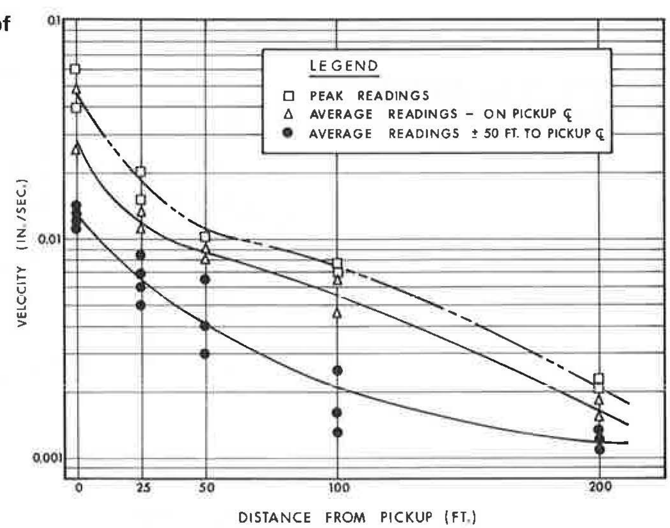


Figure 33. Longitudinal vibrations of D4 tractor rapidly passing—test 16.



from other equipment passes were all below 0.1 in./sec at 25 ft with frequencies between 20 and 30 Hz. Such vibrations were also subjectively very noticeable but much too small to cause any damage, according to the criteria reviewed.

With regard to blasting, however, the situation is very different. Blasting operations must be monitored by instrumentation, at least initially, to ensure that safe velocity levels are not exceeded. Details are given in the earlier report (1) on sewer blasting under a multilane expressway (the Queen Elizabeth Way) that caused fissures to develop in the road shoulder. Recordings established that the contractor was using charge weights that gave velocity levels of 22 in./sec. It is quite likely that, if blasting had proceeded under the roadbed with the same weight of charge, a cave-in could have resulted. Monitoring at this site was continued until the contractor was able to maintain a consistent velocity of approximately 5 in./sec, which, although high by residential criteria, appeared satisfactory for that operation.

Throughout those investigations, it was evident that a convenient, portable instrument for measuring velocity levels would be of value, and a portable velocity seismograph was developed at the Ontario Research Foundation to meet that need. Three-axes velocity signals are recorded on magnetic tape, and instant field readout is achieved by reducing the tape speed 10:1 and displaying the signals on a pen-chart recorder built into the instrument.

It was found that operation of construction equipment caused no damaging vibrations in nearby buildings, although the subjective effect of these vibrations could be unpleasant. With respect to blasting vibrations, it was found that theoretical values agreed reasonably well with actual measured values, using the formula developed by Edwards and Northwood (7). A need for portable instrumentation, suitable for operation by contractors and consultants, was found that embodied the velocity measurement principles used in the latest damage evaluation criteria.

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construction equipment: environmental tools for progress or destruction

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How man's activities affect his environment is probably the major public issue of the seventies. There are many definitions to the terms environment and ecology. In this paper we will use a fundamental yet inclusive definition, which is that ecology is the study of the interrelation between the various life systems of the earth to the end that man's activities will not upset the balance of nature and eventually destroy his own environment and perhaps himself.

Ecological concerns are expressed in many ways: elimination of pollution, preservation of natural beauty, slowdown of population growth, and elimination of possible hazards to life such as nuclear radiation, unsafe vehicles, and unsafe work places.

Environmentalists can point to a string of successes in stopping—at least temporarily—the construction of proposed major highways, electric power generating plants, airports, and countless small-scale construction projects on municipal and county levels. The environmentalists are now turning their attention to the contractor for his supposedly inattentive attitude toward pollution and particularly his housekeeping habits on jobs in urban areas.

Construction equipment manufacturers who provide the industry with its tools are also being given their share of attention. A host of new regulations and standards are being applied to construction machines through regulatory actions by all levels of government. Those new rules for equipment cover the full spectrum of environmental concerns—water and air pollution; noise abatement; and safety and health of the construction workers and the public who are on or near construction sites.

The proliferation of new laws and statutes directed toward construction equipment raises serious questions about the compatibility of those machines with the environment. Does construction equipment seriously and in large degree contribute to air and water pollution? If it does, what are equipment manufacturers doing about developing improved products to reduce pollution levels?

Some critics often count construction machines among the worst polluters. The environmentalists contend that earthmovers open up the earth and turn it into mud that

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clogs sewers and silts streams when it rains. They say the borrow sites and gravel pits dug by those machines become unsightly scars on the landscape. They say the smoke, fumes, and particles spewed out by asphalt batch plants are an intolerable nuisance and that crushing, screening, and washing processes of aggregate production plants are major contributors to air and water pollution. They point to the familiar blue-black diesel smoke appearing at times over typical construction sites and say machines powered by those engines are a source of harm and annoyance to the lungs and eyes of everyone who comes within range. They complain that the construction machines raise dust storms and create intolerable noise wherever they work.

Safety critics, too, have voiced concern about machines such as construction cranes. The big cranes that lift the heavy steel and pour the concrete on busy job sites do a marvelous job and rarely are involved in accidents. But even minor accidents with this equipment get headline notice in the press. Installing roll-over devices to protect operators of equipment such as bull dozers, front-end loaders, scrapers, and graders is a key safety issue. Soon federal law will require every piece of that equipment to be equipped with that type of safety unit.

In the current debate, how do manufacturers of construction equipment define the role they must play? The manufacturers are aware of the temporary inconvenience and discomfort created by various types of construction activity. Equipment builders recognize that construction projects can permanently alter the environmental and aesthetic values of localities. However, most of the latter problems concern land use and are properly the business of the governmental planning agencies. Similarly, good housekeeping practices on the job are the contractor's responsibility. We must leave selection of highway corridors and building sites to planning officials. For all practical purposes, we must leave choice and use of specific equipment and the environmental aspects of the specific job site to the contractors and to the local control agencies.

As manufacturers, we can continue efforts to design and build productive, long-lasting, heavy-duty machines. We can expand our concern and efforts to make them contribute less noise and air pollution and thus be less of an irritation to the community at the construction site. We can expand our efforts directed to machine safety.

How are manufacturers set up to get the job done? To do the job on a total basis is one of the prime reasons the industry joins together under the umbrella of the Construction Industry Manufacturers Association (CIMA). The association is composed of some 180 U. S. equipment and major component manufacturers who account for approximately 95 percent of the U. S. dollar volume of this multibillion-dollar construction machinery industry. The association is a central coordinating body for the manufacturing segment of the construction industry in the areas of safety and environmental performance standards; marketing data; government liaison; and liaison with other segments of the industry including contractors, distributors, and other associations.

CIMA exists because of the willing participation of its members in projects for public benefit and industry progress. Member companies have welcomed the responsibility to apply their expertise toward helping shape responsible and effective legislation and regulation that fully consider total social needs at satisfactory costs and compromises. Action taken by the association some 4 years ago to discharge that responsibility has, some believe, made it uniquely qualified to act as the spokesman for the industry in environmental matters.

That action consisted of organizing CIMA-member company experts into product-oriented committees to recognize and to promote the development of performance standards (1). The term "performance standards" refers to performance criteria for machine safety, protective devices, and the like as opposed to commercial standards that refer to capacity or production ratings or as opposed to design standards that refer to machine design. Currently there are 10 CIMA committees that represent a wide variety of construction machines and equipment.

In this entire matter of standards, completeness, clarity, and uniformity are extremely important and necessary considerations because of new, evolving safety and environmental regulations. Each new regulation can in some way influence engineering, manufacturing, and marketing procedures.

There is wide variation of environmentally oriented regulations that government agencies are writing and attempting to enforce at local, state, and federal levels. The city of Chicago in March 1971 passed an antinoise ordinance that sets specific noise limits on vehicles and machinery, including construction equipment. No construction equipment manufactured since January 1, 1972, can be sold or leased in Chicago if it produces a maximum noise level exceeding 94 dBA at a distance of 50 ft. Recently, the city of New York wrote some stringent noise level requirements into a contract for excavation of a subway tunnel under Central Park. There, the contractor must observe a maximum noise level that considers the surrounding residential character of the neighborhood. Compressors are limited to 102 dBA at 3 ft, 91 dBA at 23 ft, and 77 dBA at 100 ft. Paving breakers are limited to 104 dBA at 3 ft, 90 dBA at 34 ft, 79 dBA at 100 ft. Those are among the strictest noise controls in the country. As a consequence, a compressor or a breaker that can be used lawfully on a job in Chicago would be outlawed in New York City.

Where does that leave the manufacturer? Unless there are nationally accepted standards, a manufacturer cannot build a construction machine that is usable in all parts of the country.

The prime purpose of the CIMA committees is to promote uniform and reasonable standards that will serve the objectives of government regulation but without unnecessary confusion. Such standards permit machinery manufacturers to design and manufacture construction equipment without restrictive creative design limitations. They recognize fully any state-of-the-art limitations. They also promote an awareness of the possible resultant economic impact that the standards may have.

During 1971, 2 major events related to environmental concern occurred that vitally affect the manufacturing segment of the industry. The first was the issuance of regulations by the U. S. Department of Labor for the Safety in Construction Act that shortly after became part of the broad Occupational Safety and Health Act (OSHA). That act places newly defined safety responsibilities on all construction employers and requires special safety devices for certain equipment. The second event was the creation of the U. S. Environmental Protection Agency (EPA) and its announcement that its first major concern is the problem of construction-site noise levels. EPA is developing noise standards that may well have critical impact on equipment design and construction procedures.

The Occupational Safety and Health Act of 1970 has been called the most significant piece of federal legislation to affect the construction industry within a decade. The first OSHA regulations were published in the Federal Register of May 29, 1971, with a general effective date of August 27, 1971. The construction regulations are the same as those in the Safety in Construction Act of 1969 (7). Although the Safety in Construction Act covered only construction workers on jobs wholly or partially federally funded, the omnibus OSHA is designed to protect all workers in all industries, including construction. The U. S. Department of Labor, which is charged with administering the law, estimates that OSHA provides umbrella coverage of 57 million American workers in more than 4 million workplaces. One major group of workers not covered includes federal, state, and local government employees. Those governmental units must develop their own safety and health regulations comparable to OSHA.

In contrast to regulation practices of the automotive industry, the regulation for the construction industry designates responsibility for safe construction machines and their safe operation as defined by OSHA to be that of the employer—the owner-user of construction machines. So, the machinery requirements of contractors and their buying specifications will logically be expected to change and come to the attention of manufacturers as the impact of regulation is felt by those buyers.

It might be argued that tailoring a product to its current market is standard operating procedure; the manufacturer's basic philosophy is to be responsive to his customer requirements. Yet, in actual practice, it does not work quite that way. The research and development time requirements, the allocation of resources—people and capital, the development of manufacturing facilities, and many other factors mean that, traditionally, the manufacturer must anticipate new machinery requirements and be ready for them.

As the industry becomes more and more involved with federal regulations, manufacturers have found that CIMA's performance standards organization has provided a sound basis on which to make an effective critique of the proposed regulations and to submit industry-wide consensus recommendations to government agencies. The U. S. Department of Labor has accepted and adopted a number of CIMA-endorsed standards as part of its regulations.

To discern the actual meaning of OSHA regulations as they are currently written requires intensive, interpretive action. Frequently, it is difficult to obtain general agreement among labor department inspectors, contractors, unions, and equipment manufacturers on the intent of the regulation. Safety requirements for specific types of construction machines are often written in obscure "legalese" and located in unrelated sections of text scattered throughout thousands of pages of the Federal Register. The applicability of a regulation to a particular construction machine is often doubtful because the distinction among various equipment classes is ill-defined. There is no universally acceptable standard nomenclature for classifying construction machines.

In addition to definition problems, there are exceptions based on machine application, changes in effective dates for the regulations, and numerous amendments that a construction employer must consider before determining what he must do to comply with the law.

CIMA is attempting to relieve this confusing situation by suggesting changes in regulation format to the Department of Labor and by staging a continual thrust to use national consensus standards as the basis for future regulations. It is hoped that widely scattered regulations will eventually be gathered into one consolidated section applicable to a specific class of construction machines.

CIMA is sponsoring 2 new important projects that are under way: product requirements index for OSHA and a product classification system.

The product requirements index will attempt to pull together, under specific machine headings, all OSHA machine requirements that are now scattered and hidden in obscure, unconnected paragraphs. CIMA will present the index to the Department of Labor for checking and will strongly recommend that regulations be revised to bring the requirements together.

The product classification system will be recommended to the Society of Automotive Engineers for action; it attempts to make a determination of "families" of machines and their subgroupings. Definite identification will be assigned to each type and subtype of machine so that all concerned parties—government agencies, users, manufacturers, or standards writers—can for the first time precisely and positively identify the machines under consideration. As of now, vague terms such as rollers, earth-moving machines, and vehicles, are creating mass confusion.

Perhaps one of the most important CIMA efforts was to establish with the Department of Labor the realization that safety device requirements for construction machines could not be handled with a broad-brush approach that encompassed all existing machines and new machines yet to come off the production line. Several of the major regulations now specify different effective dates and in some cases different requirements between new and existing machines.

One prime example of this is the proposed treatment for roll-over protective structures (ROPS). When the original proposal for ROPS regulations first appeared in the Federal Register in 1971, the labor department was considering giving the construction industry fewer than 90 days to retrofit 400,000 pieces of field-located construction machinery with those devices (2). The assumption was that those devices could be added as easily as a decal could be stuck on the surface of the equipment. The wording of the regulations made no distinction between new machines coming from the factory and old machines already in use. The proposals, of course, drew sharp objections not only from equipment manufacturers through CIMA but also from other industry groups such as the Associated General Contractors, the American Road Builders' Association, and the Associated Equipment Distributors. Public hearings generated such widespread criticism that the whole ROPS question was placed on a "reserved" status by the labor department pending possible modification and new effective dates.

The types of machines affected by the ROPS proposal are crawler tractors, crawler loaders, rubber-tired self-propelled scrapers, rubber-tired dozers, rubber-tired front-end loaders, and agricultural and industrial wheeled tractors used in construction work. Those machines are, of course, designed by manufacturers with inherently good stability qualities. On many types of earth-moving projects, however, the equipment must be used over rough, steep, uneven terrain. ROPS equipment—in the form of a specially engineered steel-frame canopy or other device over the operator's conpartment—is intended to minimize the possibility of the operator's being crushed by a turned-over or rolling machine. The ROPS equipment is designed and tested to offer that kind of protection within certain practical limits of speed and grade.

As of this writing, the pending ROPS proposal requires that all new earth-moving machinery manufactured after July 1, 1972, be equipped with ROPS that generally conform with SAE minimum performance criteria. Manufacturers saw only a few major obstacles to installing the equipment at the factory, provided sufficient lead time were allowed for manufacturing logistics.

But retrofitting machines already in the field is another matter. At issue are 2 additional provisions of the pending regulations that require all existing equipment, regardless of age, to be retrofitted with ROPS by their owners by specifically designated dates. Equipment manufactured between July 1, 1969, and June 30, 1972, would be subject to a staggered schedule for ROPS retrofit during a 24-month period ending in mid-1974. Of greater concern to the industry is the even farther-reaching proposal that all machines manufactured before July 1, 1969, be retrofitted by July 1, 1975.

The main objections to such a massive retrofit program are the physical size of the manufacturing-sales-service task, the insurmountable engineering problems involved in some instances, and the poor ratio of the cost to effectiveness. The complexity of the problem is illustrated by the fact that the ROPS ruling can affect approximately 1,000 makes and models of equipment, some 600 of which are no longer in production. The total cost of ROPS installation in some 400,000 pieces of existing equipment could be close to $700 million!

CIMA members would be willing to accept a requirement that machines manufactured between July 1, 1969, and July 1, 1972, be retrofitted with ROPS. Those newer machines should present no serious problem because, in most cases, the ROPS proposed for current production machines are adaptable. However, the installation of ROPS on older machines presents a serious, if not insurmountable, problem in that those same mass-produced and adequately tested ROPS units are not readily adaptable, and the basic machine designs may be incapable of supporting the loads imposed by ROPS. Field retrofit of those older models will at best result in machines equipped with marginal, or even less than marginal, safety devices. Manufacturers also believe that retrofit of ROPS on machines having unknown capabilities may actually give the operator a false sense of security and therefore is not in the best interest of safety.

All known technical and safety facts tend to point out the fallacy of remanufacturing old machines or calling a machine safe when some kind of structure has been arbitrarily welded on it without consideration being given to the integrity of the machine to support the structure.

The construction equipment industry is being singled out by federal rule-makers to be the only class of manufacturers required to retrofit vehicles already in the hands of users. No such requirement has ever been imposed on automobile manufacturers for instance, who are only required (with generally adequate manufacturing lead time) to equip new models with safety devices such as seat belts, head rests, and collapsible steering wheels. To date, no one—including public officials, contractors, safety organizations, or labor unions—has produced statistical data or proof that an expensive undertaking like ROPS retrofit is critical to safety and worth the tremendous costs.

A survey was conducted among 2,600 American Road Builders' Association member contractors to investigate the frequency rates of roll-over accidents. The survey results totally refute previous contentions about accident and fatality rates relating to the highway construction industry (3). Nearly 1,200 completed and signed survey forms were received by ARBA, representing about a 45 percent return. Table 1 shows that, during approximately a 4-year period from 1968 to 1971, more than 26,000 pieces of

Table 1. Construction equipment roll-over survey results.

Equipment	Pieces Owned	Roll-Overs	Fatalities	Hours Worked
Rubber-tired, self-propelled scrapers	4,669	65	4	21,477,000
Rubber-tired, front-end loaders	4,770	27	4	21,942,000
Rubber-tired dozers	396	4	0	1,821,600
Crawler tractors	7,099	19	3	32,655,400
Crawler loaders	1,813	10	2	8,339,800
Motor graders	4,390	19	1	20,194,000
Agricultural or industrial tractors	3,095	14	1	14,066,800
Total	26,195	158	15	204,970,000

earth-moving equipment worked an estimated 205 million hours and suffered 158 roll-over accidents, a frequency of 0.77 accidents per million hours worked. Fifteen of those accidents were fatal. That is a frequency rate of 0.073 fatalities per million hours, a far cry from an allegation made in earlier testimony to the Department of Labor that roll-over accidents were responsible for 1,000 deaths per year in construction. The public should be aware of the extremely high ratio of cost to supposed benefits of mandatory ROPS on all earth-moving machines.

One aspect of the safety question that has gone practically unnoticed is the almost total absence of any government rule-making directed toward the operator—the person who operates the construction machine that is designed with inherent safety if operated properly according to instructions. OSHA requires the construction employer to provide a safe environment for the workman, and that responsibility is indirectly transferred to the manufacturer who provides the construction machine. But OSHA makes only passing reference to the need for operator training. It does not require the operator to have a license or to have a certain amount of experience under supervision to run the equipment.

Manufacturers have a sincere interest in operator safety. No one has ever deliberately designed and built an unsafe or half-safe machine. But machines can be and are misused through carelessness or ignorance of correct operating practices and safety precautions. Safety, like so many other matters, is a grass-roots thing. If it occurs, everyone must get involved in it—not just the manufacturer who designs a machine but the contractor who buys it and the operator who actually runs it. The safety-designed machine loaded with the best electronic or other types of safety devices can become a death trap if the operator is careless because he is tired, distracted, bored with his work, or likes to take short cuts.

Although manufacturers believe that the actual responsibility of operator education is mainly that of the contractor, they recognize they can offer technical assistance. Several years ago CIMA, as a supplement to its performance standards activities, authorized development of an operator safety manual for crawler tractors. The manual was released for distribution as a trial project in 1969 and proved to be a great success. More than 100,000 copies have been sold on a self-supporting basis to contractors, manufacturers, training groups, labor organizations, operators, and other interested parties.

The widespread acceptance of that manual as an educational and training aid in accident prevention prompted the development of others. Currently, safety manuals for rubber-tired loaders, off-highway trucks, cranes and excavators, motor graders, and rubber-tired scrapers are also available through the association. Those manuals are designed to supplement rather than replace the individual manufacturer's manufacturer's operation manuals. CIMA manuals have been widely accepted by users of equipment not only in the United States but also in other countries. For instance, the crawler-tractor manual has been translated and printed in Vietnamese and Japanese and is currently being translated into Greek. The wheel loader-dozer manual has also been printed in Japanese.

In response to demand, several of the safety manuals have also been converted into slide presentations for group training purposes; more are being converted. Here is concrete evidence that manufacturers are interested in safety and doing something about it! The efforts substantiate the contention that education, not legislation, should have top priority as the most effective way of achieving greater safety for the operator—and all workers.

Another segment of the equipment industry affected by OSHA is the crane manufacturers. The impact on those firms is not so heavy as it might have been because OSHA regulations refer to a commercial standard adopted a few years ago by the American National Standards Institute (4). That standard, covering cranes, was accepted as a voluntary industry-wide standard by members of CIMA's then independent Power Crane and Shovel Association and now a special department of CIMA.

OSHA requires cranes to be in compliance with the B30.5 standard. It specifies safety equipment such as antiskid walk surfaces on the machine platform, guardrails, wire rope guards on all drums, drum rotation indicators, boom hoist shutoff devices, and machine level indicators. Still to come are proposed regulations (adopted from longshoring crane safety rules) for approved boom angle and load measuring devices. That equipment is designed to prevent accidents such as machine tipover or boom collapse by warning the operator that he is exceeding prescribed operating limits of the crane. The prices of those computerized load warning devices start at about $2,000 and go as high as $10,000.

From the standpoint of exhaust emissions, most construction machines are not extremely large contributors to air pollution because most are powered by diesel engines. Although diesels can emit dense smoke while being revved up, the actual gaseous pollutants they give off are far less damaging than those exhausted by gasoline engines. One prominent diesel manufacturer estimates that diesel engines contribute less than 1 percent of the total air pollution burden (5). Nevertheless, engineers are working on the problem of cleaning up diesel emissions. But, until standards are set, about all that can be done is to measure the amounts of hydrocarbons, carbon monoixide, carbon dioxide, and oxides of nitrogen emitted into the air from exhausts and to improve the systems.

CIMA is not actively engaged in implementation of emission standards for engines because that effort falls quite naturally within the province of the Engine Manufacturers Association. CIMA's policy is not to duplicate efforts of other industry associations but to maintain communications with those groups in order to keep equipment manufacturers informed of new developments.

Another important area where equipment manufacturers are working is in noise abatement. Noise pollution is a factor for construction operators and workmen and for the surrounding community.

A pending congressional bill would allow the EPA administrator to impose noise standards on all construction equipment. That law will be keyed to community annoyance, not worker protection.

CIMA has published an industry position paper that placed the problem of construction machine noise into proper perspective (6). It points out that manufacturers have traditionally placed major emphasis on designing construction equipment for greater productivity rather than for quieter operation. During the past few decades, the demand of construction economics for more production at less cost from equipment has prompted the development of today's remarkable machines with more power, automation, and speed than ever before. But machine improvements that lowered production costs generally tended to raise sound levels. A major shift in goals is now beginning to take form. Scientists in both industry and government are conducting studies to determine just what man-sound relations are acceptable from an occupational standpoint and what sound exposure is tolerable at the community level.

Through CIMA, machinery manufacturers are cooperating in a joint effort among government, sound specialists, and contractors to accumulate the great masses of actual on-the-job sound data required. New and updated SAE standards and recommended practices on operator and exterior noise levels are being developed as this work progresses. In the meanwhile, industrial researchers are working to evaluate the many sound sources peculiar to individual machines and are developing quieter components and systems for models still on the drawing board.

Although EPA is concerned with limiting construction noise from the standpoint of environmental effects, federal regulations are already in effect under OSHA limiting noise from the standpoint of occupational safety. OSHA noise regulations refer to an SAE measuring code that relates the duration of exposure to the sound level expressed in dBA. Under OSHA, sound exposure of operators and workmen may not exceed the following values (7):

Duration (hours/day)	Sound Level (dBA)	Duration (hours/day)	Sound Level (dBA)
8	90	$1\frac{1}{2}$	102
6	92	1	105
4	95	$\frac{1}{2}$	110
3	97	$\frac{1}{4}$ or less	115
2	100		

Oversimplification frequently leads many to believe that the noise problem is created mostly by engine exhaust noises and that the solution is larger mufflers. To be sure, engine exhaust noise is part of the problem; however, reducting exhaust noise permits other machine noises to become dominant. Other noise sources that are of the same order of magnitude as exhaust noises, depending on the machine and its configuration, are internal engine noises exclusive of the combustion itself; engine air inlet; transmission and other gear noises; hydraulic system noises including pump, tubes, valves, cylinders, and hydraulic motors; air noise from the fan and radiator; and various moving mechanical elements such as crawler tracks or scraper elevators. Very likely on a large machine today each of those noises is individually more than 90 dBA. In the case of 2 equal noise source levels, the sum is about 3 dBA higher than either source alone. For 4 equal noise sources, the sum is about 6 dBA higher. In reverse, noise acts much the same way. Suppose the total noise of a machine is 100 dBA and is composed of 4 equal noise sources: exhaust, engine, gear and hydraulic, and fan noises. If exhaust and internal engine noises were reduced to zero, the machine would still have a noise level of 97 dBA. That is the challenge to the engineers who are studying each noise source and striving for noise reduction of each component.

The operator of a vehicle can now be protected from noise by simple devices such as earmuffs or earplugs. However, the operator must be required to wear them in the same manner that he is required to use hard hats, safety glasses, or safety shoes. That, of course, is a short-term solution. In the long run, the noise problem will be resolved by the manufacturer.

The economic costs of noise abatement in the general environment should be considered by all levels of government. Noise consultants warn that the increased cost of sound control is not in exact proportion to the number of decibels reduced. The cost increases much more rapidly as the required sound level drops.

EPA guidelines for air pollution control have already been issued. Enforcement through state implemented plans of national air quality standards set up in the Clean Air Act of 1970 will force many new changes in equipment design. By August 1972 every state must have enacted emission standards so that their air quality falls within EPA guidelines. The states must begin enforcing their regulations by the summer of 1975, or the EPA will step in and do the job. There will have to be drastic reductions of particulate emissions from aggregates, asphalt, and concrete plants. The guidelines also imply the possibility of dust controls on construction activities like drilling and blasting. The following steps are some that will have to be taken if EPA guidelines are met.

Contractors will be required to use dust-suppression devices on drilling operations to catch fine airborne particles resulting from cleaning drill holes with air. Highway contractors have found that detergent dust-suppression systems now on the market and costing about $200 may do the job. The process uses a small amount of detergent in the water. Water is fed into the air stream that is used to clean the hole, and the dust particles are dampened as they are created.

To control cement particulates at concrete plants may require fabric filters, electrostatic precipitators, or other types of equipment. Aggregate storage bins may have to be enclosed to eliminate fugitive dust. EPA estimates the new control equipment needs at $110 million for installation and $30 million annually for operation.

Stringent standards for particulate emissions will require additional expensive control devices, such as expansion chambers, skimmers, centrifugal dry collectors, wet washers, or bag houses, to be installed at asphalt plants. The National Asphalt Pavement Association estimates that total cost to the entire industry during the next 5 years to implement all EPA guidelines will run close to $500 million.

CIMA has not become involved in standards activities for asphalt plants and concrete industry equipment because they are specialized fields that fall within the province of allied industry associations such as the National Asphalt Pavement Association, the National Sand and Gravel Association, the National Crushed Stone Association, the National Ready-Mix Concrete Association, and others. Nevertheless, those specialty fields are experiencing many of the same problems that face earth-moving builders or crane-excavator manufacturers.

NAPA contractors and manufacturers object strongly to a proposed new EPA air quality regulation that would reduce the maximum allowable particulate to 0.03 grains/ ft^3 of standard exhaust gases as being unjustifiable from a technological and economic standpoint. NAPA says that compliance with the proposed regulation could cost as much as $100,000 per asphalt plant. For the small producer, that type of expenditure during a short period of time would present an unjustified economic burden that would force many contractors out of business. The hot-mix business is highly competitive. Contracts are won and lost on the difference of a few cents per ton of asphalt. The smaller producers, if forced into the huge expenditures required by impractical regulations, would have no recourse except to go out of business.

The problem areas discussed here represent only the tip of the iceberg—much more lies beneath the surface. Many environmental protection and safety regulations are untenable, uneconomic, impractical, and unworkable and will have to be solved through negotiation and compromise between governmental agencies and industry. We can also expect a multitude of similar new problems to crop up as regulations unfold. Some trade-offs must be made to determine whether the actual good accomplished by design changes for health or safety's sake outweighs total costs.

Equipment manufacturers are sincerely dedicated to the cause of safety and environmental welfare. They also feel responsibile to the people who use their products. They are concerned that customers and eventually the public do not spend money wastefully or unnecessarily on machine improvements that really do not increase safety or that may be just "band-aid" treatments that will not provide a long-term solution.

As costs of some of the proposed pollution clean-up and safety programs begin to take on astronomical proportions, it is appropriate to quote from President Nixon's message to Congress in August 1971, transmitting the second annual report of the Council on Environmental Quality.

> We should not expect environmental miracles. Our efforts will be more effective if we approach the challenge of the environment with a strong sense of realism.
>
> We must recognize that the goal of a cleaner environment will not be achieved by rhetoric or moral dedication alone. It will not be cheap or easy, and the costs will have to be borne by each citizen, consumer, and taxpayer. How clean is clean enough can only be answered in terms of how much we are willing to pay and how soon we seek success. The effects of such decisions on our domestic economy concerns—jobs, prices, foreign competition—require explicit and rigorous analyses to permit us to maintain a healthy economy while we seek a healthy environment. It is essential that we have both. It is simplistic to seek ecological perfection at the cost of bankrupting the very taxpaying enterprises which must pay for the social advances the nation seeks.
>
> The work of environmental improvement is a task for all our people. The achievement of that goal will challenge the creativity of our science and technology, the enterprise and

adaptability of our industry, the responsiveness and sense of balance of our political and legal institutions, and the resourcefulness and the capacity of this country to honor those human values upon which the quality of our national life must ultimately depend.

Despite the torrents of environmental rhetoric directed toward the construction equipment industry, manufacturers do not have to adopt a purely defensive posture. There seems to be a popular misconception about construction machines. Environmentalists who tag construction machines as being bad for ecology would be far more realistic to tag them as being indispensable tools that will protect resources like lakes, streams, and rivers by building sewers, sewage treatment plants, and industrial waste disposal systems. Those same earthmovers and excavators that dig, growl, fume, and raise dust also build the housing that the population requires. They must rebuild the decaying central cities and help solve the urban transportation crisis by constructing transit systems and bus expressways. They will replace and modernize thousands of miles of unsafe streets and highways and build new, safer airports. They will do many other tasks that contribute greatly to the health, safety, and quality of life of everyone.

Operation of construction equipment can be an annoying, disruptive intrusion into the daily habits of people who live or work near job sites. But construction work is always transitory in nature. Although neighbors are disturbed by noise, dust, and vibrations during the project, relief comes when the job is completed and the big machines move on. To obtain a certain good, a price or penalty must always be paid. Nothing gets built without construction equipment; no eyesore gets beautified, and no pollution control facilities are put in place.

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pollution: sources and solutions in bituminous construction

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Pollution or the presence of substances in concentrations sufficient to interfere with comfort, safety, or health comes from many sources. The increased concern for the environment has resulted in the establishment of federal, state, and local controls on particulate, water, noise, odor, and noxious gas pollutants.

Construction operations using bituminous materials must conform to such regulations. For example, of the 53 states and territories surveyed by the National Asphalt Pavement Association, only 2 states, West Virginia and Florida, had specific hot-mix asphalt plant regulations (1). However, 33 states had legislation that would allow control agencies to establish regulation. That enabling legislation resulted in a substantial increase in the number of agencies with specific air pollution regulations for hot-mix asphalt plants (2). Furthermore, a substantial number of state and local governments have regulations that are applicable to industrial processes to control pollutants emitted from hot-mix asphalt plants.

Examples of specific regulations on hot-mix asphalt plants (2) are given below; those regulations include controls for particulate matter and smoke but do not include controls for water, noise, odor, and noxious gas.

1. Florida—No portable asphalt plant shall be operated within the state of Florida unless (a) the maximum discharge of particulate matter is 0.3 grains per standard cubic foot of dry gas or (b) it can be shown that within a circle centered on the plant and having a radius of 1 mile there are a maximum of 2 occupied residences.
2. Hawaii—0.85 lb of dust emission per 1,000 lb of exhaust gas (adjusted to 50 percent excess air).

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3. Kentucky—

Plant Production (tph)	Allowable Emission (lb/1,000 lb gas)
0 to 100	0.6
101 to 150	0.5
151 to 200	0.45
200+	0.35

4. Michigan—

Plant Production (tph)	Allowable Emission (lb/1,000 lb gas)
All stationary	0.3
Portable	
0 to 100	0.6
101 to 150	0.5
151 to 200	0.45
200+	0.35
Remote portable	0.3 or 1-mile buffer zone with no residences

5. New Hampshire—Permanent plants must have efficiency standard of 80 percent minimum efficiency for wet or dry collector. Portable plants must be located so as not to create a nuisance.

6. Oregon—Efficiency standard of 80 percent minimum collection efficiency by weight. Process weight table with cutoff at 60,000 lb/hour input (40 lb/hour output maximum).

7. Texas—Minimum buffer zone of 1 mile based on land use.

8. West Virginia—Process weight table, 50 lb/hour allowable emission at 600,000 lb/hour or more; smoke, greater than No. 1; Ringlemann not allowed.

9. Wisconsin—0.3 lb/hour per 1,000 lb of exhaust gas (proposed); smoke, greater than No. 2; Ringlemann not allowed (proposed).

10. Milwaukee County—0.3 lb/hour per 1,000 lb of exhaust gas; smoke, greater than No. 2; Ringlemann not allowed.

Similar pollution control ordinances may be or can be expected to be developed for all types of construction using bituminous materials. Thus, it is becoming increasingly important that the bituminous paving engineer become familiar with those regulations and develop methods to satisfy the intent of the regulations.

A recent study conducted by the Louisiana Department of Highways (3) indicated that in many states hot-mix plants may have difficulty meeting present requirements with existing equipment. Because the current trend toward stricter regulations is expected to continue, that problem can only increase in severity.

A recognition of the sources of pollution in bituminous construction will afford the opportunity to recognize potential solutions. This paper gives a brief summary of possible pollution sources and discusses methods to solve some of the problems. Correction of pollution can be achieved by use of auxiliary pollution control equipment, use of new and innovative equipment, and use of special mixtures.

SOURCES OF POLLUTION

Construction operations using bituminous material can be divided into central-plant mixing, road mixing, seal-coat and surface treatments, prime and tack-coat operations, and certain maintenance operations that use cold-laid mixtures. Typical bituminous materials used for those applications include asphalt cements for control mixing and for seal-coat and surface-treatment operations. Cutbacks and emulsions are used most often for road mixing, prime coats, and tack-coat operations.

The selection of the type of bituminous material to be used is often determined by construction and service demands. However, under certain conditions, any one of the common forms of bituminous binder can be used successfully. Under a wide range of conditions, both emulsified asphalts and cutback asphalts can be used satisfactorily. Thus, the selection of the bituminous material type may depend on pollution and economic constraints imposed for selected conditions.

The use of cutback asphalt in southern California has been severely limited because of the solvent requirements set by the Los Angeles County Air Pollution Control Districts. It is estimated that compliance with regulation will increase the cost of cutbacks about $4/ton (4). Additional control districts must be formed throughout California as required by state law and will likely adopt similar restrictive ordinances. Control on a national scale appears to be just ahead. It, therefore, seems appropriate to discuss possible pollution associated with those construction operations.

Central-Plant Mixing

Because the vast majority of central-plant mixing operations are hot-mix operations, this discussion will be limited to that operation. The sources of pollution will be separated into the categories of particulate pollution, water pollution, noise pollution, odor pollution, and noxious-gas pollution (5).

Particulate Pollution—Aggregate dust, fly ash, soot, and unburned droplets of fuel oil are the main particulates resulting from asphalt plant operations (Fig. 1, 10).

Aggregate dust is created during the aggregate storage operation, the drying operation, and the screening process. Aggregate dust can also be created by traffic within the batch plant area and by wind. However, the major source of dust is the dryer. For an average-sized dryer without a dust collecting system, 5 to 10 tons of dust per hour leave the drying chamber. Few, if any, of those dryers are in use in this country today. Fly ash and soot are formed during oil or gas combustion. Pollution due to drying of the aggregate is a far more serious problem than that due to heating the asphalt. Pollution associated with both the heat source and the aggregate dust in the drying operation makes the aggregate operation especially critical.

Fly ash results from impurities in fuel oil or incomplete combustion. The completeness of combustion, which is controlled by fuel quality and type and oxygen availability, controls to a large extent the amount of fly ash produced. Soot consists of unburned carbon particles emitted from the combustion process. The soot is often considered to be of a particle size less than 1 μm, and fly ash may be considered to fall between 1 and 100 μm.

Poor combustion control often results in unburned oil droplets beign either emitted from the stack or deposited on the aggregate in the dryer. The presence of that unburned fuel on the aggregate can create poor adhesion between the aggregate and asphalt and thus result in a pavement that ravels. A poorly functioning burner, lack of oxygen, or insufficient fuel oil heating contribute to the formation of that pollutant (5).

Water Pollution—Dust can be effectively controlled by the use of one of several types of wet washes. The washes usually require that the dust-water mixture be drained and subsequently deposited in settling ponds. Sometimes, however, the water is drained into rivers or lakes and, thus, creates a pollution problem. Contaminants contained in the water may consist of dust, oil, gasoline, asphalt, and soap. In addition, the water may be hot and acidic.

Noise Pollution—Noise at an asphalt plant is usually caused by the friction of metal against metal, aggregate against aggregate, and metal against aggregate; by the movement of compressed air into the atmosphere; and by the combustion of pressurized fuel in the burner (5). Maximum noise levels normally occur at or near the hot-bin screens, the pug mill, the exhaust fans, and the burners. Noise pollution is greatly reduced at partially enclosed and automated plants.

Odor and Noxious-Gas Pollution—Offensive odors and noxious gases are primarily produced during the fuel combustion process. The odors and gases produced vary with the type of fuel used, the burning temperature, and the efficiency of the combustion process. Odors from the stack area are normally caused by the use of high-sulfur content fuel or unburned natural gas. Odors emitted as the asphalt concrete is deposited into trucks are caused by the mix coming in contact with kerosene or fuel oil that is used to coat the truck bodies or from the volatilization of the light fraction of the asphalt cement. Noxious gases are most frequently carbon monoxide, sulfur dioxide, sulfur trioxide, nitrogen dioxide, and nitric oxide.

Road Mixing

Road-mixing operations use either cutback asphalts or emulsified asphalts because they can be mixed at relatively low temperatures. A petroleum distillate is used to "soften" the cutback asphalt, and water is used with emulsion asphalt. According to the U.S. Bureau of Mines, 4.06 million tons of cutback asphalt for paving use were shipped domestically in 1969. Thus, nearly 1 million tons of distillate were emitted as atmospheric pollutants. The loss of water, the liquefying agent for emulsions, creates little hazard.

Road-mix construction operations consist of roadbed preparation, windrowing of material, addition of asphalt, mixing aeration, and compaction. Each operation normally requires diesel- or gasoline-powered internal combustion engines that are sources of pollution. Dust created during the roadbed preparation, windrowing of material, and mixing is another pollutant.

The asphalt distribution, mixing, aeration, and compaction furnish the time necessary for a large portion of the volatiles to escape to the atmosphere. If sufficient aeration is not allowed to occur during the construction operations, volatiles, which may be noxious and odorous, may be given off during extended periods.

Seal Coats, Surface Treatments, Prime Coats, and Tack Coats

Most seal-coat, surface-treatment, prime-coat, and tack-coat operations involve spraying bituminous material on either a base course (surface treatment or prime coat) or old surfacing material (seal coat or tack coat). Those spraying operations, in which motorized equipment and heaters are used (Fig. 2, 10), create the following pollutants:

1. Exhaust gases from motorized equipment and asphalt heaters,
2. Gases and odors from the overheating of asphalt cements and the volatilization of the lighter molecular weight fraction of the asphalt cement,
3. Volatiles from cutback asphalt,
4. Dust from construction equipment on the unsurfaced roadway and from spreading and compacting aggregate or chip seals, and
5. Asphalt blowing from the spray bar under windy conditions.

Although the quantity of those pollutants is not large compared to the quantity of total pollutants, it is large enough to be visible and thus can be expected to come under more severe restrictions.

Slurry-seal operations use emulsions to form a slurry in a small mixing chamber at the rear of a transport truck and emit a certain amount of dust and exhaust gases. Maintenance materials used for pothole repair and leveling work often contain a significant amount of volatiles that escape during storage and use. Dust-laying and road-oiling operations also involve the spraying of bituminous materials that create pollution in a manner similar to that associated with seal coats.

POLLUTION CONTROL

Pollution control can be achieved in a number of ways; in this paper, those ways are divided into 3 categories: auxiliary equipment, new equipment, and special bituminous mixtures.

Auxiliary Equipment

Most of the auxiliary equipment used in bituminous mixing and handling operations has been developed to control pollution at central-mixing plants (5). A brief summary of that equipment is presented below.

Dust-Control Systems—Dust-control systems must be adequate to control emissions from the dryer, screen cover, weigh and mix area, and hot elevators (fugitive air). Common devices used include expansion chambers, skimmers, centrifugal dry collectors, wet washers, and bag house dust collectors. Those devices are often used in series to achieve adequate control. Typical systems include the dry-wet system, dry-dry-wet system, and dry system (5).

The dry-wet system often consists of a centrifugal dry dust collector, fan, and wet washer. If adequate washers are used and the plant is not operating above capacity, that type of equipment will produce sufficient dust collection to meet many existing air pollution codes. Although that type of system is relatively inexpensive compared to other control systems, its disadvantage is that fines collected in the wet process must be disposed of. The fines are often placed in settling basins; thus, construction, cleaning, and disposal of wet mud or sludge could be a major problem (5).

The dry-dry-wet system often consists of a large-diameter primary centrifugal dry dust collector or a high-efficiency cyclone grouping, a fan, and a wet washer located at the discharge side of the fan. That system, which uses a secondary dust-collection system, has the advantage of collecting a significant amount of dust that would normally become sludge in settling ponds (5). Dry systems usually make use of a bag house dust collector. Under certain conditions the bag house may be preceded by a centrifugal dry dust collector or skimmer. The use of bag houses of sufficient capacity will normally ensure that an asphalt plant can operate within pollution control limits (5).

Figure 3 and 4 (5) show examples of dry dust collectors and wet washers.

Dust in the plant area can be controlled by one or by a combination of several of the following actions:

1. Stockpiles can be protected from wind by proper placement, by construction of windbreaks, or by storage of aggregates in bins or silos;
2. Control of vehicle speed and use or paved driveways and approaches will greatly reduce dust created by trucks (dust control chemicals might be used on unpaved areas);
3. Frequent cleaning to eliminate accumulated dust and waste materials can be employed.

Water Control Systems—Wet washers usually require settling basins. A well-designed settling basin is large enough for settlement to take place and for the water to cool. Chemical flocculents, drag chains, screws, or other dewatering devices can be used to hasten the settlement and removal of sludge from those ponds (5).

Noise Control Systems—Noise control can be achieved by soundproofing, using employee protection devices, and removing personnel from high noise areas. Automated plants have reduced noise in hot-mix plants.

Odor and Noxious Gas Control Systems—Control of odor and noxious gases can be achieved by proper selection of fuels (low-sulfur content) and by the use of more efficient combustion systems. Pollutants in road-mixing operations and in seal-coat and surface-treatment operations can be reduced by using pollution control devices on all vehicles, by using emulsions rather than cutbacks, by working materials in a damp condition, and by controlling construction traffic speeds.

New Equipment

Pollution control ordinances have been adopted only recently in most states and local governments. As a result, equipment manufacturers have made improvements to their equipment.

A relatively new mixing concept that combines the aggregate heating and mixing process in a single operation in the rotating drum offers promise of a relatively pollution-free plant (6). That operation appears to offer several advantages.

1. Pit run or screened aggregates can be stockpiled in a moist condition, thus, eliminating the normal hot-screening process and reducing the dust pollution in the plant yard and cold-feed areas.
2. Aggregates are mixed with asphalt in the same drum in which they are heated, and, consequently, dust that usually passes out the stack is trapped.

Figure 1. Typical operation of asphalt plant.

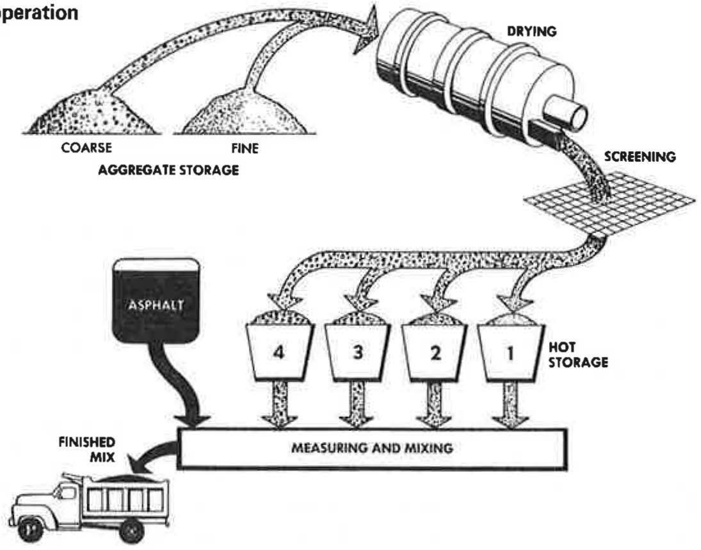


Figure 2. Asphalt distributor.

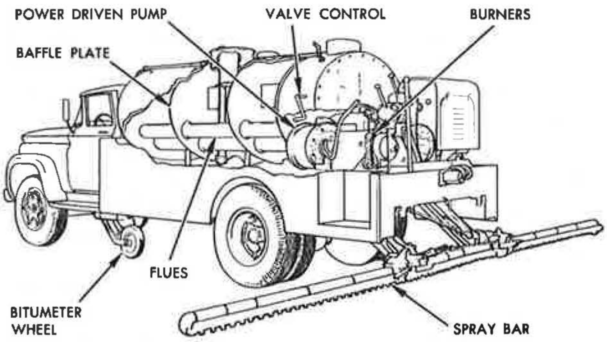


Figure 3. Dry dust collectors.

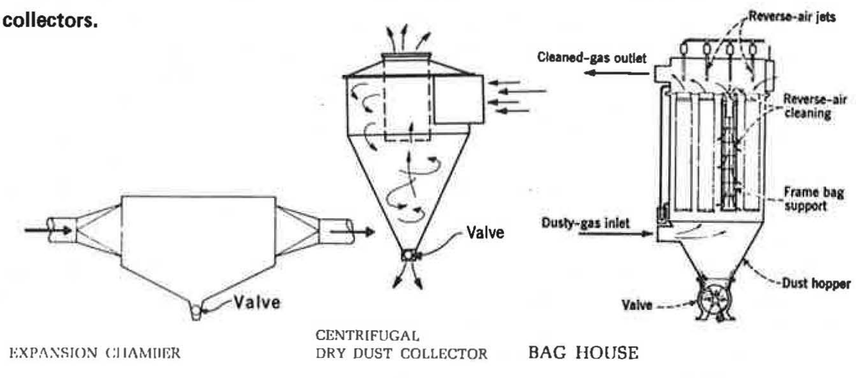
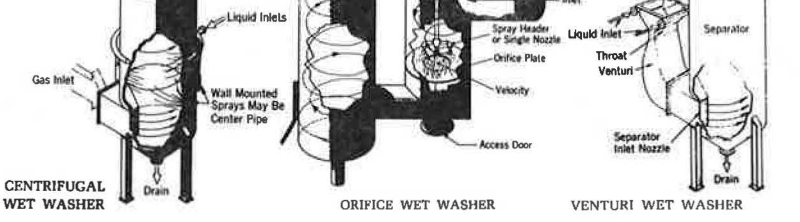


Figure 4. Wet washers.



3. Required mixing temperatures are lower because water is present in the mix, and, thus, overheating of the asphalt and subsequent pollution are greatly reduced.
4. Depending on the location and local regulations, the need for auxiliary dust control equipment is lessened or eliminated.

Research and development of the dryer drum concept are currently under way (6, 7, 8, 9). A study of the Shearer process is being conducted by the Federal Highway Administration in the state of Washington to investigate both mixture quality and air pollution control. Further development and testing appear to be warranted even though several state highway departments have already elected to permit that type of production at least as an alternate in the bidding.

Pollution associated with the plant yard and the immediate plant area often cannot be effectively controlled because of the large amount of plant areas and pollutants associated with present auxiliary equipment. Therefore, the hot-mix producers should not be surprised if pollution standards require that the entire plant be enclosed. The pollutants would be collected within the enclosure and subjected to dry-collection processes such as bag houses to reduce dust and other pollutants. Wet washers may not be satisfactory because of the added problems with water pollution and additional costs.

Special Mixtures

Special mixtures may be developed to control pollution. Those mixtures would probably contain a small amount of fines, require bituminous binders that would satisfactorily coat and mix at relatively low temperatures, and require aggregate gradation control that could be easily obtained with natural aggregates. A number of hypothetical mixtures that would be satisfactory are suggested below.

Mixtures containing reduced amounts of fine material could be used effectively as stabilized base material and as open-plant mix seals. A mix that would have the appearance of popcorn or marbles glued together with asphalt could be used as a base course or drainage layer provided adequate durability could be obtained. Open-plant mix surfaces could be effectively used to provide drainage on pavement surfaces to reduce the potential for hydroplaning (11). Mixtures with reduced fines content (produced by a wet separation process) will reduce the amount of dust produced in the dryer and fugitive air systems and in the stockpile, cold-feed, and hot-screening processes.

Bituminous binder that will coat and mix at relatively low temperatures offers significant advantages. Emulsified asphalts appear to be worthy of serious consideration, provided a quality asphalt concrete mixture can be obtained.

A cost analysis of emulsions rather than asphalt cement for asphalt-aggregate mixtures of approximately equal quality indicates that first cost favors emulsion mixes only slightly. The probability of job success is generally less with emulsion mixes, and the expected pavement life is decidedly less on an equal-thickness basis.

The use of cutback asphalts appears to be limited because of the emission of volatiles. In fact, Los Angeles County, California, prohibits the use of cutback for that reason.

Natural aggregates that can be mixed with little processing to produce desired gradation offer significant advantages. Those materials can be used without stockpiling in multiple locations, do not require secondary screening, and can be effectively used for base courses and selected surface courses.

Pollution from the production of aggregates occurs mainly in the form of dust. Processing that requires crushing and dry screening usually creates more pollutants than processes that use naturally occurring aggregates and wet screening and sizing operations.

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effects of channelization on the aquatic life of streams

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The great growth of population and the concentration of 70 percent of that population in the coastal zone have caused rivers and their floodplains in that area to be increasingly altered for man's use. Much of the channelization has been or may be undertaken in that area. Often we forget that a river or a stream is a flowing body of water that has slowly evolved a channel and a slope that are in equilibrium with continuous inputs and outputs of water and sediments from the drainage basin. Typically a natural river overflows its channel every 1½ to 2 years onto the floodplain. The extent of the overflow is predictable for a given frequency, and the amount of overflow at various times is indicated in the floodplain by various terraces representing the extent of overflow.

CHARACTERISTICS OF FLOOD PLAINS AND SWAMPS

The floodplain is an integral part of the river, and its preservation is important because it helps to regulate the quality and the amount of water in the stream. When a river floods, a considerable amount of sediment is deposited on the floodplain. Those sediments, if they are rich in plant nutrients, fertilize the floodplain and help to maintain its high productivity. Also, considerable amounts of floodwaters seep into and recharge the underground water system. Wharton (9) emphasizes the importance of the floodplain in recharging streams in the North Carolina Piedmont.

During the period of flooding, particularly in the spring when the floodwaters are relatively high, floodplain ponds develop and remain intact after the water recedes. For example, the floodplain of the Savannah River before it was drained was well supplied with those floodplain ponds. An examination by the Academy of Natural Sciences has found that those ponds act as breeding and nursery grounds for many forms of life. Indeed, some organisms spend most of their life cycles in those ponds. With subsequent reflooding, that life enters the river. Thus, the ponds act as seeding areas for the river and increase its productivity.

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Often the floodplain bordering lower reaches of small streams that flow into larger streams are flooded throughout the year. Those areas are known as swamps. In the northeast and middle Atlantic states, swamps are usually covered with herbaceous plants, whereas in the southeastern states they are usually forested. The wetlands and the floodplain proper act as sponges or reservoirs and thus prevent flooding of adjacent land and reduce downstream flood peaks at times of high flow. Niering (8) reports that, during the 1955 flood in the Pocono Mountain area of Pennsylvania, the only highway or road bridges that survived were the ones downstream from a several-hundred-acre cranberry bog swamp. The absorptive capacity of those vegetative depressions siphoned off enough floodwaters to prevent damage. Leopold and Maddock (6) have pointed out that the overbank flow constitutes an important part of the natural valley storage during a flood. The natural storage provided by river channels and floodplains is similar to the kind of flood control provision that man attempts to build by engineering works such as dams.

The current is less in those flooded swamp areas, and sediments drop out of suspension so that as a result the water is clearer and light penetration is greater. Thus, those areas are very favorable for photosynthesis and the development of aquatic life. They are valuable as feeding, breeding, and nursery grounds for fish, invertebrates, and many species of birds. Indeed, many of the flyways of migrating birds are located across swamp areas. The relative inaccessibility of swamp areas has made them ideal for relic species and rare species to continue to live against the perturbations caused by man.

It has been well documented that plant growth in floodplains produces valuable organic detritus for downstream fisheries. The kind of species of plants is important, for the value of the detritus varies according to the types of plants present.

Swamps and marshes absorb a great deal of nutrients and thus improve water quality. We have found in studies of Tinicum Marsh (3) that a 512-acre marsh that received effluent from sewage-treatment plants absorbed phosphorus at approximately a rate of 4.9 tons per day, absorbed ammonia at the rate of 3 to 4 tons per day, and produced oxygen at the rate of 20 tons per day. Furthermore, according to Wharton (9), a survey of the Flint River showed that within 6 miles of flow through an area surrounded by marshes there was vast improvement in the bacteriological and zoological characteristics of the stream. Thus swamp areas improve water quality for aquatic life in the streams proper; act as breeding, nursery, and feeding grounds for the aquatic life and thus improve productivity; and are reservoirs for a highly diversified and sometimes unique group of species that help maintain the ecosystems of flowing waters.

CHARACTERISTICS OF THE STREAM CHANNEL

One of the obvious characteristics of water in a stream is that it does not flow in a straight line. In the headwaters we often find braided as well as sinuous channels. In areas of greater flow, the usual pattern is sinuous and results from the undulating course of flowing waters as they seek equilibrium with the channel. Thus, one edge of the channel becomes the cutting edge and the opposite is the depositing edge. In the shallow waters on the depositing side of those meanders, abundant aquatic life develops because light penetrates to the substrates; fish may be found in deep holes on the cutting side of a meander. The depositing edge is ideal for highly productive, short-generation organisms such as algae, the grasses of the aquatic world, and many kinds of invertebrates that feed on the algae. Fish come to the shallow waters to feed and spawn, and the young of each year mature there. Over time the river sometimes changes its course, breaking through a meander and creating oxbows. Most of the flow will then bypass the meander although some will continue to course through the old channel, which becomes the richest area for aquatic life. The current is slower, the silt load drops out of suspension, and the photosynthetic zone extends completely across the channel. If it were not for oxbows, the productivity of a river would be greatly decreased.

Other important shallow water habitats are entrapped floating debris and trailing branches from trees with their associated leaves. One has only to visit the Savannah, the Mississippi, or the Schuylkill to appreciate the great value of those floating habitats to deep water streams. Because floating habitats can rise and fall with the water level, they form a more or less continuous habitat. Large fish populations often congregate under floating log jams because they offer high food production and cover. The great diversity of substrate and current patterns allows many different kinds of communities to develop.

The shallow water communities are composed of many species of animals and plants. Typically those species have high predator pressure, and as a result one rarely sees a bloom or large population of a single species in the natural stream.

EFFECTS OF CHANNELIZATION

The effects of channelization depend on the type and amount of change in the stream structure that is induced by the type of channelization employed. Channelization not only affects the life in the area of the stream that is channelized but also the upstream and downstream ecosystems.

The purpose of channelization is usually to increase the rate of flow in the streams, although sometimes streams are channelized to obtain road-building materials. Snagging and removing vegetation from the banks are often considered the least harmful types of channelization, yet they produce profound change in the ecosystems of the stream. The removal of floating debris eliminates one of the most important habitats for aquatic organisms and greatly reduces the productivity of the stream. Removing overhanging branches of trees and trailing leaves also reduces the productivity of the stream. Clearing the banks of the stream often results in the death of the bank vegetation, and that causes the banks to erode and slump into the streams.

Eroded sediment reduces light penetration in the stream and as a result primary productivity is lessened. It also accumulates in unsteady berms on the river bed, and those quickly erode once the rate of flow changes and produce considerable turbidity not only in the immediate area but also downstream. Organisms that have used the substrate as a habitat are destroyed once the berms start to move. Occasionally more or less consolidated berms develop within the stream channel and become a favorable habitat for aquatic life. The spawning of fish is dependent on the availability of a suitable substrate in a desirable current, which is one that is fairly slow but predictable. Such areas are often eliminated by channelization because the diverse substrates are removed and stream velocity becomes faster and more uniform.

The destruction of the overhanging vegetation in a stream has several effects. One of the most pronounced is the increase in water temperature. We have found in studies of White Clay Creek in Pennsylvania that in an area from which the trees had been removed a rise of temperature of only a few degrees seemed to be responsible for the elimination of stone flies. Brown and Krygler (1) have shown that the maximum annual temperature increased from 57 to 87 F after clear-cut logging on a small watershed in Oregon. Terrestrial insects and other types of invertebrates falling into the water are also important food sources for stream life. The importance of leaf fall-in to the food chain of a stream has been well documented by many. Vannote has shown that tipulid larvae have certain species preferences, and their growth rates are much better when fed the type of leaves they prefer. Thus, removing the natural vegetation from the stream banks may greatly curtail not only the development of certain species of insects but also the overall productivity of the stream.

Usually channelization involves the dredging of the stream channel. The dredging homogenizes the bed structure, reduces its roughness and diversity, and destroys the diversity of the current pattern. That inevitably leads to reduction in diversity of aquatic life in the channelized area. Because the substrate suitable for many forms of aquatic life is lost or greatly reduced, productivity is likewise curtailed. For example, the spawning beds of many fish are dependent on the availability of suitable unsilted substrates in a current that is of a moderate speed but predictable.

If dredging cuts out the shoaling side of meanders and destroys the oxbows, the productivity of the stream may be almost eliminated. Usually in order to increase channel capacity, the channel is made wider and deeper. If the channel is dredged wider than necessary and the banks are clear-cut, the eroding banks will slump and build up berms within the cross section. The stream usually cuts a new meandering channel within the dredged channel, thus defeating the purpose of channelization. Furthermore, the unstable banks may continue to erode, under bridge approaches and require the brodge to be rebuilt (2). The extent to which the channel is deepened has varying effects. The gradient or slope of a stream is one of its most conservative characteristics, and when man alters it he invariably causes erosion upstream and downstream because the flowing water seeks equilibrium with its new structure. Such erosion naturally destroys habitats of aquatic life.

When the deepening of the channel lowers the bed of the stream below that of the aquifers with which it was formerly in equilibrium, the aquifers are drained and the floodplain dries out. Floodplain habitats suitable for muskrat, deer, many species of birds, and otters are then changed to ones suitable for rabbits and quail. Likewise water-living plant species are replaced by vegetation requiring drier conditions. In the southern part of the United States, species such as sour gum, true cypress, swamp maple, and hackberry are replaced by sweet gum, oak, and loblolly pine. In the Florida wetlands (4), alligators feed on raccoons that feed on eggs of egrets and ibis. When the wetlands were drained, the alligators moved elsewhere and the egret and ibis rookeries were eliminated by raccoons.

Underground aquifers maintain stream channels during low flows. If those are drained, there is no reservoir of water for maintenance of stream flow. As a result of channelization, streams that once were free-flowing during low water periods may become a series of isolated pools. That, of course, greatly alters the aquatic life that composes the stream ecosystems.

The straightening of the channel that often accompanies such dredging means that the water flows more quickly along its course. Slowly moving water allows streams more time to assimilate wastes and nutrients that enter them. Increasing the flow can bring about various serious consequences for downstream bodies of water. An example is Lake Okeechobee in Florida. Sewage-treatment plants discharge their effluent into tributary streams of Lake Okeechobee. Formerly those streams assimilated the mineralized wastes before the waters enter the lake. Because of the faster flow, the waters now empty more quickly into Lake Okeechobee and are causing the lake to fast become a large polishing pond for mineralized effluents.

The clearing of the floodplain of its natural forest or grassland for urbanization, agriculture, or pasture increases the erosion of sediments that clog the channel of the stream that channelization was designed to correct. Thus, continual maintenance is required if the channel is to remain clear. The nutrients entering the water are often increased depending on how the floodplain is used. The fertilizing of crops and pastures and the grazing of cattle increase the organic load. Pesticides sprayed on crops find their way into the streams where they are toxic to many forms of aquatic life. If the adjacent area and drained floodplain are urbanized, the floodplain often becomes the site for sewage-treatment plants, and their poorly treated effluents enter the stream. These increased nutrients may produce several effects. The species may change from those that are highly desirable food sources with high predator pressure to those that are undesirable food sources with little or no predator pressure; thus, nuisance growths develop. The increased nutrients also tend to develop floating and rooted aquatics that clog the channel that was channelized to increase the flow of water and intensify flooding rather than reduce it.

Another stream activity that often occurs concurrent to channelization and highway development is the taking of gravel and sand from the stream bed for road improvement. The materials are often taken without regard to the gradient of the stream and its natural bed contours. Large holes may develop in which stagnant water accumulates. Those anaerobic deep-water areas often produce toxic substances and have little or no oxygen so that aquatic life cannot survive. When a channel is straightened the banks are often riprapped with quarried stone at a vertical angle. The result is that the sun reaches the water surfaces for an insufficient period of time to support algal growths that are important as food for animals in the ecosystem. If the banks were riprapped at an angle of 30 to 45 deg with natural water-worn stones, current patterns would be produced that favor native stream organisms. As a result, the areas would be much more rapidly colonized, and the riprap would support a fairly diverse community of aquatic organisms. If dredging is done, attempts should be made to restore the natural contour of the channel bed, for example, create pools and slackwaters in shallow streams or restore the roughness of the channel bed. That would interfere very little with the carrying capacity of the channel under flood conditions, but would greatly improve the bed habitats for species occupancy.

Man must remember that the stream and the floodplains have evolved during long periods of time and have developed a system that is best for the natural conditions at hand. He should study these conditions carefully and make sure that modification follows the dicta of nature.

SUMMARY

The stream and its floodplain are an integrated system that is well designed for moderating the effects of flooding waters and for maintaining high productivity in the stream proper. Disturbing the system inevitably results in a reduction in diversity of species and productivity. Because the functioning of the aquatic ecosystems is impaired, the ability of the stream to cleanse itself and to assimilate wastes is lessened, and the improvement of water quality is slower. The stream, instead of being one that is aesthetically pleasing and highly productive, becomes degraded and its recreational use is minimized. The chief effects of channelization are as follows:

1. Removes the natural diverse substrate materials that allow the development of many types of habitats for aquatic organisms;
2. Increases sediment load that decreases light penetration and primary production;
3. Creates a shifting bed load that is inimical to bottom-dwelling organisms;
4. Simplifies the current pattern and eliminates habitats of diverse currents;
5. Lowers the stream channel and often drains adjacent swamp areas and aquifers that help to maintain stream flow during times of low precipitation;
6. Destroys floodplain ponds that are the breeding ground for aquatic life and that act as a reservoir of species for the river proper; and
7. Reduces the stability of the banks and causes cave-in of trees and other overhanging vegetation that are an important food source for stream life and whose shade reduces high stream temperatures during the summer months.

If man is going to interfere and modify natural waterways, he should design his alterations to maintain the functioning of the aquatic ecosystem that makes possible the continuance of a stream's high water quality.

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nonchemical means of pest management in the highway landscape

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The highway landscape system in California, one of the most extensive in the world, covers many thousands of acres. Much of this landscape consists of plant communities bordering and dividing highways in urban areas, where the natural flora of the region is generally absent and where alterations in topography during construction of the highway have caused impoverished soils. As a result, the landscape may consist largely of a man-made community of introduced ornamental plants, growing under the conditions of stress induced by deficient soils, pollutants, and poor drainage. In such situations, attack by insect pests is often more severe than in landscapes where the natural flora has been retained relatively undisturbed; yet, it is generally in the urban areas where aesthetic standards are expected to be highest, and the corresponding tolerable injury levels the lowest.

In California, most pest outbreaks in the highway landscapes can be controlled by chemical insecticides, but there is a tendency to diminishing periods of control following application. That appears to be due to the lack of specificity of the chemicals used in that the insecticide treatment also eliminates beneficial species of insects. It is believed that many species of pest insects are able to migrate faster than their natural enemies and can re-infest an area previously treated and so multiply unchecked. Also, the predilection of urban gardeners for introduced ornamental plants provides breeding sites for some pests over large areas surrounding the highway. Unfortunately, most gardeners know little of biological control and do not manage their gardens to favor beneficial insects. Thus, one possible result of a chemical treatment is that control is provided for a time, then the pest reappears, now in the absence of natural enemies, and so the outbreak is often more severe than before. That phenomenon has been called pest resurgence. Further treatments are required to control the resurgence, and pest control costs increase as does the exposure of the landscape maintenance personnel and the public to potentially hazardous materials.

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A further complication is that the pest may develop resistance to the insecticide being used for control. That has happened many times in the control of pests of agriculture and public health but does not appear to have occurred to any extent with landscape pests in California. With or without resistance, the net result of this system is a tendency to more frequent treatments and to higher pest control costs.

A large proportion of the most damaging landscape pests in California are the caterpillars of various moths. For those, our efforts have been to devise programs with nonchemical means of control. We have substituted a bacterium, Bacillus thuringiensis, as a first phase replacement for the chemicals previously used. When applied, B. thuringiensis is lethal only to caterpillars and does not harm beneficial insects, fishes, birds, animals, or man. Because the beneficial insects are left unharmed, the probability of pest resurgence is greatly reduced and will be reduced further if beneficial insects can be managed to keep the pests in check. That is the objective of the second phase of the program development and should result in reduced pest control costs because of the reduction in number of control operations necessary per season. In California, several highway landscape pests are under investigation for nonchemical or biological control. One of those projects is described here.

In 1969, the California Division of Highways cooperated with the Insect Pathology Laboratory of the University of California, Berkeley, in a series of field trials for the biological control of the California oakworm, Phryganidia californica with B. thuringiensis. The results were so successful that the following year the division sponsored a new research project to develop and test nonchemical control methods for a variety of caterpillars causing damage to the highway landscape. The prime candidate for control was the red-humped caterpillar, Schizura concinna, a voracious defoliator of a wide variety of orchard and ornamental trees.

During the initial phases of the project, red-humped caterpillars were bioassayed against various commercial formulations of B. thuringiensis to obtain dose-response data necessary to evaluate the control potential of those formulations and to provide guidelines for application rates in the field. The results indicated that the red-humped caterpillar could be readily controlled by appropriate rates of B. thuringiensis, and extensive field trials in several areas of California proved that to be the case. To date, 25 intensive field trials, in which knapsack equipment was used for spot applications and large hydraulic spray rigs were used for extensive applications, have all given highly successful control and yielded valuable data whereby the application rates and selection of formulations have been further refined. These data are given in California Highway Research Report RN 71-8.

The first result of this project was that during 1970 and 1971 chemical insecticides formerly used were replaced with B. thuringiensis formulations for control of the red-humped caterpillar throughout California. Because B. thuringiensis, at the rates of application used, is specific for caterpillars and harmless to other forms of life, there was an immediate reduction in the possible exposure to hazardous materials of landscape maintenance personnel and those traveling on or residing close to highways where control of red-humped caterpillars was in progress.

A further benefit is that the natural enemies of the red-humped caterpillar are not harmed by B. thuringiensis and can begin to exert some degree of biological control. From the beginning, the project had included a study of the indigenous natural enemies of the red-humped caterpillar so that their potential for eventual control could be determined. It was found that 2 small parasitic wasps or parasitoids, Hyposoter fugitivus and Apanteles schizurae, could parasitize and kill red-humped caterpillars under highway landscape conditions. The elimination of the broad-spectrum chemicals permitted populations of the parasitoids to increase and persist in the highway landscape, but the incidence of parasitised red-humped caterpillars, although high during spring and early summer, declined rapidly during June. That decline in the parasitoid population occurred about the time that most shrubs ceased flowering and began to set fruit. The presence of flowers was believed to have been an important factor affecting the reproduction or longevity or both of the parasitoids.

A series of laboratory experiments was designed to ascertain the importance of flowers to the reproductive economy of H. fugitivus, the most effective parasitoid.

Successful breeding of H. fugitivus in the laboratory was accomplished in 1971, and it was quickly established that the parasitoid is indeed highly dependent on a nectar source for survival. Work is now in progress to select perennial shrubs that produce flowers acceptable as a nectar source to H. fugitivus and that have a long flowering period commencing at the end of June. The selected shrubs must also possess the characteristics necessary for survival when interplanted in the highway landscape and must not be so susceptible to any insect species occurring in the landscape that those insects become pests on the introduced shrubs.

Three of many species of shrubs tested have proved to be acceptable as nectar sources to H. fugitivus: jasmine, Trachelospermum jasminoides; myrtle, Myrtus communis varieties; and abelia, Abelia grandiflora. Under screen-cage conditions H. fugitivus adults survive 4 days in the absence of a nectar source and 14 days when flowers of T. jasminoides, M. communis, or A. grandiflora are present. Those species all have long flowering periods that occur at about the required time during the summer.

M. communis is the only species yet proved to be fully compatible with highway landscape conditions, but unfortunately that shrub yields few flowers. T. jasminoides and A. grandiflora produce flowers in profusion, but their compatibility with highway landscape conditions is yet to be determined.

Because the red-humped caterpillar has 5 or 6 generations per season, it is particularly likely to develop resurgences in landscape situations. When chemicals were the only means of control, several applications were required each season. Some areas of California reported 6 treatments of insecticide for the control of that insect during a single summer. In many areas, with the program described above, only a single application of B. thuringiensis, or none at all, has been required for control. The ultimate aim, of course, is for effective control to be maintained by the parasitoids so that no applications are needed. For that, the artificial nature of the landscape must be modified to provide the appropriate parasitoid-pest ratio, and that may not be possible in some areas even with the introduction of appropriate nectar sources. In those areas, the balance will be restored by a single B. thuringiensis application.

A further consideration is that a single pest should not be considered in isolation but should be included in the overall strategy for pest control in a given landscape area. The introduction of biological control for the red-humped caterpillar would be futile if broad-spectrum chemicals were still used for other pests in the same locality. In the Sacramento Valley of California, an example of that problem arises with the control of aphids on Pyracantha in the same areas where the red-humped caterpillar is a prime pest. The aphids may be readily controlled by various organo-phosphate insecticides, but that treatment would kill not only the parasitoids controlling the red-humped caterpillar, triggering a resurgence of that pest, but also the predators of the aphids that would otherwise produce adequate control later in the year. Where that problem has arisen, we have found that a spray of medicinal soft soap solution will physically remove approximately 70 to 75 percent of the aphids on Pyracantha and cause minimal harm to the parasitoids and predators. That treatment prevents the aphid populations from increasing too rapidly early in the year, and allows the aphid predators to catch up and exert satisfactory biological control. Thus, the control of the aphids on Pyracantha has been integrated with that of the red-humped caterpillars on the ornamental trees in the same landscapes and has, incidentally, further reduced the use of chemical pesticides.

The project described above is just one of several nonchemical pest management research programs sponsored by the California Division of Highways. Another example is the importation by the division, in cooperation with the University of California at Berkeley, of Australian insect predators for suppression of Albizzia psyllid, an insect that was accidentally introduced from Australia years ago and is now a pest in highway landscapes. The projects all form part of a long-established objective of the division to maintain its landscapes as economically as possible and with minimal use of chemical pesticides. As new developments occur, they must be fully implemented into the statewide pest control program before the benefits of the research are fully realized. The training of the landscape maintenance personnel in the new techniques

Table 1. Pesticide purchases.

Pesticide	1969	1971	Percentage Change
Carbaryl, Sevin, gal	620	25	-96
Diazinon			
Gal	1,619	390	-66
Lb		150	
Malathion, gal	675	0	-100
Methoxychlor, lb	413	0	-100
Bacillus thuringiensis			
Gal	110	313	+470
Lb		314	

of biological integrated control is accomplished by a series of illustrated lectures and demonstrations by University of California faculty, U.S. Department of Agriculture scientists, and other experts at the Highway Landscape Academy. Those lectures provide the essential contact the maintenance personnel need to fully understand the principles involved and to relate them to their own districts.

An indication of the progress made to reduce pesticide level is shown by data given in Table 1. A comparison of the relative costs of materials purchased in 1971 compared with those purchased in 1969 shows an estimated saving of 58 percent. Overall pest control savings, because they are more sensitive to labor costs than to those of materials, may be much greater as a result of fewer pest control operations.

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The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented, and not necessarily the official views or policies of the state of California or the Federal Highway Administration. This paper does not constitute a standard, specification, or regulation and has not been reviewed by the sponsoring agencies.

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