Cost optimization in rural gravity schemes

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ONE OF THE fundamental shortcomings of the water and sanitation sector in Nepal has been the unsustainability of implemented schemes. Lack of regular operation and maintenance (O&M) of rural water supply schemes implemented by various agencies has led to inefficient functioning of a majority of such schemes. It has been observed that the major cause of unsustainable water supply schemes was not lack of technology, but rather lack of ownership feeling among the beneficiary communities. A strategy, therefore, has evolved whereby the communities are to be involved in all stages of the scheme cycle including identification, design, implementation and subsequent O&M program of the completed schemes. The JAKPAS Project (The Rural Water Supply and Sanitation Field Testing Project under the UNDP - World Bank Water and Sanitation Program) is a pioneer to have internalized this realization in its framework at the implementation level. Since the community is expected to share the cost of the scheme - both in cash and kind - it is equally essential that they are involved in the planning and engineering design stages. It is at this stage that the beneficiaries must know the kind of facility they could avail, along with the financial implications associated with it and the various alternatives available to them.

The JAKPAS Project formulated and developed partnership between the Project, Support Organizations (SOs) and the beneficiary communities. The main objective of the Project has been to develop community capacity to effectively plan, implement, operate and maintain rural water supply and sanitation (RWSS) systems on a long term basis. This approach fundamentally implies a reorientation of sectorial strategies. Instead of being target-oriented as has remained the general practice, the approach adopted by the JAKPAS Project has been demand-driven. Essentially a community-based approach, it involves a deliberate change in emphasis from physical infrastructure to software activities. Emphasizing the community role as the lead agent in implementing and managing its water supply and sanitation facilities, it aims to support community capacity building, participatory hygiene and sanitation education as well as a fundamental change in work style.

Broadly, a rural gravity water supply system can be broken into three segments in terms of its physical layout i.e., the pipeline (transmission and distribution), reservoir and the tapstands. Variation in the size and quantity of these three components significantly affect the overall cost and operation of the system. Therefore, cost optimi-zation/effectiveness of a gravity system is largely dependent on making most appropriate choice for determining the size and quantity of these three components. The term optimization implies the optimum use of the available materials and resources such that the required levels of services desired by the community are obtained, maintaining the required engineering standards. Therefore, optimization of rural water supply systems implies that size and quantity of the various system components should be fixed in a manner so as to attain a balance between the available resources and the community's needs or aspirations. The theme of this paper has been concerned with the optimization issues in system planning, engineering design and implementation of community managed rural gravity water supply schemes, which may be of interest to planners and designers working in this sector.

System layout

In the JAKPAS Project, the layout of the system is done by the concerned community itself. The process is supported and facilitated by the SOs. The final layout plan developed by the community forms the basis for the technical personnel of the SO to visit the site and conduct the survey and detailed design. Technical inputs for topographical survey and detailed design preparation begin only after all the issues related to the system layout are thoroughly reviewed with the community. These include identification of potential sources, their reliability, cost implications, etc.

Choice of source

Alternate sources, if available, are thoroughly investigated and the most optimum source in terms of its yield, quality, environmental stability, sanitary condition and technical feasibility is adopted. In other words, the selected source should have a safe yield to supply water at a per capita demand of 45 - 25 litres; it should be located in a stable zone with less chances of contamination by external agents like humans and animals; its water quality should be acceptable for human consumption; and its location should not be unnecessarily away from the community, a factor which would increase the project cost as well as cause problems for operation and maintenance. The proposed source should be void of any disputes or conflicts regarding its use. Coupled with this, preliminary environmental assessment of the source and the surrounding area is conducted to assess the environmental "stability" of the source and area under consideration.

Spring source protection

It has often been observed that existing water sources in the villages are ignored in the haste to develop and implement a totally new water supply system. These existing water points like *kuwas*, local "*dharas/pandheros*" (water spouts or points), springs, etc. can also be investigated for possible rehabilitation and maintenance. Protection works of local water points and spring sources used by the community can also be carried out as part of the water supply development program. This would result in reduced system layout and consequently reduced cost.

Individual vs clustered schemes

In highly inaccessible hill areas of Nepal, transporting construction materials like cement, pipes, fittings, etc. have been a major factor in increasing the total cost of the systems by 5 - 10 per cent. Transporting materials manually from the nearest road head to the project site in two or three days is not an uncommon phenomenon. Therefore, it is often prudent to lump several schemes in a cluster and reduce the transportation cost. Preliminary analysis of the JAKPAS-supported schemes indicate that scattered schemes cost nearly 22 per cent more than clustered schemes. For convenience, schemes within 2 hours' walk (one way) can be defined as a cluster and a cluster of 3 schemes can be defined as a sub-project.

Multi reservoir system layout

Break Pressure Tanks (BPT's) with float valves have been used for a long time in gravity water supply systems in Nepal. Excessive pressure/head often encountered in the transmission and distribution of water through pipes makes BPTs useful in dissipating water pressure. However, proper functioning and maintenance of BPT's with float valves has not been widely experienced in Nepal. Failure of BPT's, especially due to malfunctioning of float valves, results in interrupted supply of drinking water in many schemes. Designers should explore other simpler means to reduce excessive pressure in the system. One alternative advocated and practiced in the JAKPAS Project has been the "breaking up" of the system into several subsystems. Thus, separate and smaller reservoir tanks can be used instead to avoid use of BPT's and increase the reliability of the system.

Source yield and transmission length

For the design of transmission mains it is necessary to determine the design flow to be conveyed to the reservoir. If the source safe yield is greater than the required design flow, then the designer has the option of either tapping *only* the design flow or more from the source. This factor is interlinked with the size of the reservoir to be utilized. If higher flows in the transmission pipes are to be used, which is desirable when the source is closer, then the storage size of the reservoir will be reduced eventually to lower the scheme cost. On the other hand, if the source is

relatively further away the incremental cost of the transmission line as a consequence of more flow can offset the reduction in cost due to the decreased reservoir size.

Source yield and storage requirement

If the required design flow, i.e. say the $Q_{designdemand}$, is equal to or less than the safe yield of the source (or the amount tapped from the source, say Q_{inflow}), then the reservoir size can be established simply by determining the ratio of Q_{inflow} and $Q_{designdemand}$ and finding the storage size in per cent of daily demand (see Figure 1).

If the Q_{inflow} is more than the $Q_{designdemand}$, the ratio of the flows can be simply taken as 1.0, which will yield a storage size of 42 per cent of the total daily water demand (Design Guidelines, 1993). Alternatively, if more flow from the source is to be tapped, then the actual ratio of the flows will be greater than 1.0. From Figure 1, for a ratio of 1.2 the required storage capacity shall be about 30 per cent of the total daily water demand. This will translate into a storage size reduction of about 30 per cent. If the flow ratio is 1.4, the net reduction in storage requirement can be over 50 per cent.

An increased flow ratio also implies a higher flow to the reservoir from the source. This will have its bearing on the pipe size to be used for the transmission length. Thus, if higher flows are available at the source, it is necessary to carry out an exercise in pipeline design of the transmission length and its effect on the storage size due to change in system flow. It has been generally observed that up to a flow ratio of 1.3 or less, there usually is no drastic increase in the pipe diameter and the storage size requirement is reduced by over 50 per cent.

Alternative technology

Ferrocement technology

Use of ferrocement technology especially for reservoir tanks is increasingly becoming more popular in gravity water supply systems in Nepal. Generally for reservoir of sizes bigger than 6000 litres' capacity, ferrocement technology is cheaper in terms of per cubic meter of storage space than traditional stone masonry reservoirs. The JAKPAS Project has encouraged the use of ferrocement technology especially for those schemes whose distance
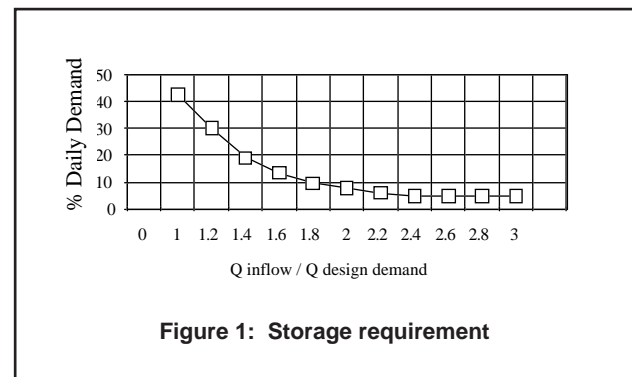

Figure 1: Storage requirement

from the road-head is not much. Ostensibly, for schemes that are located at a distance of two to three days' walk from the nearest road-head, the cost of transporting cement and re-bars can offset the reduced cost due to use of this technology.

Alternate system component options

In community managed schemes, it is the beneficiaries' prerogative to use the one from among the various design options available, particularly with regard to the tapstand. Various design options for the tapstand, for example, were developed giving details regarding their costs and benefits. As the beneficiaries make contributions - both in terms of cash as well as kind - towards the cost of the scheme, it is essential that they are made aware of the costs involved prior to taking the decision. For example, a tapstand with both back walls and side wing walls is nearly 100 per cent more costly than a simple tapstand with a pillar and platform.

Similarly, options available for other components such as the valve chambers, distribution chambers, etc. can also be explored. For example, valve chambers of stone masonry, pre-cast concrete or GI pipes are available and used in gravity systems. For places where transportation cost for cement and related construction materials are significant, the GI pipe valve box can be a better alternative. It has been observed that designers often use standard sized components while developing a system. This standardization on one hand saves time and ensures ease and uniformity in implementation, on the other, may increase scheme cost, as a uniform size is being adopted for all cases. Therefore, it is advisable to develop at least three standard sizes of various system components for different flow conditions.

Service Level

Design period

The choice of the design period is governed by the economic design life of the water system, which is a function of the particular component used, the population growth rate and the discount or interest rate. In view of the above aspects, rural water supply systems in Nepal are planned and designed for design periods of 15 or 20 years. Districts with higher population growth rates, i.e., growth rate of 2 per cent or higher, and / or where the yield of an acceptable source does not allow the use of higher design period, a design period of 15 years is adopted. While other districts with lower population growth rates, a design period of 20 years is adaptable. A cost analysis for a typical gravity scheme indicates that the difference in cost due to choice of design periods, i.e. 15 or 20 years, is not very significant and is less than 1.5 per cent (DAN, 1995).

Per capita demand

A per capita demand of 45 liters per person per day is the present design standard. This rate derived from WHO studies includes allowances for personal washing, drinking, cooking, portion of domestic animal needs and some wastage. If the yield of the optimally located source does not allow the typical 45 liters demand, the designer can adopt a rate of up to 25 liters per person per day.

Analyses of demand variations indicate that the cost of typical gravity system with a total pipe length of 3.5 kms and a per capita demand of 45 lpcd costs 11 per cent more than a system with the same features but a per capita demand of 25 lpcd (DAN, 1995).

Tapstand density

A tapstand is usually located at such a place that it can serve 10 households (HH) on the average, depending on the settlement in the village. In order to accommodate scattered settlements, the average number of households per tap under certain cases are reduced to 7 households. Generally, the horizontal and vertical distances to be traversed by a household to a tapstand should not exceed 150 meters and 50 meters, respectively.

In a typical case, it was analysed that a system with 7 HH/Tap (with 45 lpcd demand) cost nearly 6 per cent more than the same system with 10 HH/Tap. Conversely, a system with 5 HH/Tap would cost nearly 14 per cent more in comparison with a 7 HH/Tap system (DAN, 1995). This implies that increased tapstand density would require additional investment, but would also increase the benefits in terms of time saved for fetching a unit vessel of water.

Conclusions and summary

The initial planning for the system layout in consultation with the community is crucial in developing the scheme. The designer should discuss and try different variations of the system layout; consider various available system component; explore the possibility of maximizing the use of local materials and alternate construction technologies. These factors may prove decisive in optimizing the cost of the proposed scheme.

Development of design criteria is often the key to the issue of cost optimization/effectiveness for rural infrastructures like water supply. It is direly essential that a designer or a planner should carefully analyse the situation on a case-by-case basis. They should not, however, impose a standard across-the-board criterion. Development of design criteria should have certain in-built flexibility that the engineer can change and adopt in a manner best suited to the prevailing conditions. Thus, factors like availability of external funds and construction materials, availability of local resources, choice and preferences of the community, physical features of the scheme area including proximity from the market, etc. all contribute significantly to the determination of the design criteria. The service level variables and the design parameters (primarily the residual heads and available pipe flow)

then can be established accordingly. These variables/parameters should be judiciously matched and balanced with the needs of the community and the available local as well as external resources.

Design of rural gravity water supply schemes does not probe into the technical competency level of the engineer, rather it is a challenge to the technical innovativeness of the individual. In a resource scarce economy of a developing country like Nepal, the challenge lies in being able to achieve the most from the limited resources available vis-a-vis the demand / requirements of the people. This involves a slight deviation from the traditional engineering design practices and exploring ways and means to "optimize" the cost of rural water supply schemes. Therefore, the ingenuity of the designer lies in being able to optimize the cost of such schemes, utilizing available local resources and addressing the requirement of the community. It is in this context, the author has tried to share his experiences with the water supply and sanita-

tion sector of Nepal with regards to cost optimization of rural gravity water supply schemes.

References

Development Alternatives Nepal (DAN), *Rural Water Supply and Sanitation Project Preparation*, Ministry of Housing and Physical Planning, HMG, Nepal and International Development Association, Washington D.C., 1995.

Design Guidelines for Community Based Gravity Flow Rural Water Supply Schemes, Department of Water Supply and Sewerage, HMG, Nepal, 1993.

Jordan Jr., Thomas D., *Handbook of Gravity-Flow Water Systems for Small Communities*, UNICEF, Kathmandu, 1987.

Fund Implementation Manual, Vol IV: Technical Guidelines for Planning, Implementation, Operation and Maintenance of Water Supply and Sanitation Schemes, Rural Water Supply and Sanitation Fund Board, HMG, Nepal, 1995.