The Needs of Developing Countries in particular so far as Design and Construction are involved

Les besoins des pays en développement en matière de projet et d'exécution

Die speziellen Bedürfnisse der Entwicklungsgebiete im Bereich Planung und Ausführung von Bauwerken

C.D. CROSTHWAITE
FICE, FIHE, FASCE, FCIT
Freeman Fox and Associates
London, Great Britain

ALF BERGAN
MNIF
Freeman Fox and Associates
London, Great Britain

1. INTRODUCTION

The following theme is presented from the point of view of the Consulting Engineer rather than the Contractor but this is not to say that purely constructional aspects have been ignored.

We begin by making certain remarks which have a substantial bearing on our approach to this matter of design and construction in developing countries.

It is frequently assumed that development, in the sense of the exploitation of natural resources, industrialization with accompanying urbanisation and changes in the pattern of agriculture from the traditional peasant farm to more sophisticated labour saving agriculture, all of which are intended to increase the wealth of the country, is an activity that should be pursued without reservation. It is regarded as axiomatic that increase in wealth equates with increase in well-being.

Liberal thinkers and environmentalists would question this, they would say that the damage to the environment resulting from massive and insufficiently planned changes in the way of life of developing nations can result in a decrease rather than in an increase in their happiness and well-being. On the other hand the peoples of the underdeveloped world could say with good reason that they have no environment to damage. We come down on their side. It is easy to decry development and exploitation of natural resources when, as a citizen of a rich nation, one has had a surfeit of the good things of life.

We mention this now because later on we emphasize that design and construction

in the underdeveloped world can and must be conditioned by a real concern for the environment. Mistakes made in the earlier years of our own industrial revolution must not be repeated elsewhere.

Before considering the needs of developing countries perhaps we should attempt to define our terms. We would say that a developing country is one which lacks the resources in manpower and equipment to extend and improve its infra-structure, industry and agriculture without recourse to outside assistance, however wealthy it may be. Some developing countries do possess in large measure such resources but are severely handicapped by lack of finance and foreign indebtedness.

The expression "underdeveloped" should not, as it sometimes is, be regarded as derogatory. Nearly all the Third World Nations are underdeveloped. Very often the wealthiest have the greatest deficiencies in manpower and equipment whereas others such as India possess substantial reserves of skilled labour which cannot be deployed because they are financially impoverished.

The problems of design and construction in the developing countries vary substantially depending upon where their major resource deficiencies lie. It is helpful to break them up into several categories and discuss these separately.

Developing countries can very broadly be grouped as follows:

- Those with economies in the early stages of development almost wholly dependent upon the export of raw materials, primarily the surplus unprocessed production of peasant farming.

- Partially developed countries, often with substantial reserves of professional expertise and skilled labour but frequently deficient in financial resources.

- Wealthy nations, especially those who have achieved this position in recent years. They may be underpopulated and in addition have not had the time to produce their own cadres of professionals and associated skilled manpower.

2. COUNTRIES WITH UNDEVELOPED ECONOMIES

These countries are unlikely to have much expertise at the professional level, and are deficient in skilled labour. There will be no local firms of consulting engineers or contractors.

The engineer-designer and contractor, particularly if their home base is a European country with an old tradition of working in the ex-colonial territories, such as Great Britain and France, in many ways have a more straightforward task than in a country which has proceeded some way along the road of self-development.

All plant, skilled labour and professional expertise must be imported. The client country's interest will be almost wholly with the end product, rather than in the way in which it is designed and constructed. It will of course be concerned with its quality and cost and ease of maintenance.

In colonial times the finance for the project would have come from the home country, this is now less likely to be the case. Firms will be chosen from an

approved short list and will have had to satisfy an international agency or an agency from their home country that they are sufficiently competent and experienced to undertake the work and will have to spell out how they intend to carry out their assignment. However, once appointed, they will have a relatively free hand on how they proceed. This being the case, it behoves them to take especial care to avoid any suggestion of damage to the environment in their operations, as it is probable that the local government will not have the expertise to ensure that this is the case.

We said earlier that there is unlikely to be a substantial amount of local skilled labour. This statement needs qualification. Labour skilled at a certain level will be there and can and should be trained as far as possible on the job. At an early stage, a decision should be made as to whether the work should be planned so as to be labour intensive or whether massive constructional equipment should be brought in. A lot will depend on the urgency of the project. For example, railways or highways, perhaps the first priority, will need constructing or upgrading as soon as possible, and even taking into account the economic effects of shadow pricing, it will probably be better to bring in heavy plant, excavators, graders and so on rather than rely on labourers with picks and shovels and headpans or baskets.

Local materials are unlikely to amount to more than rock or gravel for concrete and road stone, and timber for strutting and centering. It would be a mistake to count upon satisfactory timber for shuttering being readily available.

We have mentioned maintenance, and in this connection we would say that highway construction should, perhaps surprisingly, be of a higher standard than in a more developed country. A dirt road not properly maintained will deteriorate very rapidly. Good maintenance of a dirt or gravel road is a skilled operation. It is very hard to control corrugation which keeps on recurring. (The French "flying saucer" is one of the best machines for doing this). One cannot help noticing how much better the standard of maintenance is in the more advanced African countries than in the others. It is advisable to black-top whenever possible. Particular attention must be paid to drainage. The policy of progressive upgrading, which will be referred to later, is generally not to be recommended.

3. PARTIALLY DEVELOPED COUNTRIES

In those countries a different approach to design and construction must be adopted. It is becoming an increasing requirement that consultants should associate with a local firm, in some instances the local firm must take the lead position. This results in a situation which indeed will probably be a requirement of the government in any event, whether local association takes place or not, that so far as possible, the whole of the design shall be carried out locally. It must be accepted that in many instances this will increase costs. Firms will have to second top class men for this assignment, men who normally would be supervising the design of several projects if working at home. These men will not have readily available to them the substantial reserve of multidisciplinary expertise in the home firm.

The short list of consulting and contracting firms is nowadays prepared by the government of the country concerned, with the executing agency, World Bank or other, advising and suggesting, but very rarely overriding the government's desires.

The Ministry of Works or other body will take a close interest in the project from its inception, and will probably require "counterparts" to work alongside the consultants both in the design office and in the field during construction. The purpose of so doing is two fold, firstly to ensure the training of their nationals in the disciplines involved, and secondly to ensure a continuity in the organisation and operation of the project after the Consultants staff have gone home. Here one must make the point that the consulting firm should second its own permanent staff to the project and not as is unfortunately sometimes the case, hire people whom they do not know and who do not know them specifically for the project.

The "counterparts" must also be very carefully chosen. They should be men of high quality and seniority, who, at the end of the assignment will be in responsible positions and capable of ensuring that the work is executed properly.

If the "counterparts" are insufficiently senior, the lessons learnt may not be accepted by their superiors in the organisation from which they are seconded. There is another difficulty about "counterparts", about which it is as well to speak candidly, that is, the rhythm of their work. The consultants team working overseas will be under high pressure to complete in the contracted period. They may devote insufficient time to training the "counterparts", fobbing them off with minor tasks. The "counterparts" in their turn may be reluctant to work at the excessively high tempo required of the Consultant's staff.

Ideally both the Consultants and the "counterparts" teams should include someone fluent in the other's language. Interpreters too often do not have sufficient knowledge and understanding of technical and contractual terminology.

We mentioned earlier the necessity of considering environmental aspects. It may be that the consultant, at the risk of offending his client, has to insist on designs and constructional methods which are more costly than the client is willing to accept. Particular attention should be paid to discharges of effluent and waste, whether from permanent or temporary works. This assumes great importance when works are to be constructed in mining areas and toxic wastes may be disturbed and pass into watercourses and rivers without treatment to render them innocuous. It is always possible to ensure that this does not happen, and with careful planning the costs arising need not be excessive.

4. WEALTHY NATIONS

The wealthier nations who come in the category of developing comprise mainly the oil-rich states of Arabia and countries such as Venezuela. Where countries become extremely wealthy in a short period of time, through the export of a product such as petroleum, special problems arise. The wealth of the country will be controlled by the governing elite. A country with great wealth but no employment for its people need massive development and extension of the infrastructure before employment in new industries can be provided. This will have to be a major aim of the government.

What does this mean for the consulting engineer and contractor? Firstly it must be appreciated that because a country is wealthy it is not therefore prepared

to be prodigal in despensing this wealth. Very much the reverse. Adopting traditional World Bank and other International Agency procedures, the governments can be very strict in their appointment of consulting engineers and contractors. They will, perhaps because they are wealthy, expect the best, but will only pay for what they think they have been provided with. Because of the deficiencies in infrastructure, there is a requirement for early completion of design and construction.

The Post-war history of the Middle East has resulted in an influx of Palestinians to many of the Arabian states; an influx of well educated professionals which has triggered off the establishment of a number of local consulting firms and contractors owned and run by nationals. Consequently, as in the partially developed countries referred to previously, it is becoming increasingly advisable if not yet essential to associate with these local firms. In any event the complexity of local politics, who is in favour with the Ruler or Prince at a particular time or not and so on, makes it difficult for overseas firms if they do not have these local associations.

Most of what we have said in regard to the logistics of working in partially developed countries applies to the oil-wealthy Arabian states. There is not, as in India for example, a surplus of professionals willing to be employed on a project, but the requirement for training "counterparts" is becoming of increasing importance. It will be found that the governments, although scrupulously fair in their treatment of foreign firms, can be quite ruthless if they have cause for dissatisfaction. Those which fail to come up to expectations are unlikely to be employed again. Wealthy countries such as Venezuela require a different approach. Here it is a requisite that consultants associate with a local firm of whom there are a substantial number. This firm will generally have to take the lead. Indeed the foreign consultants name may not even appear on the drawings! However this does not necessarily mean that the local firm possesses all the necessary expertise for the project. There is a need for tact and discretion.

We said at the beginning of our paper that we were writing primarily from the view-point of the consulting engineer.

What are the main differences and similarities between the problems facing consultants and contractors in the developing world?

Both will be expected to make use of local resources in professional expertise and manpower to the fullest extent. It is easier, and requires less capital outlay to set up as a consulting engineer than as a contractor, and local consultants are assuming more and more responsibility for the design of projects in their own countries. They are also competing successfully with consultants from the developed world in countries not their own.

The position as regards contractors is still somewhat different. The number of local contractors of sufficient size and expertise in project management to undertake major constructional works without outside assistance is still limited. It is likely to take some time for this situation to change. There are perhaps easier ways of making money! This also applies to Consultancy!

In what follows our paper will primarily be directed to the problems of design and construction of highways in the developing countries. These, with other forms of transportation are the prime needs of the developing world, but what is said is relevant to other constructional projects.

4.1 Planning of the Road Network

The planning and the construction of a country's road network is usually placed under the jurisdiction of a Public Works Department, a department under the jurisdiction of a Ministry of Works, hereinafter called the PWD. These PWDs have found it difficult to keep pace with the latest technical development in modern road construction methods and cope with the explosive increase in traffic. They face the need of improving the road network, bringing it up to modern standards by using advanced engineering methods.

The PWD's lack of experience in the design and construction of modern highways may compel the government to seek outside help and assistance. The PWD will concentrate its efforts on overall planning and maintenance of roads and highways and leave the engineering and construction of roads to consultants and contractors. The PWD is normally understaffed and by restricting itself to overall planning and maintenance, it can afford to spend more time and greater effort on road maintenance, which has often been neglected.

4.2 Consulting Engineers Services

4.2.1 General

In an undeveloped country where the reconstruction of its road network is under consideration, the local consultants if any, may have little or no experience in modern road construction techniques. Foreign consultants must be called upon and the first problem which the government will face is how to select a good consulting firm with the necessary experience and background.

The consulting firm should be regarded as a confidential trustee of the PWD, acting as the PWD's representative towards the contractor when supervising the work. It should not be compelled to compete with other consulting firms as to the remuneration to be paid for the assignment. Nevertheless this frequently turns out to be the case. A consultant should be paid all his actual expenses and in addition a certain percentage to cover his overheads and profit. The technical know-how, the background and experience of the consultant staff and the firm's reputation should be the only criteria used to choose the consultant.

The engineering work involved in the construction of a new road consists normally of two parts, the preliminary engineering including a feasibility study and the final engineering including the tender documents. Thereafter follows the supervision of the contractors work in the field, which in most cases is undertaken by the same consulting firm who did the design, provided that the PWD do not feel competent to supervise the construction by their own forces.

Preliminary engineering includes the study of several possible variants of the location of the road. For each variant a feasibility study is undertaken to define the best alignment and the recommended design standards. The feasibility study will take account of government statistics on traffic flow, agricultural and industrial development plans and traffic likely to be generated by the new facility. The alignment and the design standard adopted will be influenced by the results of this study.

The next step, after the final alignment has been agreed upon between the con-

sultants and the PWD, is the final engineering. It consists of detailed design on the selected alignment including culverts, bridges, retaining walls and other structures. The consultants' calculation of the expected unit prices applied to the Bill of Quantities provides the estimated final cost of the project. On this a decision may have to be made as to whether the scheme should proceed, be modified or deferred.

To handle the heavy workload included in preliminary and final engineering, the consultant needs quite a substantial staff. A natural solution is to make maximum use of the local market by hiring local engineers, technicians and draftsmen. A further step, often a requirement, as we have said earlier, would be to associate with a reputable local consulting firm. This will give the latter the opportunity to gain experience in this field of engineering. The government should encourage this so that the country will eventually gain independence from foreign consultants. This is part of the process of development.

An example from Iran may be of interest. In 1958 Iran embarked upon a major 8000 km. road development programme which was to run over a period of 8 years and be financed from oil revenues. Local consultants with road engineering experience were at that time not available and foreign consultants had to be called upon. During the 8 years a close co-operation between the foreign and the local consultant was established with the result that Iran to-day disposes of a number of well experienced local consultants in the road-engineering branch, who can stand comparison with foreign consulting firms.

4.2.2 Design Standards

The design standards, (in particular the width, minimum grades and radii) for the new road should be carefully considered. Too high design standards increase the construction cost which in undeveloped countries with limited development funds is important. On the other hand motorized vehicle traffic requires a certain minimum of standards, which cannot be reduced. Soil conditions and weather conditions also influence the choice of design standards.

a) The width of the carriageway

In undeveloped countries the width of the carriageway should be subject to consideration. It is a waste of money to permit a too wide carriageway as the increase in the predicted traffic forecast is more uncertain than in developed countries. However, the width of a double carriageway should not be less than 7 m.

b) The alignment

The standard for the design of a modern highway is characterized by the minimum grade and the minimum radius of the curves, depending on the chosen design speed. In an area of accidented topography a reduction of the minimum radius of the curves might become necessary, in order to avoid too long and too deep cuts and fills thereby reducing the danger of slides during heavy rainfalls. This is specially the case in tropical countries, where the lack of certain soil elements makes the consolidation of the slopes very difficult and costly. A detailed soil investigation during the design stage is a necessity.

An interesting example is the construction of the East-West Highway over the Andes in Peru. On the eastern slope the road was passing through a tropical

forest area with steep hills and valleys. Originally the road was designed to normal standards with smooth curves and slopes. The many cuts and fills were constantly moving during the rainy season and compelled the government to have certain sections re-designed with sharper curves, following more closely the contours of the terrain and restricting the cutting into the hills to a minimum.

c) Paving

In undeveloped countries the paving of the carriageway of the road is mostly restricted for normal roads to a somewhat lighter pavement such as double surface treatment, at least in the first years of the road. In many cases the expected traffic is so light, that the road is left as a gravel road. A gravel road in tropical countries has certain drawbacks. First of all it is difficult to obtain a gravel with the correct grading. Secondly, it requires a certain percentage of clay in order to bind the dust during the dry season. Clay is not always available and a clay-gravel road requires regular precipitation, if not, the gravel will dry out and the traffic creates a sky of dust, which decreases sharply the capacity of the road and increases tremendously the danger of accidents. Corrugation develops and is very hard to keep down.

During the rainy season a gravel road is exposed to heavy wash-outs, which require costly maintenance and repair operations. If bad maintenance can be anticipated, then as stated earlier, black topping should be seriously considered.

d) Base and sub-base

For roads in overseas countries the design of the base and sub-base needs special attention. Rock material for crushing is not always available. The sand and gravel mix found in the rivers might not meet the technical specifications. In such cases a stabilization with bitumen or cement using the available river and or other materials might be a solution.

Such a case was the construction of a main road in the south of Iran. The area was rich in ancient oceanic sandy material, for rock one had to go 100 km. into the mountains. The sandy material was stabilized with bitumen both for the base and the sub-base with very good results.

On the other hand, the lack of solid rock, but the presence of boulders spread around the area might lead to a special design of the base and sub-base. In Iran, certain places are lacking in solid rock formations, but the area abounds in small boulders. It pays to select these boulders by hand. The stones can be used in an old-fashioned design of a typical Telford base.

e) Structures

In the design of structures it is essential to take account of the availability of materials and skills.

Should for example bridges and other major structures be built in concrete or in steel? Governments generally have strong views on these issues, depending on whether or not they have steel or cement works in their own countries. If they have neither, a decision can be made on its merits, but many developing countries now possess cement works and also produce reinforcement and light steel sections. There will then be an insistence on reinforced concrete as

against steel. In India, which has a substantial steel making industry, this is not the case. India possesses numbers of skilled riveters, a craft that has practically vanished in the West, and a large stayed girder bridge has been designed over the Hooghly as a riveted structure in consequence.

In many countries masons abound, another dying craft in the West. Masonry should then be used wherever possible for minor structures instead of concrete.

There is a great deal to be said for a policy of progressive upgrading of highways in countries which have available to them a good standard and tradition of maintenance.

Each road would be designated as having a number of characteristics such as gradient, sinuosity and design speed, width, shoulders, pavement construction and surfacing, all of which characteristics affect the capacity and journey time on the link.

As the traffic demand builds up, so it is necessary to upgrade the road in some or perhaps all its characteristics.

If the characteristics are carefully chosen and a broad band classification of each characteristic is defined it is possible rapidly to obtain a complete check on the state of the network. Using unit costs suitably factored for topography, climate and geology it is possible to estimate the cost of upgrading any section.

The effect of this process is that a typical road might begin life as an earth track and as traffic demand is made on it limited amounts of money are spent on progressive improvement such as surfacing, reconstruction, realignment, embankmentssand culverting, bridges, widening and finally, construction to motorway standard.

The advantage of this process is that capital expenditure is directly related to traffic demand which itself is related to general prosperity and thus as a fraction of the G.N.P. Sharp jumps are avoided in transport network investment.

4.2.3 Supervision of the work in the field

The PWD has in most countries supervised all the construction work under their jurisdiction by their own forces. This is connected to the tradition of the past in which the PWD's policy was to execute most of the road works by their own forces, using neither consultants nor contractors. In that case the supervision of the work had also to be undertaken by the PWD.

The construction of roads designed to modern standards using highly mechanized equipment, requires a strict and close supervision by competent engineers to ensure that the road will be built to the technical specifications agreed upon. In only a few cases will the PWD have the necessary and experienced staff for such a control.

The logical solution is therefore to engage the same consultant who engineered the project to undertake the supervision also.

The supervision pattern might sometimes have some influence on the design. In the case that the PWD undertakes the supervision by its own forces, the

consultant should consider the following. Is the PWD in a position to enforce strictly adherence to the specifications? Should for instance the base be strengthened because an unsatisfactory compaction is expected? What about the placing of the bituminous pavement and the pouring of the concrete?

4.2.4 Road maintenance

Although road maintenance normally does not fall within the domain of a consulting engineer dealing with the design of a new road, it should influence his road design thinking. Road maintenance is generally one of the least glamorous operations within the PWD. It has been seriously neglected in all undeveloped countries. To the politicians road maintenance is something invisible, construction of new roads can be appreciated by the man in the street, therefore construction of roads is given preference.

As a consequence, the poor performance anticipated on the maintenance of a new road, might lead to some reflections during the design stage. Knowing the difficulties in some countries of achieving even routine maintenance during the first years of the road in operation, should for instance the paving be strengthened in such a way that the carriageway will stand up to wear and tear over a longer period of time? Should for the same reason the thickness of the base be somewhat increased, should the slopes of the ditches receive a dry masonry cover in order to stand better up to clogging and deterioration? All these are questions which a conscientous consulting firm has to consider.

4.3 Execution of the Work by Contractors and/or PWD's own forces

4.3.1 General

A road can be constructed either by the PWD's own forces or by the use of contractors. In the case of larger road projects the execution of the work by PWD's own forces might create serious problems. Generally, the PWD is lacking the necessary equipment and the manpower to undertake large road works. Furthermore, the work is to be executed strictly in accordance with the technical specifications, which is the duty of the PWD to enforce. A dilemma arises in the case of the PWD being the executing agent of the work and at the same time supervisor, in other words, supervising his own work. Investigation of several projects both designed and executed by PWD's own forces has clearly shown the deficiency of such a system.

On the other hand, in a number of countries the PWD has inherited a large labour force from the colonial times that it cannot get rid of. In such a case the PWD should use its own forces in executing the work.

Regarding the actual cost of works executed by the PWD's own forces, figures which reflect the same cost pattern as used by a contractor and employed for the purpose of comparison, are difficult to obtain. The belief of many PWDs that their costs are equal to or lower than those of contracting firms is hard to substantiate.

4.3.2 Contractors, local and foreign

As it is the PWD's aim to get the work executed at the lowest possible price without relaxing on the standards and the workmanship, the construction work should be awarded to a competent and experienced local or foreign contractor or to a joint venture of both.

The usual pattern used in awarding construction contracts for larger projects is international competitive bidding among pre-qualified local and foreign contractors. The contract is awarded to the contractor who is presenting the lowest evaluated bid, which is not always identical with the lowest bid price. Considerations such as timing of the work, availability of manpower and equipment, a better balanced bid, etc. should justify the awarding at a somewhat higher bid price although this takes place too rarely. The pre-qualification is important, it prevents inexperienced, both local and foreign contractors, from participating in the tendering.

If the job is manifestly too large or technically too complicated or requires a too large investment in equipment, all beyond the capacity of local contractors, then foreign contractors only should be invited for tendering.

On the other hand, by dividing the project into sections, the local contractor might be competent to bid on one or more of the sections, whereas the foreign contractor can bid on all sections combined.

Perhaps local contractors should be encouraged by reducing the standard of pre-qualification in their favour.

Iran is again a good example. When the large road construction programme started in 1958, there existed not a single local construction company with experience in earthwork, paving etc. based on mechanized operation. However, as sub-contractors to the foreign companies, the local contractors gradually became experienced and were able to take over more and more of the work reserved for the foreign firms.

Sometimes, the pre-qualification of those newly experienced local companies was risky both for the government and for the international agency financing the project. It resulted in delays in the execution and overrun of cost, but gradually the local constractors overcame their deficiencies. Today Iran has a contracting industry of substantial size and competence.

A joint venture between a foreign and a local firm does not only benefit the local one, but also the foreign contractor, especially if he is operating in the country for the first time. Through the local firm the main contractor can obtain assistance in hiring staff and labour, engage local sub-contractors, assist in purchase of materials and equipment and in the contractor's communication with the local authorities.

4.3.3 Manual labour versus mechanized operation

In countries with a large and cheap labour force, the question of manual labour versus mechanized operation is a serious one and needs close attention.

In India for instance, most of the road work is today still executed as manual work using labour in all operations to the greatest possible extent. Materials for fill are taken from nearby borrow pits along the line, loaded into straw baskets and head carried to the site and dumped. No earthmoving equipment is used. Until recently, the fill was not even compacted, the road was temporarily opened to traffic without any base or pavement. The traffic over a few years

created a certain compaction after which the road was again closed for base, sub-base and surfacing to be done.

The question of using primitive construction methods compared to mechanized operation is very much a matter of economics, "shadow pricing" referred to earlier must be taken into account.

On the other hand, a road which has to be built to a certain standard in order to stand up to the traffic, requires a minimum of mechanized operation, which cannot easily be substituted by manual labour. Compaction of base and subbase can be done without compacting equipment, by the use of manual labour on a massive scale. But pavement compaction is another matter. With a hand-layed pavement the required eveness cannot be obtained. Such a pavement would not stand up to the traffic and in short time will start deteriorating.