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Autor: Ribi, R.A.

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Aspects of Design

Aspects du projet

Gesichtspunkte der Planung und Projektierung

R. A. RIBI
dipl. Math. & dipl. Ing. ETH, Vizedirektor
Elektrowatt Ingenieurunternehmung AG
Zürich, Switzerland

1. INTRODUCTION

Designing a facility has to lead to the most economical solution for the problem the facility is supposed to take care of. In principle, the most economical alternative is defined to be the one among the technically, politically, legally etc. feasible alternatives that maximizes the economic return, i.e. the discount rate which equalizes the cost and benefit streams over the expected lifetime of the facility. In cases where in particular the benefit side of the economic computation is extremely difficult to quantify (e.g. for public utilities facilities, like additions to power, water supply, and sewerage systems) the most economical solution is defined to be the alternative with the cost stream which, discounted at an interest rate in the neighbourhood of the opportunity cost of capital leads to the least present cost for achieving the same purpose (e.g. for meeting the same demand, bridging the same valley); this is valid provided the tariffs reasonably reflect costs. As esoteric and general as these definitions may be, they lead to some very basic principles as to designing facilities in developing countries.

First, we are referring to economic, as against financial, returns, costs, benefits etc. Now, economic costs are, of course, based on local prices, but they also take into account shadow-prices e.g. for foreign exchange, labour, capital etc. reflecting the relative scarcity of these basic inputs. In many countries of the developing world, the shadow exchange rate for foreign currencies is substantially higher than the official rate. If taken into account, as it should, the shadow-pricing of foreign exchange is likely to make designs (or constructions methods) requiring a large local currency input, more attractive than those leading to a large cost component in foreign exchange, because in many developing countries the local currency is overvalued as compared to the most usual world currencies. A classical example is the choice between a hydro-electric and an equivalent thermal power plant in such a developing country. In this case, the shadow-pricing of foreign exchange usually tilts the balance towards the hydro-solution. The shadow-pricing of labour often gives the labour intensive project (in our example the hydro plant) priority because in developing countries labour is generally considered to cost in economic terms less, often (in particular where unemployment is high) substantially less, than the official wages. However, we should pay attention to the fact that whereas unskilled labour may well be economically cheaper than the wages paid, skilled labour and in particular management personnel, may be very scarce and accordingly, its shadow-price even higher than the often rather high salaries paid. The third factor mentioned above, capital, because of its scarcity, has usually also to be shadow-priced at a rather high rate. This tends to counteract to some extent, the effect of shadow-pricing foreign exchange and labour, because foreign capital might be available at reasonable cost, e.g. from developing agencies, whereas local money may be exceedingly scarce and hence expensive.

The preceding suggests the following basic conclusions:

1. For designing economically, we need a large amount of economic input, specific to the country in which we work, and this input should essentially be available at an early stage of design, namely then when the basic choices are made.

2. Comparison between alternatives even at an early stage of design should be economic and not financial; or if for reasons of simplicity we make the comparisons on a financial basis, we should be sure that the introduction of economic costs and benefits will not affect the substance of the conclusions reached on the basis of purely financial calculations.

The following chapters deal with some more specific aspects of designing in developing countries. We should, however, always look at these aspects against the background of the general economic considerations suggested above.

2. INFLUENCE OF LOCAL PHYSICAL CONDITIONS

The local physical conditions (topography, meteorology, hydrology, accessibility of construction site, geology, soil characteristics) in developing countries often confront the designer with two types of problems. On the one hand, data may be scarce, incomplete, recorded in unusual ways etc. On the other hand, conditions may be objectively unusual; e.g. the hydrology of the Senegal River in the last 600 km of its course with its polyvalent relationship between water level and discharges has its equal only in the relatively few other large rivers of the world with a very low gradient. When such a peculiarity appears in combination with doubtful data, which is by no means unusual, it is evident that the designer faces problems for which the solutions may not be found in books.

As to topography, we may be used to rules about what kind of precision is required for a map to be used for various design purposes. If we analyse these rules, we may detect that some of them are derived from the fact that, in developed countries, at least good basic mapping is generally available and detailed mapping relatively cheap, because a dense geodesic infrastructure already exists. This is mostly not so in developing countries. An example from tropical Africa may illustrate the consequences of this fact. The Government of the country in question intended to have an engineer carry out a survey of sites for possible hydroelectric developments together with a first evaluation of such developments. Since the evaluation requires at least a very preliminary design, the problem of the needed mapping was upmost in the mind of both the officials and the engineer because it was evident that due to the dense vegetation along the river the cost of the ground work associated with aerial survey, would be exceedingly high. Therefore, it was decided to make a first selection based on a preliminary assessment using a longitudinal polygonal of the river and a few transversal profiles in sites which had a certain likelyhood of being developable. Proper mapping was then limited to only two sites for which, after careful analysis of the results of the summary survey, it was obvious that the most economical first stage development would have to be located in one of them. This procedure had, of course, the disadvantage that the long term development could not be outlined immediately, but the main purpose, namely to define beyond reasonable doubt the first step development was achieved, and this at a relatively low cost. The further investigations leading to the long term planning were then carried out in the context of the construction of the first stage plant. Though not ideal, this procedure proved quite practical.

Hydrological data in developing countries are often scarce and from time to time, of relatively poor quality; though usually there is no objective basis for demonstrating that they are bad, there is no proof either that they are good, e.g. no gauge curves for long periods etc.; the engineer is bound to doubt such data. But, if he does so, since according to his books he is supposed to design on the basis of a certain amount of data (say 10 years of river discharges) he may be tempted depending on temperament to ask for further data which may result in a multi-annual delay in the construction of the envisaged facilities or to ignore the fact that data is lacking and design the facility without particular consideration of the risk involved. Neither of these extreme positions is, of course, the reasonable way to proceed. No doubt there are cases in which it may be necessary to delay for some time the construction of e.g. a hydroplant in order to make time to improve on the quality of the flow data; thus, e.g. the construction of a hydro-plant on one of the medium size rivers forming the border between two West African countries, had to be delayed in order to allow time for improving the entirely inadequate data basis in the frame-work of a UNDP project. On the other hand, waiting for the data to meet quantitatively and qualitatively the standards usual in developed countries might well mean delaying construction indefinitely. The answer is risk analysis and flexible design. First, the design data resulting from the existing data must be established, the risk using them, judged, and then based on this judgement, the facility may be designed, but this has to be done with a very keen sense of the risks involved (see paragraph on Flexible Design). A classical example, is the design of the temporary flood discharge facilities during the construction of a high dam on one of the large rivers in Africa. Among other reasons, because of relatively scarce flood data, this design allowed for flooding of the foundations under construction for a once in 3 years flood, thus taking a deliberate risk. However, it was associated with a thorough flood warning system, making sure that if a higher flood comes, damage could be minimized. In fact, twice during construction time, the place was flooded and at that by floods far beyond what had been computed as the 1 in 1000 years flood! Secondly, the economic risk mus be analysed. To this effect, the design engineer has today quite valuable tools in the analytical risk analysis and the more subjective but relatively simple sensitivity analysis which the engineer would find particularly easy to interpret.

Problems concerning geology and soil conditions are usually rather similar in substance in developing countries to those encountered in developed countries, with the difference that general basic information is often much scantier. Most of the time, it boils down also in this field to how much one is willing to spend to reduce the risk by a given amount. However, the dimension of the decision is from time to time dramatic. For instance, in a tropical country, a railroad tunnel about 6.5 km long is to be constructed. The geological information available consists of (i) a few rock outcrops in the area of the planned tunnel, (ii) trenches and borings in the tunnel axis from both ends, (iii) borings to tunnel level in two valleys crossing the tunnel axis near the entrances, and (iv) the geological information from a tunnel executed 20 years ago in the same mountain range about 25 km from the planned tunnel. After a thorough analysis of the available information, the engineers reached the conclusion that short of digging a pilot tunnel, there was no method that could give further reliable information on the rock through which the planned tunnel would have to be driven. At last, the parties involved decided that it would be too expensive to drive the pilot tunnel. However, to take into account the additional risk, the engineers in agreement with the owner and the financing agency, introduced an allowance for physical contingency in excess of 25% of base line cost, which of course had the effect to make the economic decision less clear-cut than it would have been with more normal contingency allowances.

3. LOCAL DESIGN CODES

Many developing countries have a limited number of design codes, at least in the construction branch. If there are any, they usually concern the construction of buildings, housing in general, and maybe roads. Often, the construction of large works, like urban water supply, sewerage systems, irrigation facilities, dams and power plants is unregulated and burdens the designer with a further responsibility i.e. the use of standards adequate to the local environments. That this is really a further responsibility derives from the rather obvious but still often overlooked fact, that the codes of the developed countries may not fit the circumstances in a given developing country. Thus, e.g. the Swiss code for civil construction (SIA) may be entirely inadequate for the construction of a structure in a highly earthquake-prone country like the Philippines. Similar statements can be made e.g. on the environmental codes. Such codes might be, in certain parts, far too strict (e.g. as to quality of fumes from a thermal power plant when an industrial power plant has to be built at the southern limit of the Sahara) but on the other hand, it may not cover a field as crucial to tropical countries as the rules to be observed for avoiding such water related plagues as bilharzia and river blindness. It is well known that some of the artificial lakes created in black Africa have been designed taking into account such factors to a degree, which now is generally considered insufficient. In any event, the designer has always to remember - and this particularly in developing countries - that even if there is a local code, adhering to it, does not mean designing correctly.

There may be further reasons for being particularly careful about the codes one uses in designing facilities in developing countries, because in case international financing agencies are involved in the financing of the designed items, these institutions will want to be sure that the codes adopted (and of course, the design itself) do not restrict in an unfair way, the choice of equipment or contractor. To assure fair international competitive bidding -which is still considered a valid tool for assuring reasonable cost for the developing countries- the IBRD e.g. has included into its "Guidelines for Procurement" a rule spelling: "If national standards to which equipment or materials must comply are cited, the specifications should state that goods meeting other inernationally accepted standards, which ensure an equal or higher quality than the standards mentioned, will also be accepted."

4. LOCAL CONSTRUCTION PRACTICES

The designer is well advised to study the local construction practices. These may allow him to find solutions particularly well fitted to the country he is working in. Such special practices may have their source in materials peculiar to the country or in skills particularly developed in the region in question. For instance, the very heavy load of extremely fine material transported during the flood season by the rivers on the western slope of the Andes allows to design certain canals and tunnels with relatively porous concrete, and to rely on the fine particles carried in the water flowing through the channel or tunnel to seal the pores in the lining; however, the designer has to be careful to control this sealing procedure because it may be efficient only in a small range of pressure. Now, if the designer is aware of this peculiarity and has a good grasp of its fine points, he may be able to use crushed concrete aggregates without having to add costly fine sand from a sandmill or a far away sandpit. Another example for local practices which may influence the design: For relatively small structures (say a small dike) high in mountains, the designer would -under usual conditions- assume that the structure would be constructed with the help of a small cableway. However, there may be countries in which transportation on animal back (e.g. llamas in the Andes) is technically feasible and economically justifiable, in particular taking into account that the economic shadow-cost of such transportation may be extremely low if there is high unemployment and no alternative use for the animals. However, the designer has to know, in quite some detail how such an operation would have to be carried out; he may have to adjust not only the construction procedure, but also his design, because e.g. a llama carries only 40 kg and there is no way to have it work together with another of its kind.

In other countries -in particular tropical ones- the design may be influenced by the fact that heavy loads can reach a given construction site only on a boat or a raft. In this context, it should be added that, in developing even more than in developed countries, the design of the accesses to the work sites, as well as the infrastructure required for construction (water supply, hospitals etc) has often to take into account aspects entirely extraneous to the main structures to be built; indeed, as important as the facilities to be built may be, the fact that through the implementation of the project, a part of the country previously all but inaccessible can be reached, may be crucial, too. Therefore, it may be justified to build a road to the sites although a temporary cableway could be absolutely sufficient for the construction, and possibly by far less expensive. But the road can allow a vast increase of trade between localities along it, and between these localities and the further developed parts of the country. It can also trigger the cultivation of products whose marketing depends upon the existence of fast and reliable transportation of substantial quantities of goods.

As to local construction practices related to local skills and materials, the classical example is the dichotomy steel versus timber in a country with a highly developed forestry and carpentry. In such a country, a wooden construction may be fare more advantageous than a steel structure even though in a developed country, there would not be the least doubt that steel should be used. But again, the designer has to have sufficient knowledge about the characteristics of the timber available. Deciding about the material to use, is not only a question of cost effectiveness, it can also be one of reliability. Indeed, using the local skills can lead to a structure whose technical characteristics are far better known than those of the alternative using imported material because in the former case quality may be assured by the skills and the pride of the local workers who execute the work to known strict traditional standards. In the latter case, execution of the key jobs by expatriates can lead to not easily detectable weaknesses, because e.g. there may be communication difficulties between the local people and the expatriates. Even if the structure executed according to local practice is of lower standard than the design using foreign know-how, this lower standard may be known to be achieved, whereas, it may be very difficult to judge to what extent the higher standard of the latter has actually been achieved.

5. FLEXIBLE DESIGN

In developing, more often than in developed countries, it happens that a structure has to be designed for the event that some of the extrapolations made on the basis of possibly scarce data, prove grossly wrong (see the example given on page 3 and concerning the temporary flood discharge facilities in a large Arican river). If there is such a danger, the structure should be conceived in such a way as to make sure that if the possible, but highly unlikely happens, there is still a way to avoid a major catastrophe. For this purpose, we may e.g. design a spillway for a reservoir on the basis of the flood expected to occur once in a 1000 years, but to take into account the fact that the data were scarce (say 10-15 years) we may design a small dam, which happens to cut off an outlet into a side valley in such a way, that if a flood in excess of the design flood occurs, this small lateral dam is overflooded and, of course, destroyed, before the main dam is overtopped and in danger of collapsing.

Another type of elasticity in design is the one dictated by the uncertainty of development. In an insular developing country, there is a large hydropotential at a certain site on a river. In the short run, electricity demand is relatively small and could be met by a run-of-the-river plant at that site. However, a large industry is planned as the long run main power consumer. To meet the requirements of this customer, the utility needs, at the above site, a large plant with a dam creating a large storage. The problem is that the development of this industry is still at a very early stage. It was planned to start soon when the recession struck. Then the development was postponed because of financing difficulties. However, in the same period, fuel cost increases made it highly desirable for the utility (and the country, to replace as much as possible of its diesel driven generating capacity by hydro-power. Therefore, it may well be reasonable to build the run-of-the-river plant and to place the intake of this plant in such a way as to be able later to build the main dam under the temporary protection of the weir of this intake. As obvious as such a solution may appear, it creates many problems and a decision on the design can only be made after studying many possible alternatives for the large plant and in particular for the transition from operating the run-of-the-river plant to the large plant. Should the pressure tunnel and the pressure shaft for the small plant be lined to resist the pressure which will occur once the dam is built? Can interruptions in the supply from the small plant be tolerated? If yes, to what extent? In answering these questions, the designer might conceive quite unconventional solutions e.g. he may suggest to the utility to agree with industries having their own plant, which after commissioning of the first stage small hydroplant would be used only as an emergency plant, to produce during the above transition period for themselves and to feed the surplus power into the utility's network.

The intake mentioned in connection with the preceding illustration is an example of a structure whose expected life would be limited, therefore, one could imagine to discharge unusually high floods over a series of collapsible gates, on the spillway instead of the usual sector gates. The collapsible gates risk to be damaged each time they collapse, but they are much cheaper than the sector gates. However, cases in which there is a real practical possibility to design for a shorter lifetime than usual, are by far fewer than one would think off-hand. This is due mostly to the fact that on the one hand, there is sometimes a good chance that the structure in question is to be replaced in a short time by another. But every so often, there is still a substantial probability that the structure has to last for longer than envisaged because at the time of construction, neither the programme for the further stages, nor the design may be well established. Furthermore, political, financial, even technical circumstances may change and make further developments redunant etc.

6. DESIGN FOR MAINTENANCE

This is the most obvious aspect which can lead in developing countries to designs entirely different from those which would be adopted in developed countries, under similar circumstances.

Thus, as an example, in an African country, there was an argument between the power utility and a financing institution which in principle, was willing to finance the installation of a new diesel unit of about 7 MW. The utility wanted to install a low speed unit (120-150 r.p.m.) and the technical experts of the financing entity took the position that a substantially less expensive (at least in terms of capital cost) medium speed unit (about 500 r.p.m.) should be the choice responding to the weighted needs of the utility. They argued that the medium speed unit is a fully proven design - which undoubtedly it is - and that since there is a reasonably high probability that the unit would be assigned reserve duties after relatively few years of base load duty, because a hydro-plant is planned to be commissioned in the system before 1985; they added -which again is undoubtedly correct- that not even hiring two expatriates to maintain the medium speed unit could make this unit more expensive on a discounted cash flow basis than the slow unit. However, the utility had a strong argument for the latter. Indeed, they could point at the fact that they already have several low speed units of about the size of the one planned and that they had had enough difficulties to maintain these slow and relatively simple machines. The utility people are absolutely convinced, that in the next five years, they have no possibility to train the local people to maintain -even under the guidance of expatriates- the more complicated medium speed engines, let alone to have them maintain the two types simultaneously. Ultimately, the more conservative thinking of the utility prevailed, although the justification was based to a large extent on partly unquantifiable benefits related to (i) the easier and hence cheaper maintenance of the slow unit (ii) the fear that the hydro-plant may be delayed for several years beyond what is presently expected, and (iii) the conviction that to be reliable most of the maintenance must be done by local manpower. This is one of the many cases in which there was no clear-cut solution. Incidentally, in this case, the engineers were also confronted with the possibility of designing for a shorter than usual economic life. However, ultimately, the risk involved was judged too high and although the financial situation of the utility (and of the Government) was very poor, the additional capital cost of the slow unit was considered a fair price to pay for the reduced risk. Unfortunately, there is no way (not even success) to show that the decision was correct, because the alternative may have worked out, too. Furthermore, to assess whether the price paid was worth the risk is more related to guessing than to estimating.

In general, the designer should be very critical of any solution which involves maintenance by expatriates or by people having to come to the country from far away. He has in particular to get a very good judgement on the problems of maintenance and spare parts. He cannot take for granted the assurances given by the manufacturer and/or the suppliers, but has to make sure that, and how, the given suppliers have solved these problems in similar cases in the past.

7. CONCLUSIONS

The aforementioned considerations on designing facilities in developing countries give some salient features of the problems rather than a survey of the field. Nevertheless, they lead to the conclusions that the designer when working in a developing country, needs to a very particular degree the following qualities:

- extensive knowledge of the country, the local practices and resources including a good judgement on the possibilities and limitations of using these practices,

- a flexible approach to allow to avail himself of the local opportunities and to avoid the pitfalls of local drawbacks without ending up in doing nothing,

- good judgement on the risks involved in (i) using design bases of sometimes doubtful reliability (ii) availing himself of local practices which may be uncommon in more developed countries, and (iii) introducing new methods and technologies to the developing countries.

Many of the problems related to designing in developing countries can be reduced very substantially by associating with local designers. Though their level of sophistication may sometimes be somewhat lower than that of the foreign designer, they often bring extremely valuable local knowledge which it might be impossible to acquire as a foreigner.