Quality as a Function of Traffic Demand and Available Funds in Design and Construction of Low-Volume Roads

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The importance of constructing low-volume, low-cost roads, both in developing countries and in the United States, is increasingly recognized. Their importance must be viewed not just from the viewpoint of the transportation service they provide but also from the broader perspective of their economic and social impacts on the lands they serve. A significant problem in administering low-volume roads is the extensive number of miles of roadway to be constructed and maintained in relation to available resources. Although provision of transportation services to key areas is a basic low-volume-road criterion, low-volume roads must also provide economical transportation, preserve or develop the economic vitality of areas, provide for cultural interchange, and assist in low-public-enforcement and emergency operations. Thus, quality is in terms of both engineering and economic activity. Decisions made at each stage of planning, design, construction, and maintenance activities restrict the options and related cost considerations of the next stage. Design and construction standards must be simplified to minimize costs but also consider maintenance costs that will be incurred. Planning and programming techniques must be based on very limited data and should also be as simple as possible. All recommendations regarding planning, design, construction, and maintenance of low-volume roads must be thoroughly discussed with all affected public agencies and private interests. This will help ensure understanding of recommended road programs, obtain the necessary coordination with related land use programs, ensure optimum use of limited resources, and obtain support for implementation.

Of this nation's 3.9 million miles of roads and streets, almost 2 million are either unsurfaced or have a surface of slag, gravel, or stone. Another million miles have a minimum surface that ranges from surface seals and chip coats to not more than 7 in of combined surface and base, which is classified as having a low load-bearing capacity.

Whereas constructing and maintaining high-volume, high-design roads receives primary emphasis, the importance of constructing low-volume, low-cost roads is increasingly recognized because of their important role in economic development. This is true in both developed countries such as the United States, where major Interstate highways are nearing completion, and in developing countries, where rural development is being given increased emphasis. Low-volume roads must be evaluated from the viewpoint of the total development potential of the areas they serve.

OBJECTIVES

Many existing low-volume roads came into being without planning or engineering, yet planning and designing low-volume roads can be more difficult than designing high-volume facilities. Careful planning and programming are required to ensure the optimum use of increasingly constrained resources. The objective of this paper is to explore and provide direction on the following questions:

1. What are the criteria that lead to design and construction of low-volume roads?
2. Where should these roads be constructed?
3. At what level of quality should such roads be constructed?
4. Who determines the type of road that will be put in place?
5. What is the basic purpose of such roads?
6. What has been the experience with such roads in various countries?

BACKGROUND

In the United States, prior to the use of motor vehicles, owners of abutting land were responsible for roads. Since the early 1900s, local governments have assumed primary charge for constructing and maintaining roads and streets, and the burden for major interregional and Interstate highways has shifted from local agencies and funding by the property tax to state agencies and funding by state and federal highway user revenues. The administration of low-volume roads has usually remained the responsibility of local officials. Some local officials (e.g., county and city) have jurisdiction over both major arterials and low-volume roads. Others (e.g., township and town officials) have jurisdiction over very limited low-volume systems.

The argument for retaining road administration by a multitude of local officials is that local officials are more sensitive to and responsive to local needs and concerns. The problem is that some officials have the revenue base to employ skilled personnel to do the necessary planning, design, construction, and maintenance activities and to purchase and maintain the required road equipment but others do not.

Low-volume roads feed city, county, and state collector and arterial highways and thus are part of a total interconnected highway network. They provide access to food and natural resource production and recreational facilities in rural areas and to residences in towns and cities. Their importance must be viewed not just from the viewpoint of the transportation services they provide but also from the broader perspective of the economic and social impacts on the land uses they serve. Planning and programming decisions must consider these impacts in establishing road designs and construction priorities. Because planning and programming techniques will have to be based on very limited data, they should be kept as simple as possible.

A significant problem in administering low-volume roads is the extensive number of miles of roadway to be constructed and maintained in relation to available revenues. The property tax is usually the primary source of funds to local officials for these roads; gasoline tax or other funds from a higher level of government are another source. A problem frequently encountered in using these other sources of funds is the administrative control of the higher level of government, particularly in the required use of standards. Agencies that administer low-volume roads want to stretch their limited resources over as many miles of road as possible but find that they must make fewer improvements at higher cost in order to receive the funds from the higher level of government.

The alternatives or choices open for construction and maintenance are far more numerous for low-volume than for high-volume roads. This calls for a wider range of judgments. Most design standards are neither economical nor feasible for low-volume roads. Low cost is always the prime objective on low-volume
roads, and this makes their design very sensitive with regard to the quality of the paving material, pavement thickness, geometric design, and other factors.

The design of the low-volume road must include consideration of such items as vertical and horizontal alignment, roadway width, surface type, and the relation of these to the required maintenance efforts. Also, it is considered that such variations as terrain, climate (temperature and moisture), soil types, traffic (volume and composition), and driver behavior. Generally, accidents are not a design problem. More important from the user's point of view are the operating costs, which tend to be higher on low-volume roads because of sharp curves, steep grades, and road roughness that results in slower speeds. Road roughness also decreases the useful life of vehicles and equipment. The level of maintenance objectives that are established and implemented will also affect both user costs and maintenance costs.

About 75 percent of the roadways in the United States are low-volume roads. Too little attention has been directed to this system. These roads must be revitalized at a time when funds and resources for doing so are decreasing. Furthermore, developing countries must construct low-volume roads in order to utilize their resources so that they can fully participate socially and economically with other nations.

CRITERIA FOR DEVELOPMENT OF LOW-VOLUME ROADS

The basic criterion for the development of low-volume roads is to provide transportation service for key areas. The use of the phrase "key areas" may appear strange in this context, but it seems clear that roads of any type will not be constructed unless there is some need for transportation operations in the area in which the roads are to be built. This suggests that the locations are truly key areas, although this may be viewed in a relative context. The fact that low-volume dirt roads are provided in one area while high-quality paved eight-lane highways are constructed in another is an immediate indication of the relative significance of the two areas in which the facilities are to be located.

Normally, the key areas are rural areas, in which producers must find some way to transport their products to the marketplaces as discussed earlier, and those areas are needed to transport goods and services from the marketplaces to the producers. However, if some form of road transportation can be provided that will allow two-way interchange between rural and urban areas, there is a strong possibility that the rural areas will grow, providing they have a certain level of productivity that can be turned into agricultural production. Although agricultural production obviously comes to mind, the same is true for many mining areas throughout the world. In some parts of Australia, for example, much of the mineral wealth that has been discovered lies in rather arid and remote areas. Because it is much cheaper to provide roads than, say, railroads to carry out the minor areas, low-volume roads have been constructed.

It is worth noting that because such roads carry very heavy loads in the form of large trucks, it has been necessary to reinforce the roads far beyond the level that might be expected for agricultural-commodity roads in countries like India and New Zealand.

A further criterion for the development of low-volume roads is the provision of social and cultural interchanges between areas served by the roads themselves. This point is somewhat different from the ones listed earlier and suggests that, instead of merely providing a link between a production and consumption area, the low-volume roads will provide internal links between subareas within the total rural area. This is the pattern that has grown up in the American Midwest, with its large farming community.
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sophisticated design concepts is quite costly. In
the Outback areas of Australia, where the sheep
and cattle stations are connected by low-volume roads
that, in many cases, are nothing more than bush
tracks. Subject as they are to considerable prob-
lems with weather conditions, these roads neverthe-
less provide a much-needed link between those rather
remote habitational in areas outside the urban and
semiurban areas. Furthermore, this rather primitive
road network allows residents within the rural areas
to move into small towns that will grow to serve the
population as the need arises. In other words, al-
though the major emphasis may be on the movement of
crops and other produce that is produced in the rural
areas, in the case of Mexico, of the total
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million and throughout the entire country there were
only 40 000 motor vehicles. In 1950, the population
had increased to 26 million and some 300 000 vehi-

A further reason for the development of low-vol-
ume roads lies in the need to assist in law enforce-
ment and emergency operations. While the pursuit of
troops across the ranges and through the valleys is
romantic to read about, it was obviously very time
consuming and rough on the lawmen, since the crim-
nals always seemed to have a better knowledge of the
country. With the coming of the railroads in the
United States and the subsequent development of
country roads, the role of the criminals became
tougher and they found it more difficult to carry on
unlawful pursuits and get away with them. The road
network throughout the rural areas made it possible
for law enforcement agencies to catch up more
quickly with the criminals and to restrict crime to
those areas not served by efficient transportation.

The same thing is true of emergency needs for
rural areas. In cases of floods, fires, or earth-
quakes, it is essential that some form of road ac-
cess and egress be available in order to move people
away from the danger areas as quickly as possible.
There are numerous examples of this in every country
affected by these events. They range from earthquakes
that have had significant impacts on life and property in
countries like China to the comparatively recent
volcanic explosion of Mount St. Helens in Washington
State. The Mount St. Helens incident was modified to
some degree by the fact that many people in the area
were able to move out of the danger zone over good roads
before the major explosion occurred. But in the ab-
sence of such road communication, many people may be
killed or injured under conditions of extreme emer-
gency.

Finally, the provision of low-volume roads is
seen as desirable because of the contribution it
makes to the total transportation network in an
area. It is not suggested that in most areas trans-
portation planners should go out and draw lines on
the map to indicate in detail where the transporta-
tion network will go. But there seems little doubt that
they should have a conceptual idea of what is
required and regard low-volume roads as an important
part of the total. In addition to the railroad and
aviation networks, low-volume roads will supplement
the major arterials and collector roads that are
constructed through an area. But the contribution of
the low-volume roads will be very real. It is
difficult to suggest in general terms what this
might be, but it seems clear that it will incorpo-
rate all of the points already discussed and provide
overall cost-effectiveness for a developing area.
In addition to being cost effective, the low-volume-
road component will also provide an operational sup-
plement to the total transportation network and en-
force its efficiency in serving the area through
which it has been constructed.

QUALITY CONSIDERATIONS IN LOW-VOLUME ROADS

Enough has been said to this point to indicate the
importance of low-volume roads in developing nations
and also, for that matter, in areas that already
have achieved a significant degree of development.
As stated, the basic need lies in the rural areas of
the nations considered. Such roads can range from
bituminous-surfaced roads many hundreds of miles
long to earth tracks only a few miles in length.
Most often, such rural roads involve simple con-
struction and drainage, are relatively short in
length, and have relatively low traffic volumes.
But they also represent the grass-roots provision of
the means of transportation between rural areas and
regional urban centers.

Such roads cannot be considered in isolation from
either the vehicles that use the roads or the fac-
tors that determine transportation demand. They
are best considered as a component of a much larger
total transportation and distribution system. Thus,
changes in one aspect of the system may have effects
on all other components. Where extra crop storage

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for the railroads. The situation reflected by these
figures is changing: The annual rate of increase in
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Such a move would raise the design standards and the
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Mexico's road infrastructure: There were 1980, the population had reached 70 million and there were more than 6 million motor vehicles. Thus, between 1950 and 1980 the population multiplied almost 3 times and the number of motor vehicles more than 20 times. This dramatic change in Mexico has resulted in the emergence of problems in the road transportation network. Although the existing network of highways and roads provides communications for Mexico's total urban population, it reaches only some 50 percent of the rural population, which means that approximately 14 million Mexicans are still without any form of overland connection.

It appears that two serious problems confront Mexico's road infrastructure:

1. An inability to meet the growing demands of road transportation and
2. Limited coverage that leaves a large portion of the country's area and numerous villages without any suitable permanent means of communication with the rest of the Mexican people and, consequently, without one of the essential factors for development.

The government of Mexico is aware of the need to improve the quality of service offered by the national highway network and is reconstructing some sections, widening others, and modernizing still others by building additional lanes when this justified by traffic demand. The need of the rural areas has been very closely defined, and attempts are being made to extend the system into those parts of the country now suffering from the lack of adequate rural highways. The considerable difficulties involved in doing this are discussed later in this paper.

In undertaking this type of analysis and expansion, the Mexican authorities, like their counterparts in other parts of the world, have looked at the need for effective quality standards. In the case of highway standards, these vary by the country involved, although some degree of consistency may be imposed by engineering knowledge. Thus, for example, safe stopping distances and speeds, grades, curvature, and superelevation relations will all play a part. With these, however, assumptions regarding factors such as driver behavior and coefficients of friction can lead to wide variance in results. Regardless of how standards are set, for low-volume roads the aim is to set minimum standards that are consistent with economy. This is a problem that is tackled by highway engineers in various parts of the world every day. It is not possible here to spell out every design standard that might be applicable, but a few observations can be made.

For major highways, it is often required that side slopes on high embankments and back slopes in deep cuts be flatter than the absolute minimum. This is intended both to reduce erosion and to lower the probability of slides, which will delay or block traffic. With low-volume roads, this practice is not warranted unless the consequences are severe, as when slides will seriously contaminate or otherwise damage waterways or streams or prevent the passage of essential traffic.

Similar considerations apply in the use of materials and construction methods. Highway agencies have developed elaborate and carefully controlled procedures for material selection and construction. Thus, embankments are often built in layers of carefully chosen material that has been moistened and compacted to a required density. The grading and other operations involved in the materials and underlying pavements are also carefully controlled, and requirements for the pavement itself are quite rigorous. Although such practices are justified for major highways because they result in a road surface that remains intact and smooth under many repetitive loads of heavy wheel loads, it is not clear that such provisions are justified for a low-volume road with an earth or gravel surface. It may be possible to use roadside material for the embankment, perhaps the surface and to specify less stringent controls—or, in certain cases, no controls at all—on moisture and density. It is clear that deficiencies in the high-design type of roadway are difficult and costly to remedy, but surface irregularities in a gravel surface can be corrected easily and cheaply. The problem is to decide which among the many requirements and procedures developed for high-volume, heavily loaded roadways are necessary or cost effective for low-volume roadways.

Some attention should also be given to the quality standards necessary for the maintenance of low-volume roads. Maintenance has proved to be crucial in many developing nations because many roads have been allowed to fall into disrepair and become impassable. This suggests that the highway authorities in these countries should look at three sets of issues:

1. Maintenance, management, scheduling, and control must be properly organized.
2. Levels of maintenance must be determined, depending on the local issues and the need for an adequate road surface.
3. Maintenance equipment and procedures must be selected.

For low-volume roads, all of these and many other maintenance issues need to be examined from the economic point of view. In addition, it should be stressed that the quality needed in low-volume roads depends on a whole series of factors, most of which have already been mentioned. Their development is crucial to an effective program.

To this point the quality standards have been devised and applied through the design, construction, and maintenance programs, effective economic evaluation must be made to determine that the results are, in fact, beneficial. The two principal components of benefit commonly found in rural road planning are (a) user cost savings and (b) increases in agricultural and mining production (land development benefits). The ability to quantify these items and bring them into the analysis will determine how well the analyst is able to understand and quantify the factors that are significant in this total economic framework (there are other benefits that should be considered, but at this point these two factors will suffice).

All too often, agricultural benefits have been included in rural road analyses in a somewhat arbitrary manner. Forecasts have sometimes been made with no empirical justification. The results of such an appraisal do not inspire confidence. For example, in one appraisal agricultural production was forecast to grow at a continuous rate one-third more with the road investment than without it. In this case, benefits were estimated to be 90 percent of the final market price of the agricultural products. In a second analysis, cotton production was forecast to grow 3 percent faster with the road investment than without it and benefits were estimated to be 70 percent of the final market price of cotton. These ambitious projections were based on the desire to justify rural road development under any circumstances whatever. It is most essential to accurately undertake the appropriate cost-benefit analysis and include all economic costs as well as these, and other, benefits.

In summary, the matter of quality is both an engineering and an economic activity. It is possible
to develop appropriate design, construction, and maintenance standards for virtually any road in any part of the world, but it is more difficult to assess the impact in rigorous economic terms. But it is essential that this be done in order to make it possible to expand the network and bring total economic benefit to a country or an area. As indicated, this is currently being undertaken in Mexico, and it is hoped that the results of that effort will prove highly successful for the Mexican economy and the Mexican people.

**POLICY DECISIONS IN DEVELOPMENT OF LOW-VOLUME ROADS**

Even after criteria are established for the development of low-volume roads and their cost-effectiveness is determined, decisions have to be made as to when and where such roads should be put in place. Certain institutional requirements must back up the planning process. Decisions made at one stage in the planning, design, construction, and maintenance of the roads restrict the options, and related cost considerations, of the next stage.

**Planning**

Analyses of high-volume roads place primary emphasis on transportation economics and secondary emphasis on broader economic and social considerations. For low-volume roads, especially developmental roads, the emphasis is reversed. Analyses of low-volume roads must encompass the whole range of economic and social considerations, since transportation planning is only one aspect of the total planning and decisionmaking process.

Traditionally, transportation planners work within a framework that involves national, state, regional, and local perspectives. Transportation plans by the agencies range from formally adopted, comprehensive transportation and land use plans to general policy and objective statements to guide project selection.

Typically, those responsible for project planning and programming carry out these analyses in coordination with those in other agencies who are also responsible for road development. Although this process of liaison among those responsible for road development works well for high-volume roads, a broader perspective and involvement are required in planning and designing low-volume roads.

Those responsible for low-volume roads must have much broader communication and interaction with local governments and other persons who have economic and social interest in the area under study. The low-volume-road planner must work closely with governing agencies responsible for agriculture, timber and mineral resources, recreational facilities, education, health, and other branches of government activity. The planner must also be aware of private development interest. Through ongoing liaison with affected agencies and individuals, the planner must select and analyze the various inputs and develop recommended actions.

Specifically, policy direction is needed in the following areas.

**Total Developmental Potential of Area Under Study**

In addition to identifying existing land uses and economic development, the developmental potential of the area, through expansion of existing development and introduction of new development, must be determined. This involves identifying policies and development plans of other agencies responsible for agriculture, timber and other natural resources, and industrial, commercial, recreational, and other types of development. From these individual agency policies and plans, a composite set of areawide policies guiding expansion of existing development and the introduction of new development can be determined. Constraints on these potential developmental policies may result from policies of such related agencies as water supply, electrical utilities, sanitation systems, housing, schools, health and medical facilities, and ports, terminals, and airports. The impacts of these constraints must be carefully considered in developing the areawide policies and plan.

**Schedules for Development Programs**

Policies that set the general time frame and sequencing of developments must also be determined. Again, the policies of some agencies may constrain the alternatives open to the implementing agency. Implementing agencies must have realistic estimates of time frame, budgets, and costs for their proposed developments. In addition, they must consider the availability of manpower to construct and operate the development as well as the institutional constraints placed on it. The institutional constraints include both those noted in the paragraph above and such constraints as may be imposed by zoning, building standards, environmental considerations, and local and national economic conditions. The agency must also establish the financing plan to support construction and operation of the development. Again, the low-volume-road planner must work closely with the various agencies to determine their most likely time frames for construction and their specific locations for expansion of existing development or introduction of new development.

**Road Development Plans**

The characteristics and the adequacy of the existing roadway network must be evaluated to determine what roads must be developed or redeveloped to meet the transportation requirements of the development programs. Policy decisions to be reached in determining the required road network involve the following road improvement categories:

1. Establishing a new route to serve a new area of development,
2. Upgrading (realigning) an existing route to provide a more direct route,
3. Upgrading an existing route for which greatly increased traffic is expected, and
4. Improving an existing road that has deteriorated through inadequate maintenance.

The need for the road improvement is determined by relating road improvements to the developments to be served. Forecasts of traffic are based on analyses of how improved access enhances economic activity and production (perhaps measured by how inadequate access inhibits the economic development). Both levels of employment (employees per vehicle trip) and levels of production (tons produced in relation to vehicle size and use) assist in forecasting travel demand.

**Road Development Programs**

Policies for preparing low-volume-road construction programs must be closely integrated with the schedules for implementation of development programs, within the constraints of available revenue. A basic policy determination is the proportion or amount of total revenue that will be designated for
low-volume-road programs. Once that determination is made, additional policy decisions are required to allocate funds for construction or reconstruction and for maintenance activities.

Because low-volume roads have received only minimal levels of funding, the establishment of construction priorities is a critical step. As previously noted, both user and nonuser benefits must be considered in determining the location and time sequence of improvements. The predominant user benefit will be the reduced operating costs that result from the higher-quality road. The higher-quality low-volume roads will have higher speed and shorter travel time. The predominant nonuser benefit is the enhanced economic viability and added economic development that result from the greater accessibility provided by the road improvement.

The projects can be prioritized by using benefit-cost, present value, or rate-of-return economic comparisons. Project benefits and project costs can also be compared with the number of vehicles and tons of freight served by the improvement. Generally, capacity deficiency comparisons or accident reduction savings are not a consideration in analyzing low-volume roads.

Not to be overlooked in preparing the financing plan for low-volume-road programs are the interest and participation in the project costs of a private agency or another government agency because of the benefits of the improvement to their programs.

Design and Construction

Planning decisions that determine the volume and characteristics of forecast traffic and the location of the road restrict the number of optional designs to be considered. Some of these options are further restricted by climate, soil type, topography, and availability of roadway construction materials. Construction materials should be from a locally available source to the maximum extent possible in order to optimize the use of limited funds. Construction staging and schedules should minimize disruption of existing traffic movement to the maximum extent feasible.

The design standards at which the low-volume road is to be designed should enable the road to serve existing and proposed levels of economic development. Too low a design standard may inhibit growth, and too high a standard may encourage growth beyond that indicated by the areawide development policies and plan. Too high a standard will also result in two many funds being expended in one area to the detriment of other locations where improvements are needed.

Maintenance

The surface types, roadway geometries, and types of bridge structures on low-volume roads vary with travel demand, which is influenced by the land uses and functions being served. The level of maintenance service to be established must be consistent with the functions of the road. Generally, there is an inverse relation between construction standards and the level of maintenance effort that will be required. A maintenance level that is too low will have negative impacts on developmental activities, whereas a maintenance level that is too high will incur unnecessary costs and could encourage greater development than that anticipated by the areawide development policies and plan. In the absence of specific guidelines for determining levels of maintenance, and their related maintenance activity costs, judgments will have to be made on the basis of appraisals of the quality of roadway surface needed in relation to the traffic volumes and land uses served. Routes can be prioritized in relation to their function and maintenance activities and funds allocated accordingly. The stated levels of maintenance should clearly define what activities are and what activities are not to be done for each priority of road.

All recommendations regarding the planning, design, construction, and maintenance of low-volume roads should be thoroughly discussed with the various affected agencies to ensure their understanding of the recommended programs. This understanding is needed for successful implementation of the recommendations.

CONCLUSIONS AND RECOMMENDATIONS

The comments made in the previous sections suggest that low-volume roads are an important part of the transportation network of many countries. Much work has been done in planning, design, and construction of such roads, but more remains to be done. This is particularly true in determining the economic viability and the social consequences of constructing such facilities, particularly in times of increasing costs and revenue shortages. In addition, persons responsible for undertaking low-volume-road development programs should be aware that there are many aspects of the problem that need to be considered. This is well demonstrated by the work of Tipping in Tanzania (1).

Tipping points out that it has become orthodox procedure in road appraisal studies to take road user savings as the principal class of benefits. But insufficient attention has been given to the changes to which vehicle operating costs will be subjected over the life of a project, and these changes will make a large difference to a project's estimated rate of return. Persons involved with the development of low-volume roads should develop the data, from whatever historical records are available, to allow them to reach conclusions on this point.

Tipping also suggests that the income distribution effect should be given more attention for reasons of equity and fiscal balance. The levying of tolls, where practicable, could achieve these aims, and all roads should be sought as a vehicle to generate funds in one area to the detriment of other locations where improvements are needed.

The difficulties of project appraisal make it more necessary to have a good sectional study. This would ideally give the information needed for making decisions on maintenance and investment programs, in the light of anticipated traffic flows and the economic and other developments that will generate them. A carefully structured evaluation, leading to a program of construction and maintenance, is necessary in most developing countries. Mozambique is another example of this. The road network in Mozambique is relatively dense for a country so sparsely populated. However, it is generally in poor condition. Most of the roads are unpaved and almost all roads are in dire need of maintenance. This lack of road maintenance creates serious problems for road transportation operations. Average speed is very low, and the wear and tear on vehicles is extremely high. There is no connection between the traffic planning of the road transportation opera-
tors and current maintenance planning. Road accidents are numerous. In 1979, the number of persons killed in road traffic accidents per vehicle was 15-20 times higher than in Northern Europe. In addition, the material damage caused a lot of vehicles to be wrecked. Obviously, the inadequate quality of the low-volume roads in Mozambique has created its own series of economic and social losses.

In Australia, the situation is somewhat different. In that country, there is a high level of expertise among those persons planning and building roads to serve low-volume traffic. In addition, funds have normally been available for construction and maintenance of high-priority links. This does not mean that funds are available to meet all of the needs expressed by the various areas, but the trend has been generally positive and upbeat. Part of the reason is Australia's longstanding dependence on its agricultural and pastoral sectors and the political influence of certain rural legislators. As the economic dependence of the country has moved from agricultural-pastoral development to mineral extraction, the emphasis has changed. A new type of low-volume road is being constructed to serve the mining areas while the agricultural-pastoral roads are being effectively maintained. Australia has thus experienced the best of both worlds.

Reference has already been made to the problems in Mexico. This is a country where additional low-volume roads are needed, and this requirement is known to the central government. But there is not a consistent, widespread development program in Mexico (as there is in Australia), partly due to the lack of adequate resources in many parts of the country. The same situation applies in large parts of Australia, but in that country those areas have simply not attracted settlement. There is no population pressure in Australia as there is in Mexico. The financial options open to Mexico are limited, mainly because of the demands on the central government for support for so many basic social and economic programs.

This paper demonstrates that the quality of low-volume roads cannot be considered in isolation. It is tempting to suggest that there is a direct relation between desirable quality and anticipated traffic demand, and this seems to be the premise underlying much of the low-volume-road construction that has taken place. But this is an oversimplification that may have confused many issues, including potential benefits and the value of the road investment. This is not an easy problem to solve; quality and cost are two measures that must be considered jointly.

It is suggested that all persons responsible for low-volume-road programs should go back and redefine the needs of the areas in which they are interested. That redefinition should cover the links that are necessary for proper development, and the question must continually be asked as to whether or not these roads are essential. There is a need to assess the quantity of roads needed along with the quality necessary to do the job.

Once this important step has been completed, funding requirements will then appear in a more realistic light. There will no longer be a "wish list" of high-quality roads designed to crisscross an area but, more properly, a limited number of essential links. Out of that will come some form of priority array that will be consistent with the needs evaluation, the quality concepts, and the funding constraints. In putting this together, the coordinators will normally be looking to a long-term construction program supported by a short-term (ongoing) maintenance program. In developing these programs, a conscientious effort must be made to increase the technical skills of all persons associated with the various projects.

If all of this can be achieved, quality programs will result. The role of the decisionmakers will then become one of monitoring implementation and continuing to review and modify the needs and programs.

REFERENCE