# Designing Aids for Physically Handicapped in Developing Countries*

P. K. SETHI

*Emeritus Professor of Orthopaedics, S. M. S. Medical College, Jaipur*

Since 1981, which the United Nations declared to be the "Year of the Handicapped", there has been, at long last, a growing awareness about the disabled population in our country. Special census have been carried out on the disabled, and their staggering number in our vast country, with 80% of its people living in inacessible rural areas, has posed major challenges to our planning bodies. But we are passing through some heady days in our country and the numerous problems which beset our society are believed to be solvable by mere technological and managerial interventions. Technology Missions are being set up to speed our entry into the 21st Century because firm promises have been made. This has set the pace for some hectic activity since targets have to be achieved. 'Targeting' is the new word. We need more targeted research, more mission-oriented science. This is said to be the new drift. There is little time to waste in rediscovering the wheel and so it is considered prudent to buy technology packages from the west. This is affirmed as the speediest path to tackle the problem of the vast numbers of disabled in our country.

I sense serious trouble when we initiate such a "top-down" move. Such moves require a much greater store of usable information, with coherence and connectedness, than actually exists. We presuppose that we know what the needs of the disabled are, and all that is required is to activate our already existing centralised production agency for rehabilitation aids, prepare managerial flow-charts to set up an efficient distribution system which can reach the remotest areas in our vast country and use the existing government machinery, with some NGO's thrown in, to assist the implementation of our schemes and another problem would be solved. Statistics are being reeled out to demonstrate the success of such a move.

There is one factor which does not figure in all this hectic activity and that is the disabled persons themselves as human beings. We have never really bothered to find out what their felt needs are. Are they really using the appliances we are handing out to them. What is the incidence of a drop-out rate ? If the appliance is not being used, is it because our people are ignorant and do not realize what is good for them, as is being affirmed by many specialists, or is there a possibility that our appliances are not suitably designed for them ? Can there really be a standard universal solution for a particular locomotor deficiency or dysfunction or do we need a more culture-specific and location-specific alternative ? Is it fair to offer them only one design option, take it or leave it, or is it better to work out a range of options from which a particular individual has the possibility to chose what suits him best? Doling out such aids as if the disabled are objects of pity or charity or a mere statistic is a demeaning business and instead of making the beneficiaries more self-reliant, which ought to be the purpose of such aids, one can often erode their pride and confidence.

Raising such questions is always awkward

*Professor B. D. Tilak Lecture 1988, delivered on 16 January 1989. "Reproduced from the Proceedings of the Indian National Science Academy, Part B (Biological Sciences) Vol. 55, PP. 7-14 (1989)".

and one is likely to be misconstrued as an obstructionist. It is my submission that the central figure in all such activity has to be the user himself. If the appliance actually helps him or her, it would certainly be used. If not, it will be rejected and good luck to him/her. After all it is the user who knows best what is good for him/her.

Designing such aids, I have learnt, is a very complex business. It not only calls for more science but a much better understanding of our society, its culture, its gross economic disparities and its stratified structure. One would then realize that there is a lot more of basic work which needs to be done and even though this would necessarily be time-consuming, it is likely, in the long haul to be more cost-effective and more appropriate for our target group. Such work, of course, must obviously take into account the pressing needs of our deprived and marginalised people, and reaching the largest number in the shortest time has got to be one of the objectives of such research.

I would like to illustrate some of the complexities of this problem by using two examples. One involves an appropriate design of artificial lower limbs for our amputees and the other deals with the polio problem which still remains the largest single cause of physical disabilities in our country.

It is almost exactly three decades from now when I got involved with the problem of providing physical aids to many of my patients. I could not amputate a limb and then wash my hands off by directing the patient to fend for himself in trying to get an artificial limb. Likewise, there seemed to be little point in correcting neglected deformities in children affected by poliomyelitis, performing multiple operations to straighten out the lower limbs and then advising them to get braces which were then required to support their otherwise flail limbs. From where could they secure these appliances? At that point of time, the only available facilities for such appliances were located at Bombay or Poona. While the affluent could go there, the majority of my patients were poor and the advice to travel a thousand miles away for securing an appliance was totally unrealistic. I realized that without a neighbourhood facility, the bulk of the disabled would remain deprived of aids they desperately need.

This impelled me to organize a workshop in our hospital where such appliances could be made. I somehow succeeded in achieving this objective and I became rather proud when we started making artificial limbs and braces locally.

Having been a product of western education and with a psychology which was heavily influenced by a colonial heritage, my ambition was to see that our appliances were as good as anywhere in the west. Of course, all I could achieve were "blurred xerox copies" of the limbs made in London or New York. Inspite of this, I seemed to be satisfied with the progress made.

My initial elation soon received a setback when I started encountering some of my amputees reverting to their crutches. Whenever I encountered such a situation, I questioned them. "Why are you not using the limb we made for you", I would ask. My suspicion was that there was some technical flaw in them; the socket might be hurting their stump or else something must have broken down. But the feedback I got was something completely unexpected. It became obvious to me that I was taking a very simplistic, almost naive approach to the problem of limb substitution. I was taught in the medical school that the function of the lower limbs is to be able to stand and walk on them. I now realized that there are many other attributes in our lower limbs which are equally important to our people but which the western-designed limb did not cater for.

## Two Cultures—Floor-Sitting vs. Chair-Sitting

In the cold climate of Europe or North America, the feet have to be protected from cold by using warm socks and closed shoes. One has to move away from the cold floor and design a chair to sit on. A table then becomes their work-surface. Also, in most advanced countries, people walk on paved floor and level streets and the foot is not required to adapt to uneven surfaces. On the other hand, our warm climate makes a closed shoe uncomfortable and most of our people walk barefoot or else in open, well-ventilated footwear, often on the rugged terrain of our countryside where the suppleness of the foot becomes a vital attribute to adapt itself to uneven surfaces. We use the floor for squatting, sitting cross-legged, working, eating or sleeping on it. And so there is the social custom of removing one's shoes on entering a home, or a kitchen, or a place of worship. This is a sensible and hygienic thing to do to prevent dirtying the floor.

It is important to distinguish thus between a chair-sitting and a floor-sitting culture because, as you would see, there are important design implications involved.

### The Western Designed Limb

One of the important features which characterises a western limb is its footpiece. It is not shaped like a human foot. Instead, its shape is such that it can easily slip into a shoe, which then hides its odd appearance and also protects it from damage. A closed shoe, in other words, is an integral part of the limb design. Take the shoe off and you cannot use the limb.

Providing this kind of limb to our amputees, therefore, made it compulsory for them to wear shoes to be able to use it. You can easily appreciate how such a simple demand can lead to major problems when closed shoes are not only uncomfortable in our hot climate but because they have to be repeatedly removed in a floor-sitting culture. Our women would not agree to wear such shoes anyway and in a rural environment, one cannot expect a farmer to wade through water and mud wearing a pair of expensive Oxford shoes!

Not only this, Squatting requires a range of mobility in the knee and ankle which is not available in a western limb. Likewise, the foot is twisted inwards when sitting cross-legged on the floor. The western footpiece, which is otherwise a very clever design, has a solid wooden keel, which prevents any movements at the ankle. So the patient cannot squat on the floor. An attempt to sit cross-legged presses the stiff footpiece, which in turn forces the entire limb to rotate, causing unbearable pressure on the stump. The upshot is that an amputee using a western limb has to remove it repeatedly several times a day when entering his home. When he works sitting on floor, he takes the limb off and then has to use crutches to be able to move around. And so, unless the amputee changes his life style into a shoewearing, chair-sitting culture, this artificial limb disables rather than helps him. My colleagues keep on telling me that our people are uneducated, stupid and stubborn. The fact is, and I have repeatedly learnt this lesson, that our people are not irrational. They are perfectly capable of making rational decisions. It is we, because of the blinkers we wear, and our lack of sensitivity, who are unable to understand the rejection of our solutions.

### Evolution of Jaipur Foot

So the first item we took up was to redesign the footpiece. A set of desirable functions was listed out. The footpiece should not require a shoe to hide it and protect it. So it should look like a normal foot and be made of a material which is not only flexible but also tough, abrasion-resistant and waterproof. The internal design should provide adequate mobility to enable sitting on floor and walk on uneven ground where the foot is required to adapt to the rugged terrain of our countryside and yet the foot should offer a stable support while walking.

We decided to use a solid rubber elastomer as the outer casing for our footpiece. Several reasons prompted us to choose this material. Solid rubber has many unique properties combining flexibility, toughness, and abrasion and tear resistance. A material which is durable enough for an automobile tyre should be adequate for our footpiece. The material is readily available in our country and an extensive trade in retreading tyres has made our people familiar with vulcanization.

To reproduce the shape of the foot, a 4-piece aluminium die was prepared locally by our traditional craftsmen, who used the age-old sand-casting methods and the cost of this mould was a fraction of what the fancy die-designing firms were asking. By packing rubber into the die and vulcanizing it in our hospital autoclave, a footpiece resembling a natural foot can be obtained.

But mere appearance is not enough. The desirable range of mobility must be available to provide the activities already listed out. Our first sample was made of solid rubber and it was so heavy and stiff as to be totally unusable.

To reduce the weight of this foot, it occurred to us to place a western footpiece into our aluminium mould and then fill the remaining space around it with solid rubber. This encapsulation substituted for a built-inshoe which resembles a natural foot. The footpiece was now much lighter and became suitable for barefoot walking.

However, the problem of mobility still remained. The main obstacle was the wooden keel of the western footpiece which prevented squatting on floor. We tried to tinker with the keel, cutting wedges into it to provide mobility but these proved inadequate. Our minds were still wedded to the conventional design and it is no easy matter, you would agree, to move away from our preconceived ideas.

Repeated failures ultimately forced us to make a fresh start and finally we arrived at a completely new design concept. For the ankle region a block of wood had to be provided for securing a carriage bolt which connects the footpiece to the leg. The front part of the foot (forefoot) also had a separate block of wood to provide stiffness when this part of the foot is loaded when the heel is off the ground. Between these two rigid wooden blocks, a large microcellular rubber block was interposed and this behaved like a universal joint, with a freedom of movement in all directions.

Now squatting was possible.

We had tested our footpieces in the engineering college laboratories and characterised its behaviour under different loading conditions. Fields trials on amputees revealed that we could meet all our design criteria. The foot was shown to be very strong, breaking up only under a vertical loading strain of two tons. We were happy.

What we did not take into account was the problem of fatigue as well as disaster failure. Soon amputees started returning with the external shell of rubber cracking open and the internal components virtually spilling out. Then it was suggested that we use reinforcement with rubberized tyres cord which is used in car tyres to prevent such disaster failures. We had then to became familiar with this new material, learn how to lay out the re-inforcement so that the desirable range of mobility was not adversely affected and we ended up with a product which had a durability span of 3 to 5 years under tough field trials in rural areas.

Periodically, amputees would come back to us with cracks in the footpiece. The curious thing we noticed was the almost consistent location of distribution of these cracks. So we started plotting the cracks in the damaged footpieces. These were always around the ankle region. The moment we realized this, the reason become obvious. The encapsulation around the wooden blocks was immobile. The entire mobility resided in the junctional area which was in the hindfoot region and this was the place where all stress concentration was located.

A major design revision was then made and we replaced the forefoot wooden block with another MCR block of a higher Shore hardness and appropriately stiffened with the tough tyrecord. This has resulted in a more uniform distribution of stresses spread over the entire hindfoot and forefoot. Not only has it added to the life of the footpiece but it has provided us with an additional bonus of the forefoot gaining an independent range of mobility. This allows for a much better adaptation of the footpiece to uneven surfaces.

We realized then that what started off with a relatively culture-specific design need paid us dividends in several other respects so that today even the western countries are getting interested in the functional attributes of Jaipur Foot. During the last few years, a whole series of new designs of footpieces is emerging in the west which are based on some of the design features of Jaipur Foot.

When we walk along a slope, our feet can turn in or out to adapt to the slope. In the old fashioned single axis metalic ankle joint of a western footpiece, this adaptation is not possible and so the entire artificial limb is deflected, causing considerable pressure on the skin of the stump at the stump-socket interface. In a more modern western footpiece, some degree of mobility is available and so the peak pressures at the stump-socket interface get reduced. But in Jaipur Foot, because of a much greater mobility, the stump gets very little pressure even when walking on uneven ground. In other words, our footpiece is comparable to the rubber bearings which are being talked about for earthquake proof buildings. The base isolation by these bearings reduces the whiplash effect in which top storeys are literally shaken to destruction. These rubber bearings effectively "detune" the building from earthquake frequencies by a factor of ten. Our footpiece offers a similar protection.

A study was conducted in the University of Strathclyde at Glasgow where, in a sophisticated gait analysis laboratory, a comparative evaluation of the western foot and Jaipur Foot was carried out, using data recording the ground reactions through pressure transducers in a pylon dynamometer. The Scottish amputee who acted as an experimental subject was asked to return the Jaipur Foot after completion of this study. This amputee refused to part with the foot on grounds that it enabled him to climb the mountains much more easily. Prof. Hughes, when presenting this paper, emphasized that this subjective, human response was far more valuable and revealing than any computerized study. This underscores the value of the weightage one ought to give to the user response.

Another interesting spin-off of our design was the capacity of the leg to rotate on the foot. The University of California group have been emphasizing that during normal human walking, various segments of our lower limb rotate on each other during different phases of the gait cycle. In the conventional western footpiece, the leg cannot rotate on the foot and this causes the entire artificial limb to twist around the stump while walking, causing considerable friction and discomfort. The Jaipur Foot, having got rid of the solid keel, allows this rotation and so the user of the limb is more comfortable.

The reason I am making this point is that while our original objective were to provide a limb suitable for a floor-sitting culture, some of the spin-off is being held to be of basic importance even to our western counterparts and there is now a renewed interest in the role of a footpiece as a dampener of ground reactions and what was formerly a low priority item on the research agenda in the west has suddenly been elevated to a higher level in the hierarchy of design of artificial lower limbs.

One can now match the list of our earlier objectives to what has been achieved. The foot fairly closely resembles a normal foot, and I often amuse myself by asking visiting surgeons to identify the amputated side. Even experienced orthopaedic surgeons have a 50% failure rate ! In fact, women often adorn their feet in a manner which has even fooled me.

The amputee can squat and one can witness the angle which the footpiece can make with the leg. There are amputees who are employed in our workshop who sit cross-legged on floor and work the whole day without the need for taking their limbs off.

The limb can now be used by our villagers, walking comfortably on a rugged terrain because of the adaptability of our footpiece.

The limb is waterproof and many amputees work in their farms, wading through water or mud. Drawing water for irrigation from a traditional well is a heavy duty job and yet these amputees perform such work like able bodied individuals. Rickshaw pulling is an urban vocation chosen by many poor amputees. They can even climb trees ! The footpiece can grip the trunk and adapt to its contours. Such activities widen the horizons of amputees who can continue to stay in their villages with their families and friends and carry out their former vocations. It is no longer necessary for most of them to migrate to urban areas, frequent the corridors of Social Welfare Ministry and end up with a sedentary occupation in an alien setting.

This is what 'true rehabilitation' ought to mean and it would be appreciated that there is a built-in element of rehabilitation in the design of these artificial limbs.

For the socket and the leg piece of our limbs, we opted for aluminium as a suitable material. Most of my colleagues adversely comment on the choice of aluminium. "The modern world is moving towards polymers and composites and you are moving back to metals", they comment. There are some very good reasons why I have preferred aluminium—atleast for below-knee limbs. We have skilled artisans in our country who can shape metal sheets with such ease and deftness that it takes one by surprise. A statue of a poor, emaciated amputee, which stands before the building of our Rehabilitation Centre was made by one of our craftsmen with alumnium sheets beaten into shape without any casting. It is a stunning piece of art. For people who have skills like this, and whose work adorn our handicraft emporia, shaping an aluminium limb is a child's play.

Visitors from abroad gape with amazement when, within 45 min., from start to finish, a below-knee trial limb is fitted. The tools for this work are simple; no plaster moulds are needed. The limb is shaped and fitted directly on the amputee who participates in the entire proceeding, guiding and informing the limb maker about the accuracy of the fit. This live human interaction between the amputee and the limb maker is a marvellous thing to watch. There is empathy and understanding between the two and a lot of feeling goes into this work.

Aluminium is available to us, easy to work with, light and strong and does not rust. Any pressure points can be easily lifted off with a tap of a mallet. Use modern FRP and you get into a much more expensive system where such manueverability after the resin is cured is just not available. So what is wrong about using aluminium ? It is this simplification of the technology which enabled us to increase our turnover from one limb in a week in 1975 to ten limbs a day in 1982.

Materials are important but several considerations must go into their selection. I am not averse to new materials. In fact, we are the first in our country to use sophisticated materials like carbon fibre composites for rehabilitation aids and as of today, my choice for an above-knee amputee is a combination of flexible polyprophylene socket with a carbon fibre load bearing frame. Having tried many materials, I find this, on various counts, to be a superior alternative. But for a standard below knee limb, my preference for aluminium stands.

Availability, cost, familiarity, physical properties, ease of modification, climate, skin allergy and many such factors must be put together and an entire range of options generated, from which an optimal selection ought to be made. What my be choice at Jaipur may be different from what I might use in Nagaland or Bombay.

The approval of the design of our footpiece by the west has brought out another dilemma. There is now a continuous demand by centres from abroad for our footpieces. Jaipur foot centres are already functioning in Sri Lanka, Thailand, Indonesia, Peshawar and Zimbabwe. While this excite us at one level, it makes us very apprehensive at another level. Using rubber as our basic material, we use a very labour intensive technology. Our footpieces are heavier than the western analogues and they are not refined in their appearance as the western market would expect. There is lack of standardization and no two footpieces have absolutely identical performance characteristics. We felt we should refine our product and turn to new materials such as polyurethane. The Department of Science and Technology came to our assistance and currently we are working on this material substitution. It has meant, of course, that the present properties of Jaipur Foot must be accurately characterized. The data base for the formulation of such a variable density polyurethane foot must be available before the polymer engineers can prepare proper formulations. This has forced us to generate the basic data with the help of structural engineers. This, I think, would be an extremely useful exercise which has not been carried out so far. At the same time, however, such materials require extremely critical operating conditions for manufacture. A much higher capital investment outlay is needed, both for R & D and for setting up a production unit. If optimal conditions are not available, there can be a catastrophic failure to the footpiece. A rubber foot may not be as elegant but it is much less likely to fail. An analogy of the debate on traditional vs high yielding variety of wheat may not be out of place. Amulya Reddy is fond of reciting the nursery rhyme—"When she was good, she way very very good, but when she was bad, she was horrid".

What we should not lose sight of is the "worst case scenario" rather than the "best case scenario" when evaluating costs and benefits. It is also important to resist the temptation of yielding to an applause from the west and in the process, forget our rural amputees, for whom this work was taken up in the first instance.

Comment is often made, especially from the prestigious rehabilitation centres in our large metropolitan towns that our footpiece prevents their amputees from wearing fashionable shoes. "These are two broad" they say, "and there is a major problem of "foot entry" into narrow shoes". I concede this because my target group has been the barefoot walking rural amputee. Out footpiece has to match the broader splay foot of a barefoot villager. There is nothing to prevent, however, for another set of dies to be made for the urban rich, to produce footpieces which may have all the design advantages of Jaipur Foot and yet which can easily slip into elegant shoes. We have made a few such pieces, and with a detachable heel too which can be inserted to preserve correct alignment of the limb, when the shoe is taken off at home.

There is a need, also, to update the technology for producing better rubber Jaipur feet. A lot of progress has been made in rubber technology since we started working in this field in 1965. Better rubber formulations, lighter and stronger, improved die design and a production technology which can ensure greater standardization and quality control checks, should be effective in overcoming some of the existing shortcomings of Jaipur Foot.

There are thus several options available which could be pursued:

(i) The jaipur Foot could exist as it is; it is inexpensive and has stood the test run in atleast 20,000 amputees.

(ii) For urban rich, a modification could be used to allow easy foot entry in fashionable shoes.

(iii) Improved rubber feet could be produced using updated rubber technology, or

(iv) Polyurethane could be substituted as a better material for export quality footpieces. Depending on the nature of consumer demand, a footpiece could be made available for different population groups. All these options could exist side by side.

**Appliance for Poliomyelitis**

The second example I would want to present deals with the polio problem. Policmyelitis is the largest single cause of physical disability in our country. With its disappearance from the west, not new ideas are coming forth from abroad on designs of appliances for poliomyelitis. Whatever new thinking had to go into this problem has now to be generated by us.

It is not commonly appreciated that it is much more difficult to design appliances for polio than an artificial limb. This is because the polio child has a choice. If he does not walk better with the device, he just won't use it. The amputee, on the other hand, has no choice. One of the major problems in polio is when the muscle of the thigh, the quadriceps, is paralysed. The knee joint then becomes unstable and the child has to use his hand on the thigh and press the knee backwards to prevent the knee from buckling. There is no suitable operation which can stabilize the knee and so a metal brace is used to lock the limb into it. This liberates the hand and now the child can walk upright without the fear of falling down.

Such metal calipers have been in use, without a major design change over the last century. While we keep on prescribing them, any honest follow up would reveal that there is a very high rejection rate by the users. The reasons are not difficult to understand. These calipers are heavy and the already paralysed limb has to drag this extra weight. The knee cannot bend while walking and this poses a problem of clearing the ground while swinging the limb forward. The lower limb, which normally behave like a compound pendulum, is converted into a simple pendulum with a long lever arm. This demands an extra effort by the muscles to swing the limb. And so, instead of acting as an energy-saving device, this caliper in fact becomes an energy-consuming gadget. Since the metal side bars are fixed to a heavy duty shoe which is the foundation of the device, the child gradually starts nursing a hostility towards these shoes which are not interchangeable and differ from those worn by other children. It should not surprise us, therefore, that our patients usually reject this solution.

This basic design of a caliper is related to the use of metal side bars. Metals can only be used in certain ways and impose a tyranny of their own. But now a variety of new materials are available which can be easily shaped and some of them are stronger than metals. Thus, we can now think of different ways to stabilize an unstable knee by using new geometries of designs. We have now been using a carbon fibre composite, a spin-off from aerospace engineering, and utilizing a totally different design concept. By artificially keeping the foot at an angle so that instead of the heel, the front part of the foot strikes the ground first, and with the help of two lateral bars and a cross piece in front of the knee, the device behaves like a cranked lever where the body weight from above is used to push the knee back and prevent it from buckling.

This so-called floor-reaction orthosis has now been used in over 500 cases with an 85% acceptance rate. It is four times lighter than the metal caliper, allows the bending of knee while walking and can be used with any shoes. Carbon-fibre has poor abrasion resistance but a polyurethane sole, stuck to it, can probably allow our rural patients to walk barefoot in their farms.

The cost of this appliance turns out to be actually cheaper than a conventional caliper. The technique of fabrication does not require any expensive outlay and anyone who enjoys working with his hands, without any formal education, can be taught to make this appliance. It still suffers from disadvantage that carbon fibre is an imported material, the selection of cases suitable for this appliance requires considerable experience, each appliance has to be custom made and the margins of error permitted are very narrow.

This is only a beginning. Already a number of new designs are under trial and we forsee a major shift from metals to polymers in these appliances in the near future.

Because of the need for shoes, a major problem in the logistic of supply of conventional calipers is encountered. Not only are these expensive but they need to be custom made. An analysis of the reasons for long waiting lists in the delivery of calipers in most rehabilitation centres reveals that the major hold-up occurs in the footwear section. Recalling that closed shoes are not well tolerated in our warm climate, and to speed up production, we had worked on the idea of substituting shoes with wooden clogs, an idea initially mooted by Huckstep in Uganda. Huckstep's design of a wooden sandal was too simplistic and inefficient. So we had to work out a new design, with a roll characteristic which allowed a much better gait. This wooden clog could be made very quickly and with prefabricated leather straps and a large stock of such clogs of different sizes, it is feasible to fit the child on the same day that he is seen.

The design of a caliper with its wooden clog was so simple that the idea of using out village craftsmen to prepare such calipers occurred to us. Every village has a cobbler, a carpenter and a blacksmith. They are needed by the rural community. Why can't we use this available manpower so that polio children could be fitted with braces in their own village ? An experiment was conducted at Tilonia, through the help of Bunker Roy. We took our caliper there and showed it to these craftsmen. They were able not only to make these with the locally available materials and tools but actually came out with a product which was superior to ours in workmanship. The innovative capacity they demonstrated in making their own version of a limited motion stop at ankle came as a surprise to me. Who says our rural poor are not intelligent ?

This provides a totally new dimension to a problem which is confounding our administrators sitting in Delhi, counting the millions of polio children spread out over our vast country and wondering how to handle this massive-problem. Looked at a village level, however, where there may not be more than 4 or 5 cases per village, it can be a very solvable problem provided we are willing to leave our institutional hideouts, share this knowledge with village craftsmen and encourage them to become self-reliant in providing a neighbourhood facility for preparing atleast simple rehabilitation aids. I know how our professionls react to such ideas which they find outrageous. This is truly a Hobson's choice. On the one hand, such a strategy may provide *inadequate aids*. On the other hand, adequate technologies are *inaccessible*. Sticking to the idea of providing only the best usually means that 90% of our poor population have to go without any aid whatever.

There are thus three different kinds of options available for aids in poliomyelitis. One is to continue with the present strategy of a centralised production agency, supplying factory made metal components to be assembled and fitted locally. Any change in design is not permitted here and one needs a large beaurocratic machinery to manage the supply and fitting.

The other is to continue research into the use of new material and new designs and field test them. A lot of R & D effort has to go into option because it is now futile to look to the west for any fresh ideas on poliomyelitis.

The third is to simplify the existing designs and work out a strategy of using rural craftsmen to provide a neighbourhood facility.

The costs and benefits of each will have to be worked out but in all this exercise, let us not forget the user—who would usually belong to the group of rural poor. The constraints of time prevent me from multiplying such examples endlessly.

The main point I have tried to make is that in a dual society such as ours, and this is true of all developing countries, we are constantly running into a Hobson's choice. The technologies and designs evolved in the west are preferred by our rich urban elite and they really constitute the market forces which influence our beaurocratic machinery. The poor are outside the market forces and have no voice. Modern technologies are inaccessible to them. To permit the poor to escape from this dilemma, scientists and technologists must generate new options, each more effective than the traditional, and more accessible than the modern. Ideally, the options should constitute a hierarchy of technologies with upward compatability. Then with rising income, the poor can climb from a cheaper, less cost-effective option to a costlier, more cost effective option. Only in such a situation the people will have genuine choices. Thus, the role of scientists and technologists is to be option-generators and choice-wideners.

People who control decision-making in our oountry are understandably in a hurry. They overlook that a more appropriate and equitable generation of technology involves a "learning curve". During the initial part of this learning curve, there has to be intense back-and-forth interaction between the lab and the field. The feedback from users in the field must lead to modifications and improvements of the product/process. This modified/improved product/process needs further "test marketing" in the field. As a result of this interplay between technology generation and dissemination, and between technologists and potential consumers of the technology, the penetration of the "market" is necessarily very slow during this phase. Only later, our learning curve shows a steep climb.

All these points are generally ignored when technology dissemination is planned and implemented. There is a general tendency for technology generation and technology dissemination to be thought of as two distinct non-overlapping sequential stages with the generation ending when the dissemination begins, and the generators "washing their hands off" the technology dissemination process.

However idealistic and romantic it may appear, my conviction is that the technologists must approach such work with empathy and affection for the people. Otherwise, they tend to be afraid of the people and hide behind their institutional walls. The poor are far more understanding of our failures than so-called educated who cheer when the satellite goes into the orbit and jeer when it falls into the sea.

Science and technology ought not to be "value-free" and would stand to gain from these feelings of empathy and affection. Without this value-system, it tends to become amoral, unjust and violent.

A lot of hard and painstaking work lies ahead of us. The problems facing us are open-ended. This is why I am worried about a 'top-down' managerial approach which, some people think, will quickly solve our problems. Bernard Shaw's approval of "the inevitability of gradualness", carries for me, a lot of wisdom.