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by Thomas Fricke

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HIGH IMPACT
APPROPRIATE TECHNOLOGY
CASE STUDIES

by Thomas Fricke

Series Editors: Diane Bendahmane and Judith Polsky
with contributions by A.T.I. staff

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PREFACE

"Millions Starve in Ethiopia"... "Bhopal, India Industrial Disaster"... "3rd World Debts Mount"....cry today's headlines. To many people, the Third World is synonymous with disaster and defeat; the magnitude and complexity of Third World problems seem to defy solution.

We are being challenged to use science and technology to engage the millions of people in rural and semi-urban areas in the Third World in economic activities they can control and maintain. The case studies presented here--the successful applications of appropriate technology--show this is not just an idealistic dream. Sixty to 75 million villagers in India alone benefit from the Mark II water pump; oral rehydration therapy enables countless numbers of children to survive past age 5. Water pumping windmills in Argentina provide direct or indirect benefits to a sizeable segment of Argentina's rural population. Innovative rainwater collection and storage tank technology provide potable water for thousands more throughout the Third World.

Important answers to problems in development can be found in small, commercially viable, and economically sustainable productive activities that have the potential to benefit masses of people without major capital investments. Impossible? These case studies suggest it can be done. Appropriate Technology International, a private organization funded by the U.S. Agency for International Development, supports many similar programs which adapt science and technology to the conditions of the rural and semi-urban poor in the Third World.

Ton de Wilde
Executive Director
Appropriate Technology International

Winter, 1984

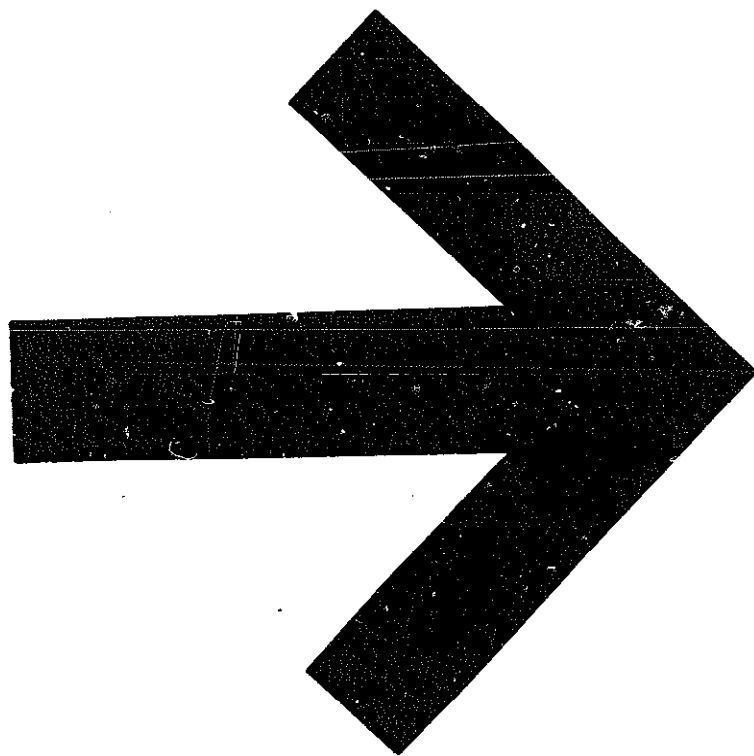


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Mark II Handpumps

Country: India, several other countries worldwide

Implementing Organizations and Enterprises:

- UNICEF
- Government of India
- Various Indian State Governments
- Numerous villages and communities throughout India and elsewhere
- Various private and public pump manufacturing companies

Magnitude of Impact

The India Mark II Deepwell Handpump has been the focal point of an enormously successful community water supply program which has found applications in virtually all parts of India, as well as in programs throughout Asia and Africa. The Mark II has become the standard deepwell handpump (recognized by the government's Indian Standards Institution) and the most popular pump in its range in Asia and Africa. An estimated 15-20,000 Mark II Pumps have been exported from Indian manufacturers to over thirty other countries over the last five years.

As of December 1984, more than 600,000 India Mark II handpumps had been installed in Indian villages, towns, and cities (Gray, 1984). An average rate of 200-250 people are served per installation; this corresponds to a minimum of 60-75 million villagers affected by this innovation in India alone.

Developed in close cooperation between the Indian government and UNICEF (The U.N. Children's Fund), the design is unpatented and remains freely accessible to the public. As a consequence, a number of Indian industries, both public and private, have taken up the manufacture of this pump design. As of December 1984, 38 firms ranging from very small- to medium-scale, were engaged in pump manufacture, and estimated total production capacity was quoted at 13,000 handpumps per month (a remarkable 156,000 units per year). An estimated labor force of 8,500 (at full production) is involved in the production of the pumps, while more than 50,000 individuals are involved in the drilling of new wells and the supervision and maintenance of existing installations (Gray, 1984). In addition, a number of subcontractors are receiving income and employment benefits from the manufacture of pump components and the assembly of pump parts, spare parts, and tools for maintenance and repair.

Technology Description

The Mark II vertical lift handpump is an extremely durable design of the reciprocating piston vertical displacement type which is generally installed in deep drilled or dug wells. The choice of the manufacturing process and materials, well drilling techniques, and installation and maintenance systems inherent in the Mark II design is a solid step towards a new focus in community water supply which began to emerge in the late 1960s and early 1970s. This new focus, supported by national and international development agencies, is based on the concept of village level operation and maintenance (VLOM).

The village level operation and maintenance (VLOM) approaches were developed in response to earlier potable handpump-based water supply schemes around the world, which until the 1970s were largely unsuccessful. In such schemes, the pumps in a vast majority of installations were left idle or quickly deteriorated due to the lack of pump durability, spare parts, or lack of user awareness. Additionally, most pumps installed in the period were traditional cast iron types imported from other countries and/or inadequately sized for community installations. According to UNICEF's Martin G. Beyer, "There was a need to develop new designs, as well as to make the communities aware that the operation and maintenance was their responsibility, that the handpumps belonged to them and that they really could reap considerable benefit from their proper use and upkeep." (Beyer, 1983).

The pump which has evolved to become India's standard deepwell handpump was a second generation adaptation of earlier Indian designs, the Jalna and Sholapur handpumps (hence the nomenclature Mark II). The pump has the following characteristics:

- it is capable of pumping water with relative ease from depths of 18 to 50 meters (two modified versions of Mark II are under field testing for under 18 and over 50 meters);
- its sturdy design can withstand continuous operation by larger numbers of people for longer periods than previously existing designs;
- all materials used in fabrication are of indigenous origin and are interchangeable and standardized;
- maintenance can be performed by relatively unskilled personnel at nominal cost;
- wells and pump are fully covered to avoid contamination of water by external sources;
- the cost is low, compared to imported handpumps of comparable characteristics.

A succinct description of the pump and detailed instructions for its installation are provided in a brochure by Industrial &

Allied Sales Private Limited (INALSA, 1982). INALSA along with Richardson and Cruddas of Madras, a public company, are the worldwide leaders in Mark II Handpump production. The key components of the pump (pumphead, cylinder, and connecting rods) as well as installation details and special tool requirements are presented in a practical fashion in this document.

The Mark II pump features a pumpstand unit located above ground with a long handle, anchored either to a platform or to the lid of a dry well; a connecting rod fixed to the handle by a chain or solid link mechanism encased in a galvanized iron 1 1/4" (32mm) diameter drop pipe reaching below into the water source; and a submerged cast iron brass-lined cylinder containing a reciprocating piston with leather washer, which is attached to the connecting rod and the handle above (see Figure 1).

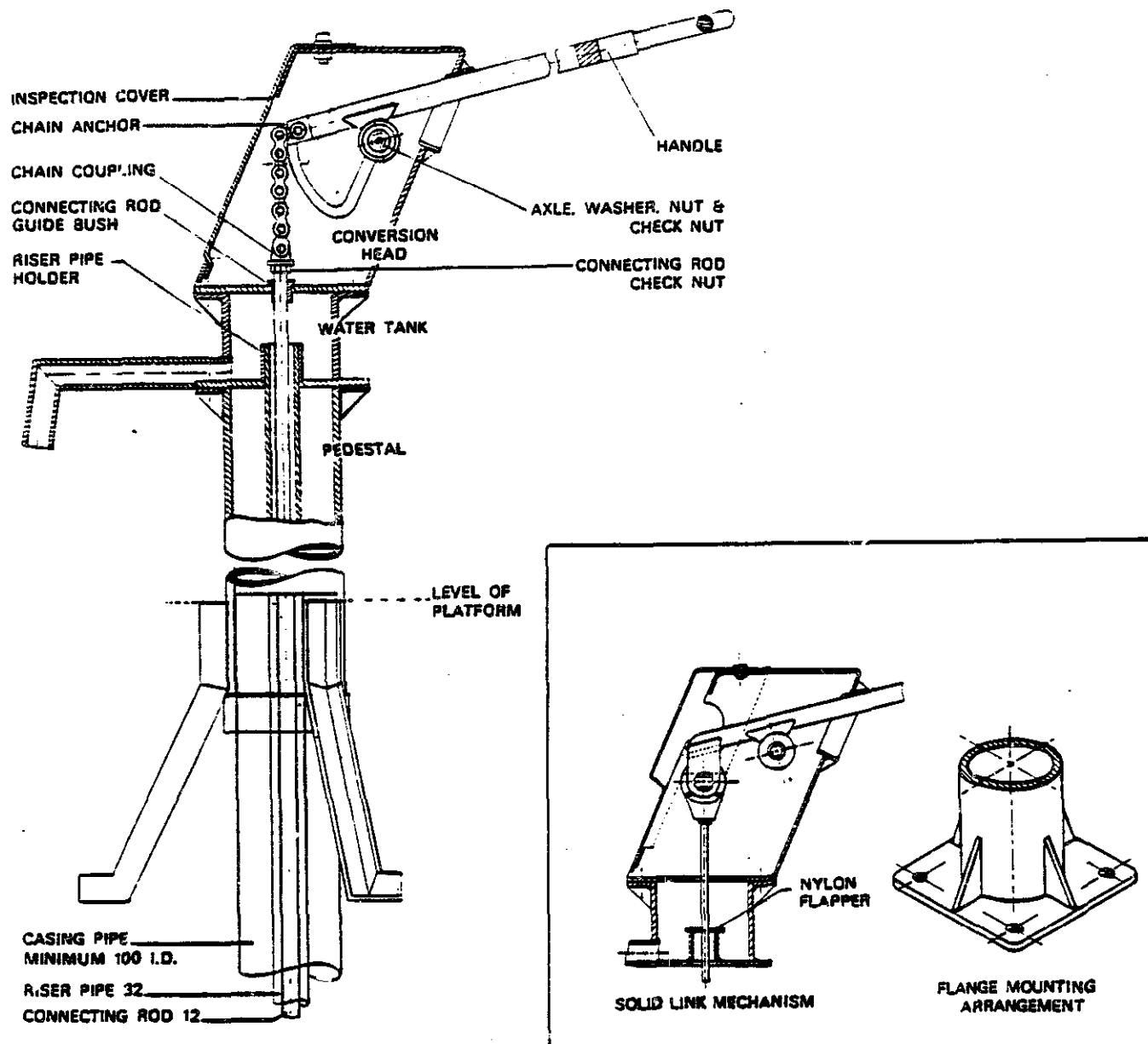
A few of the more important and innovative design features of the current Mark II pump are as follows:

- its pumpstand is constructed of galvanized mild steel instead of brittle cast iron;
- the body of the pump is easily removable and serviceable above ground;
- the pump is anchored sturdily by setting the three attached legs in concrete;
- the angular spout is turned down to prevent vandalism or contamination;
- a heavy-duty motorcycle chain is used to connect the handle to the rod and cylinder and a ball bearing inserted into the handle lever creates flexible and smooth transfer of movement.

Virtually all of the Mark II wells are drilled with an air hammer rig mounted on a large truck. This relatively advanced, rapid drilling equipment enables drilling crews to reach deep groundwater which is difficult, if not impossible, for villagers to reach using traditional manual shallow open well digging techniques. The highly mobile unit allows bore holes to be drilled to standard depths of 50 meters (150 feet) within one day, a quantum technological advance over manual or conventional cable tool rigs which require two to four months to perform the same operation when the ground is of very firm granite, gneiss, or basaltic lava formation.

The Mark II handpump technology generally conforms to local hydrological conditions. Many parts of India have low groundwater aquifers; therefore, the deepwell application is quite appropriate. Conversely, in Bangladesh the less expensive, shallow well pumps (New No. 6, Rower-Pump, etc.) which have had high success rates of adoption in numerical terms are more appropriate. One potential area of concern is the proper spacing

FIGURE I
The Mark II Handpump



SPECIFICATIONS

Particulars	Unit	Amount
Operational depth	metre	25-80
Cylinder I.D.	mm	63.5
Stroke	mm	100
Strokes per minute	nos.	40-50
Discharge per stroke	Litres	0.32
(does not vary with depth)	Imp. gallons	0.07
Discharge per hour	litres	800-1000
	Imp. gallons	170-210

Source: Industrial and Allied Sales Private Limited (INALSA), New Delhi.

of pumps to prevent potential depletion of existing aquifers due to the high pumping capacity (800-1,000 liters per hour) of the pump.

Dissemination and Funding Scheme

The Mark II pump design was the result of efforts by private agencies in Northern India during the late 1960s and early 1970s to combine effective deepwell drilling technology with a durable pump design. Initially an Indian private voluntary agency in Jalna, Maharashtra, supported by the Church of Scotland, introduced new and imported rotary drilling rigs for community wells to tap groundwater sources otherwise inaccessible to villages. In 1967 after cast-iron pumps failed repeatedly, a new, more sturdy, all-steel deepwell handpump, called the Jalna pump, was developed. Then in the early 1970s the Sholapur Well Service in Sholapur, Maharashtra (funded by the Swedish Covenant Church) made design modifications on the Jalna pump, which became known as the Sholapur pump. This improved design was more professionally engineered and accurately manufactured for uniformity and incorporated many of the features present in the current Mark II pump: a roller chain, a new pivot mechanism, and a pedestal to fit over the well casing pipe. (Gray and Talbot, 1984)

During this same period, the government of India, with the assistance of UNICEF, became involved in applying the more sophisticated drilling technology in its attempts to provide potable water to a target of 230,000 problem villages under the auspices of the massive India Rural Water Supply Program. Traditional cast iron handpumps were widely distributed thereafter, but by 1973 it was clear that many of the pumps had broken down and were not being repaired. In certain areas up to 80% of the pumps were no longer functioning.

Thereafter, a coalition of UNICEF and several Indian national and state government agencies, research organizations, manufacturers, non-governmental organizations was formed. This group tried to find new, sturdy, low-cost, deepwell handpump designs. The Sholapur Pump was selected for adaptation, refining, and testing and field trials were established in Coimbatore in south central India. When these tests proved to be successful, a way was sought to manufacture these pumps in numbers large enough to satisfy the requirements of the Indian Rural Water Supply Program.

Given the commitment of state and national governments to finance village water wells (with UNICEF support), Indian manufacturers began to get involved in the scheme. By this time, what had become known as the Mark II pump was the design of choice for state government village well installation. Manufacture of the pumps was initiated by INSALA, Ltd. and Richardson and Cruddas, a government-owned parastatal which had been a key participant in the Coimbatore trials, in addition to several smaller-scale metalworking industries dispersed throughout India.

Some of the larger firms established arrangements with cottage industries to produce single or multiple components that could be supplied on a subcontractual basis. Certain of the manufacturers, such as INALSA, Ltd. which came to be almost exclusively involved in Mark II production, emphasized interchangeability of components and quality assurance of new material.

Because the pump was developed cooperatively by public sector agencies, namely the Indian government and UNICEF, its design was not patented but was offered to manufacturers without the potential costs and complications of licensing/franchising agreements. As previously mentioned, the number of manufacturing plants has increased to 38 qualified suppliers. UNICEF also established a rigorous quality control program for finished pumps and completed installations which has continued to the present day. This program is being implemented by the international engineering firm, Crown Agents and SGS (Societe Generale de Surveillance) under contract to UNICEF.

After the design of the Mark II had been finalized and manufacture and installation were well underway, a select group of Indian engineers and administrators came together to draft standard design specifications for deepwell handpumps. These set out specific technical requirements to be incorporated and codified as Government of India standards with the national Indian Standards Institution located in New Delhi. The rationale for standardization, according to UNICEF's Martin Beyer (Beyer, 1984), was to ensure quality and standardization and to facilitate the manufacture, distribution, and use of spare parts.

The state governments of India created work crews manning high speed drill rigs to sink wells in hard rock areas designated by local communities and public officials. Pumps were contributed to local communities on the condition that they make a commitment to the upkeep, maintenance, and additional financing costs which could arise in future operations. A maintenance organization was initiated in Tamil Nadu in 1976, called the "three tier system." It addressed the difficult problem of maintenance, which has been the nemesis of countless well construction programs.

This mutually supportive system, involving users and local government officials integrally in the program, is described as follows (Beyer, 1983, Baldwin, 1983): (See also Figure 2)

Village Level:

In each village, a handpump caretaker is selected from among the villagers, given a brief but intense training (normally by the District Development Officers or by technicians from the state authorities) in health education and elementary handpump maintenance and repairs. The caretakers are provided with a set of simple maintenance tools and a diploma as formal recognition of their new responsibility.

FIGURE 2

Mark II Handpump Installation
and Maintenance Features

INSTALLATION & MAINTENANCE

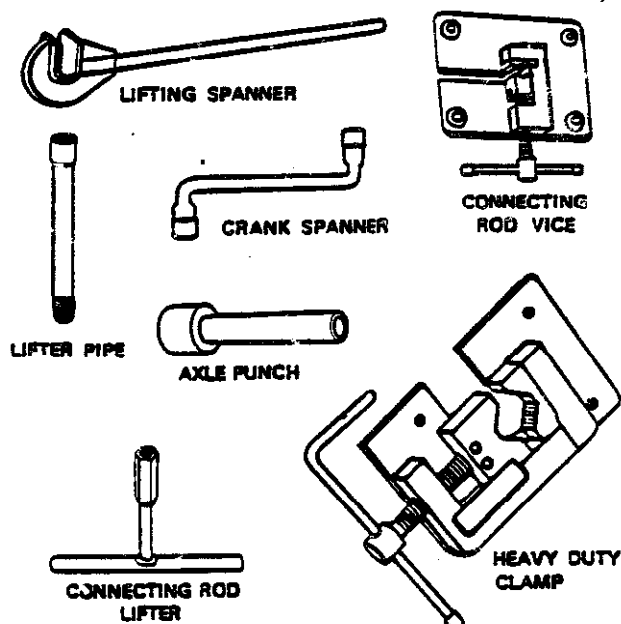
Installation and Maintenance of India Mark II Deep Well Hand Pump is extremely simple and can be done at village level with little training. A manual is also available on request, which gives step by step procedure of installation of pump through illustrations.

With normal cast iron body cylinder, this can be installed in a bore hole of minimum 100 mm inner diameter. Use of brass cylinder with flush end caps facilitates installation in minimum 80 mm dia bore hole.

SPECIAL TOOL KIT

Seven special purpose tools have been designed for ease of installation and maintenance of this pump. These are :

1. Lifting spanner (set of 3 Nos.)
—Use to lower or lift the rising main pipe.
2. Lifter pipe - 1 No.
—Use to lower or lift the water tank and rising main together.
3. Crank spanner (17 mm x 19 mm) (set of 2 Nos.)
—Use for tightening and loosening of flange bolts, check nuts and chain anchor bolt.
4. Connecting rod vice - 1 No.
—Use to clamp the connecting rod before you cut or thread the rod.
5. Connecting rod lifter - 1 No.
—Use to lift connecting rod to test pumping action.
6. Axle Punch - 1 No.
—Use to drive axle out of the bearing without damaging axle threads.
7. Heavy Duty Clamp - 1 No.
—Use to lift or lower rising main pipe and connecting rod.



Source: Industrial & Allied Sales Private Limited (INALSA), New Delhi.

Block or Sub-District Level

On the sub-district level--the second tier--roving mechanics, supplied with a set of tools and a bicycle or motor-bike and employed by the state authorities, make regular rounds, each to about 50 handpumps assigned to them. Their task is to inspect the pumps and to help the villagers with simple repairs.

District Level

At the third tier, water authority installation and maintenance teams, with one truck for every 500 pumps and equipped with a tripod and specially designed tools, are employed to carry out those repairs that are beyond the capacity of the village caretaker at sub-district level. If the mechanic is not available immediately to report major repair needs, the village caretakers can report them by mail on pre-printed postcards with a simple line-drawing of the Mark II handpump, on which they can circle the parts needing repair.

Although this extensive repair and maintenance system is not yet fully implemented to the established norms, the system has reportedly functioned well in several of the states where it has been initiated. However, concerns are being voiced about the ability of the system's field workers to keep abreast of the fast-paced developments in pump-installation technology. The system has been credited with maintaining the remarkably high rate of over 75% of installed pumps in satisfactory functioning order.

Recently, critiques of the efficacy, complexity, and cost of the Mark II's maintenance system have arisen and appeared in *Waterlines*, a development journal specializing in water supply issues and options (see Roy, 1984; and rebuttal by Gray, 1984). Modification of the pump's design and manufacturing process, as well as spontaneous and planned experiments with more locally self-reliant maintenance ("one-tiered") systems are occurring in various parts of India to address these issues. The UNDP/World Bank Water Supply Handpump Programme is sponsoring trials with new Mark II pump prototypes with PVC drop pipes, improved cylinder and other components which lend themselves to maintenance by simple hand tools and village-based mechanics. Additionally, it has been reported that in some states local communities have taken their own initiative and self-financed local mechanics to perform repair in lieu of the government (Burnet, 1984).

Economic Considerations

Economic considerations inherent in handpump installations include the initial investment (capital costs) and the costs for operation, maintenance, and repair. Total annual costs should be calculated on the basis of amortization over the life of the pump, also factoring in replacement and/or renovation of the installation.

Table 1 shows the approximate costs of Mark II handpump deepwell, hard-rock installations in India. At an average per capita cost of US \$7, villagers can have access to potable water with the Mark II handpump and related technologies. Given that per capita investment costs for potable water systems vary on the average between US \$5 - \$300 (Beyer, 1984), the Mark II is clearly an economical option.

Due to their robust, well-engineered design, high production standards, and extensive support infrastructure, the Mark II handpumps appear to be an economical option relative to both imported and most other locally-manufactured models in deepwell applications. In 1981 a comparative laboratory testing program of 12 leading international deepwell handpumps, conducted by the Overseas Development Authority (ODA) of the United Kingdom (Consumers Association, 1983), gave the Mark II the second lowest ex-factory price with the highest marks for performance, reliability, and resistance to wear and a negligible failure rate. Although other locally produced pumps may have lower capital costs for the initial installation, these models often require higher operational costs.

However, exact operational costs for the Mark II or any other handpumps prevalent in the developing world are as yet unavailable. Factor costs of intangibles such as cost/benefit analysis of health and socio-economic inputs and hidden government administrative costs and subsidies make accurate comparisons difficult if not impossible. A recently initiated study of the economics of village handpumps by Nicholas Burnet of the U.N. Development Programme/World Bank Rural Water Supply Handpumps Project may assist in closing these current gaps in knowledge. (Burnet, 1984).

Table 1

Cost of Mark II Handpump Installation

	U.S. dollars (1984)
INITIAL INVESTMENT	\$1,800
Well drilling (\$1,500)	1,500
Mark II pumps (\$200)	200
Platform and drais (\$100)	100
(Investment per capita = U.S.\$7.20)	
MAINTENANCE OVER 10-YEAR LIFE	
OF PUMP (\$ 35.00 per year)	\$ 350
(Maintenance per handpump per capita per year \$0.14)	
TOTAL: INVESTMENT AND MAINTENANCE	\$2,150

Assuming that each pump provides each of 200 villagers with 20 to 40 liters per day (5 to 10 gallons) of water over a ten year period, the per capita costs per year are \$0.86.

Source: Beyer, 1984

Environmental Considerations

The provision of clean potable water to rural areas of developing countries is considered by many national and international development agencies to be at the top of their agendas during the current International Drinking Water Supply and Sanitation Decade, designated as the decade of the 1980s. The clear connection between a host of diseases and the lack of clean water is now a well-established fact. Thus, the planners and policy-makers behind the Water and Sanitation Decade issued this extremely ambitious goal: "safe drinking water and sanitation for all by 1990."

According to UNICEF, "surveys conducted by the World Health Organization (WHO) have disclosed the startling fact that 80% of all diseases are associated with contaminated water, resulting in an estimated 10 to 25 million deaths each year. These diseases take the forms of typhoid, gastro-enteritis, and cholera, caused by drinking contaminated water, communicable diseases like scabies and trachoma transmitted through chronic water shortage, or schistosomiasis and dracunculiasis carried by snails and guinea worms, parasites that inhabit water. In addition, there are carriers of disease like mosquitoes and flies that breed in water. Mosquitoes are responsible for the dreaded malaria and flies cause river blindness also known as onchocerciasis".

"In round figures," the UNICEF report goes on, "an astonishing number of people suffer from these water-related diseases at any other time in history: 400 million with gastro-eneritis, 200 million with schistosomiasis, 160 million with malaria and 30 million with river blindness. Over half the deaths in developing countries occurred among children under five years old, and diarrheal diseases caused by poor drinking water and related unsanitary living conditions are the primary causes." (Another case study on Oral Rehydration Therapy further addresses this topic).

A 1983 UNICEF-sponsored evaluation of rural water supply programs in Bangladesh, Burma, and Nepal concluded, "Numerous studies have tried to confirm the assumption that safe water improves health. Specialists presently seem to hold the view that it is not possible to get a clear answer through such mono-causal linking of water supply to health improvements. Firstly, there are so many other factors which interfere with the relation of safe water and health. Secondly, safe water is just one of the many essential pre-conditions for health, but not sufficient by itself alone to improve the health situation of any target population. Thirdly, any possible health effect of a water system hinges on its proper use, operation and maintenance. Even the seemingly simple, low-cost technology, with which we are dealing here, needs careful planning of the engineering and social approaches in combination with proper education of the users in order to achieve the desired health effects." (UNICEF, 1984)

On the other hand, it has often been expressed, generally in

anecdotal terms, that no single innovation can change village life as dramatically as an efficient, clean, simple supply of water. There is clear evidence that community water supply installations can dramatically improve the quality of women's lives, in particular, by reducing drudgery and time demands for hauling scarce water over long distances.

The successful installation over the last 7 years of more than 600,000 Mark II pumps in Indian communities and their evident high performance and acceptance constitute a significant contribution to the lofty aims of the Water and Sanitation Decade. The Mark II's efficient, durable, economical design coupled with an effective manufacturing, installation, and maintenance infrastructure can be considered a genuine breakthrough in the struggle against water-related diseases in India. The specific design and installation of the Mark II hand-pump incorporates specific features which prevent contamination of the water source: the wells are deep, the pump head and pedestal assembly are tightly sealed, and effective drainage eliminates potential problems caused by stagnant surface water. These advantages are contingent, of course, on proper site selection to eliminate any potential source of contamination.

Social/Cultural Aspects

In the critical and complex matter of village water supply, a close fit between the technology and the aspirations and awareness of its users is essential. The elements often evoked by appropriate technology advocates are very much in evidence in this effort: performance, permanence, and participation. In many ways the India Mark II handpump compares favorably with the Model T Ford and the familiar American farm-type windmill, two standard innovations of the early twentieth century. As with these durable designs, undoubtedly many improvements and viable alternatives to this technology will arise in the coming years building upon this experience.

The salient features of the Mark II experience which effectively address social and cultural factors include:

- maximum participation by users in the installation, operation and maintenance of the pumps;
- substantial involvement of social scientists and community development workers in the design and implementation of the pump distribution and maintenance systems;
- transfer of ownership and routine maintenance responsibilities to users; and,
- user perception that the design is both indigenous and effective (measured in terms of durability, quantity, and quality of water delivered).

The Mark II is conducive to additional important social amenities and considerations such as provision of washing facilities for women, which would add minimal costs but substantial benefits from the standpoint of users.

Issues such as caste distinctions and resulting use restrictions must be taken into account on a case-by-case basis. No simple solutions are available for such matters, and these require considerable planning and participation.

The considerable achievement represented by the India Mark II Handpump phenomenon should not be cast in terms of a panacea or an ultimate solution. There is room for further improvements in the current design. Of particular interest will be a redesign of the submerged parts of the pump (drop pipe and cylinder) so that villagers can be almost completely self-reliant in maintenance and repair of the pump. Currently, simple repairs such as the replacement of leather cups and washers require the help of the government's district maintenance team.

Reasons for Success

The India Mark II deepwell handpump has proven to be a technological innovation of broad-scale impact and implications in India and many other countries. Although its specific design may not be applicable in all areas of the world, many aspects of its manufacturing, distribution, and maintenance system are relevant to other developing countries. The primary reasons for the Mark II's initial and sustained success include:

- o pump has a proven capacity to reliably deliver adequate volumes of water to substantial numbers of people with constant use in field settings;
- o design is well suited to decentralized manufacture and transportation at medium-scale workshops with rudimentary equipment;
- o pumps are installed by means of a highly effective drilling technology that speeds up and standardizes installation;
- o delivery and maintenance system is highly effective and well organized (use of semi-sophisticated drilling equipment; relatively simple labor-intensive installation; and a three-tiered maintenance system at village, sub-district, and district levels);
- o the Indian Standards Institute has made national standard design specifications available at no cost to all potential manufacturers to ensure uniform design and interchangeable parts;

- o pump users actively participate in each critical step of installation, operation, and maintenance;
- o UNICEF and competent and respected engineering inspection firms, Crown Agents and SGS, exercise continuous control over manufacture and delivery to maintain high standards of quality and reputation.

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Oral Rehydration Therapy

Countries: Worldwide

Implementing Organizations and Enterprises:

- UNICEF
- USAID
- International Red Cross Committee
- WHO
- SIDA
- International Dispensary Association
- Numerous governmental and non-governmental health-related services delivery organizations

Summary

Oral rehydration therapy (ORT) has found widespread acceptance throughout the world as the most simple, inexpensive and effective means of treating acute diarrhea, a disease which results in the death of over 5 million children per year. Over the last 15 years, ORT programs, which promise to cut infant mortality by 50% or more, have spread to virtually every country in the developing world. The awareness and accessibility of this technology has been extended to rural villagers and urban dwellers of all economic strata, and have even reached isolated communities beyond the purview of private or public health services. According to UNICEF, ORT is considered as 'potentially the most important medical breakthrough in the 20th century.'

An estimated 80 million individual packets of Oral Rehydration Salts (ORS), a glucose-electrolyte mixture, are produced and distributed annually by a broad assortment of development agencies, government health programs, and private enterprises. UNICEF alone supplies almost 30 million packets throughout the world. By 1982, using production standards similar to those set by UNICEF and WHO, commercial firms and national governments had established ORS production facilities in 20 developing countries. In addition, a simple method using locally available substances such as table salt and sugar which can be prepared in homes and community health clinics is being promoted by a variety of groups in order to make oral rehydration therapy accessible to many more millions of people. The magnitude of the dissemination of oral rehydration salts, both in prepacked or homemade form, has been phenomenal; yet, even this extensive supply still constitutes only a small portion of the projected annual global requirement.

The following are only a few examples of the numerous practical applications of ORT:

- o In Bangladesh, 900 field workers of the Bangladesh Rural Advancement Committee (BRAC) have taught 2.5 million women

how to make ORT solutions from the salt and molasses available in every household.

- o In Honduras, the number of diarrhea deaths among children under the age of two has been almost halved by the use of ORT promoted by the government health service and an extensive radio campaign.
- o In Nicaragua, 80,000 literacy campaign workers have introduced ORT to thousands of households and 334 ORT units have been set up throughout the country. Diarrheal disease dropped from first place to fifth place as a cause of infant mortality between 1980 and 1982.

Technology Description

Oral rehydration therapy essentially involves drinking a solution of water, sugar, and mineral salts to replace the fluids and salts lost by the body during bacterial- or viral-borne diarrhea. In severe cases, particularly in young children, diarrhea can lead to the onset of rapid dehydration, a loss of as much as 10 percent of body weight, shock, stupor, and death within a matter of hours. During acute diarrhea, not only are fluids and electrolytic salts (sodium, potassium, chloride, and bicarbonate) too rapidly eliminated, but the ability of the intestines to absorb fluids and salts is inhibited. Before the development of ORT, the most common form of rehydration was by intravenous means, a process requiring expensive and sterile facilities and equipment available only to a small privileged segment of the population.

In the 1960s it was discovered that a combination of glucose (or sucrose) with mineral salts in an aqueous solution, originally added for palatability, would counter the effects of diarrhea in impairing the retention of fluids and salts. Mixed in proper proportions, the sugar was found to increase the body's absorption capacity of water and dissolved salts by two hundred and fifty percent. Subsequent to this discovery, a formula for oral rehydration solution was established by the World Health Organization (WHO), comprised of the following ingredients:

sodium chloride	3.5 grams
sodium bicarbonate (baking soda)	2.5 grams
potassium chloride	1.5 grams
glucose	2.0 grams
water	1.0 liter

Optionally, 0.02% colloidal silicon dioxide is added as an excipient to improve the ability of the mixture to flow freely and dissolve easily.

The most common form of mixing, packaging and distributing the ORS packets has been through automated production in hermetically-sealed aluminum pouches by large-scale machinery. In recent

years, particularly in developing countries, inexpensive local production plants using labor-intensive methods have been developed which are able to use less durable, and less expensive, packaging devices due to their closer proximity to eventual users and distribution sites.

The ORS packages containing the complete formula (described on the previous page) have received international acceptance both by experts and practitioners but, due to problems of cost and distribution, are only reaching a limited number of potential beneficiaries. Consequently, home preparation of simple oral rehydration solutions is being promoted as an alternative production approach in various countries. These home remedies often do not contain potassium or bicarbonate and are primarily recommended in the initial stages of diarrhea to prevent dehydration.

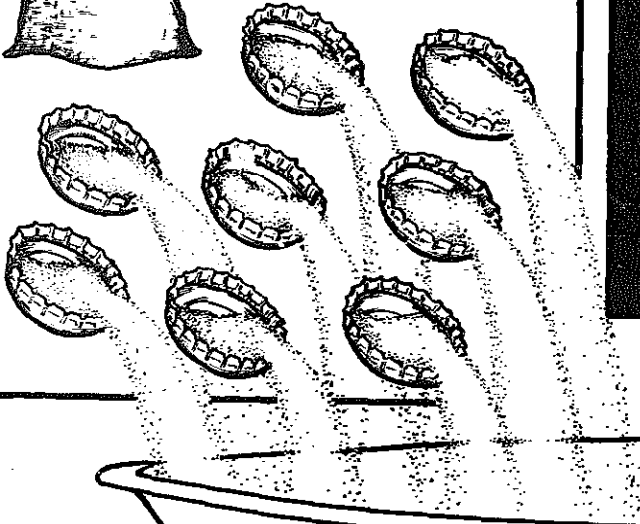
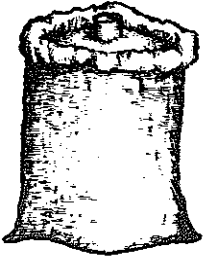
Two common technologies for domestic production of oral rehydration solutions are:

- "salt and sugar" solutions - mixtures of refined or unrefined sugar (sucrose) and cooking salt (sodium chloride) which are available in many households and dissolved in water. In certain countries molasses or unrefined sugar is used, which contains potassium and bicarbonate. A variety of recipes are available (generally within established limits) and methods of preparation include hand measures (often known as "pinch and scoop"), household spoons, and specially-manufactured double-ended measuring spoons. These methods require substantial training and extensive activities among health workers and families as well as the availability of sugar and salt, which may not be affordable to the poorest homes.
- "household food" solutions - mixtures of fluids or liquids available in the home which are byproducts of food preparation, such as rice water, vegetable soup, juices, weak teas, etc. These solutions are often prepared from boiling water, thus more hygienic, and may contain sodium, starchy sources of glucose, or potassium, which in combination can have the effect of more formal ORS techniques.

Certain potential failures or even dangers could exist in ORT programs if the concentration of electrolytic salts used is too low or too high (less than 20 milliequivalents hyponatremic or more than 150 milliequivalents per liter hypernatremic) or if unsanitary water is used in the solution. Dr. David Marley, a noted international health authority, has suggested the maxim that ORT solution should be slightly less salty than tears. Apparently, it has been demonstrated in numerous instances that many victims will imbibe adequate and not excessive amounts of a properly mixed and constituted solution if their condition is not overly deteriorated. Other considerations, such as acidosis from a lack of bicarbonate and potassium in the simple sugar-salt solution

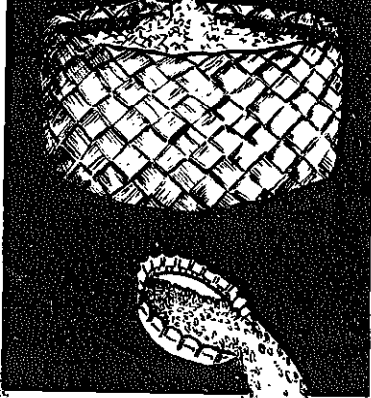
SUGAR—8 bottle caps

جول بقال خيرو آقايس شمشيرو



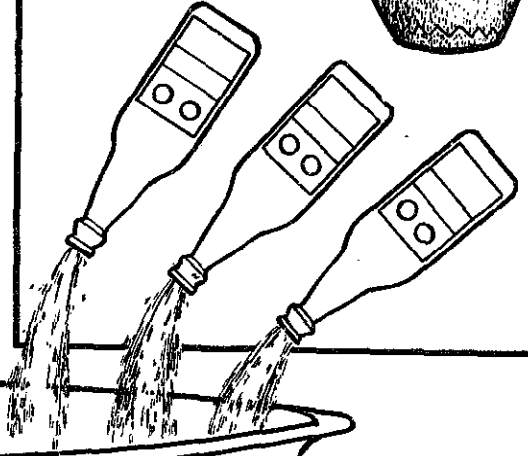
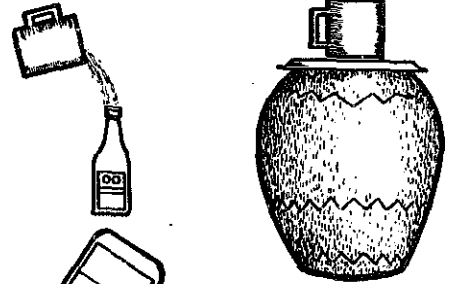
SALT—1 bottle cap

جول بقال خيرو آقايلشكو



WATER—3 Julpearl bottles

جول بقال كتبه ستہ چينو



(as is often the case in homemade solutions) are important but can be addressed by supplemental foods such as whole bananas, fruit juices, and certain vegetables. In addition, although boiled water is desirable in order to ensure proper sanitation, a survey in the Gambia found that whether the water used to mix ORS was clean or contaminated made minimal difference to the incidence or duration of diarrhea.

ORT is administered according to the stage and severity of a diarrhea case, and the age and physical condition of a patient. The intent is always first to rehydrate or prevent the dehydration of a victim by regular measured doses, and to continue treatment until the necessary level of fluids and electrolytic salts within the body is maintained. A three-tiered approach is recommended by WHO and UNICEF relying on home remedies in the first instance, ORS packets in advanced cases, and intravenous therapy as a last resort. Additionally, there is a growing consensus among medical experts and health workers regarding the necessity of resuming continuous feeding, particularly breast feeding in the case infants, as soon as rehydration is successful. The resumption of continuous feeding runs contrary to conventional practice in many areas.

Dissemination and Funding Scheme

After sporadic experiments with various oral solutions in the 1950s and 1960s, the pivotal role of glucose-electrolytes in enhancing water and sodium uptakes in adult and children patients with cholera and various diarrheal diseases was discovered. ORT was dramatically demonstrated initially on a trial basis and later on a massive scale during the cholera epidemics which swept Bangladesh after its catastrophic was of independence. Although ORT had only been tested in clinical settings at that time, the urgency of the situation and lack of availability of intravenous options pushed the new option to the forefront. The results of this mass emergency campaign were spectacular -- the death rate dropped from 25 to 3.6 percent of persons treated.

Thereafter, in countries all over the globe, a number of ORT programs with differing organizational arrangements have been launched on the local and national scale, with a common denominator of community availability of knowledge, services, and supplies. Some have been part of comprehensive health programs where ORT is but one component, whereas others have been single purpose efforts to address an immediate need. Additionally, linkages have been made with private and public family planning efforts, with variable success rates. These numerous programs have placed emphasis on devising site and country-specific appropriate approaches to the following concerns:

- composition, production and distribution of ORS products;
- use of homemade "sugar-salt" or "household food" preparations;

- accurate preparation of the solutions;
- early use to prevent dehydration;
- continuous feeding during diarrhea;
- avoidance of purgatives, antibiotics and other drugs; and
- appropriate program recognition assistance and evaluation strategies.

Two key elements have been incorporated in virtually every ORT program -- a direct personal approach to users (especially mothers of small children) and a programmatic and comprehensive utilization of various communications media and distribution channels to reinforce household availability and acceptance of the technology. In the first instance, the use of health care workers, auxiliaries, and/or local people skilled in providing practical demonstration and follow-up in the measuring, mixing, and administration of ORT is nearly always emphasized. Communication campaigns using many or all of the popular cultural and communications media, including radio, billboards, folk theatre, religious festivals, etc. have been employed to the fullest extent. Finally, existing commercial mechanisms, such as village stores, bazaars, and travelling vendors, and community service facilities such as local and regional health clinics have been heavily utilized in the distribution of ORS packets and information.

Virtually all ORT programs to date have been supported by international multilateral donors such as UNICEF and WHO, bilateral donors such as USAID and SIDA, and by national government health services. These clearly have proven to be well-spent investments in most instances. Non-government agencies such as BRAC in Bangladesh have also demonstrated substantial successes in implementing more self-help oriented schemes and in overcoming the more rigid bureaucratic character of centralized schemes. Commercial concerns are currently entering the scene in increasing numbers as competitive market niches open in various countries among urban and rural people with more stable income.

Economic Considerations

The costs and benefits of oral rehydration are well-known and favorable relative to other forms of medical treatment. UNICEF, the largest supplier of ORS products, obtains a packet for about 8 cents U.S., which includes 2.5 cents for ingredients and 2 cents for packaging. Given a frequently cited average of an annual requirement of 6 packets per child, the cost of saving lives by this method versus other medical techniques is extremely low. However, despite this and other advantages, health services in most developing countries are unable to supply ORT packets for every family without allocating the majority of their health

budgets to ORT.

Until recently, it was more economical to import packets in bulk from developed countries than to set up equivalent turnkey sophisticated facilities in developing countries. Locally premixed or homemade ORT solutions, however, are becoming a favorable alternative to standardized ORS packets due to their reduced cost and greater accessibility. In Bangladesh, per liter costs of an ORT solution using glucose are 12 cents U.S., versus 7.4 cents if made with sucrose, and only 1.8 cents if gur, a durable, locally-produced unrefined sugar, is the primary ingredient. Similarly, in Guatemala local production of ORT formula is being achieved at small-scale facilities with initial investment costs of under \$1,000 U.S. and daily production rates of 30 packets per day at a minimal cost of 1.5 cents each. A study undertaken in Egypt in 1980 (financed by USAID) concluded that ORT solutions prepared in the home were the most cost-effective method of oral rehydration; the cost per death averted (including program overhead cost) was \$52 (US) versus \$104-\$691 by other methods of ORT delivery. Nevertheless, both of the very inexpensive home-produced or locally premixed ORT solutions and the universal WHO-UNICEF packets with their greater efficacy and quality control have important roles to play in the future development of the technology.

Environmental Considerations

Over the last 15 years, a vast international body of evidence has been forthcoming testifying to the remarkable efficacy of the various forms of oral rehydration therapy in dramatically reducing infant mortality. ORT by itself cannot address the basic causes of diarrheal infection -- inadequate water sanitation and hygiene. Diarrheal disease and malnutrition form a vicious circle weakening the victim, particularly young children, and creating susceptibility to a host of other diseases. It has been clearly established by various experts that ORT combined with continual feeding during and after a diarrheal episode not only counters the acute emergency of dehydration but also improves the overall nutritional and health status of the individual. Thus ORT has become a cornerstone of integrated primary health care approaches, neither as a stopgap or a palliative, but as a catalyst for individual and community health improvement in various communities.

User Participation and Understanding

ORT therapy relies entirely on the total awareness and participation of its users and promoters if it is to successfully achieve its promise of preventing unnecessary death due to diarrheal dehydration. Interventions which fail to educate and involve potential users in a way which addresses their needs and concerns and accomodates local customs fail to achieve their desired results. For example, in a project in Menoufia Province

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in Egypt, mortality rates in six villages where an ORT promotional campaign was active were almost identical to rates in six control villages (54.5 versus 55.3 per thousand). Despite the mass availability of ORS packets and a visible educational campaign, the oral solution was insufficiently or inadequately used by mothers before and during fatal diarrheal episodes. The post mortem in this case indicated that the failure to sufficiently involve local doctors, health care auxiliaries, and credible community members in the educational process resulted in a lack of motivation, moral support, and practical help to mothers who were expected to administer ORT to their sick children.

Substantial counter examples are available, however, where interventions achieved unprecedented success in countries such as Honduras, Haiti, and Gambia. Often these programs have built upon or benefitted from experiences elsewhere. In Egypt, new programs arose after the unsuccessful Menoufia experience which acknowledged that ORT can only be successful in reducing deaths if the primary administrators, mostly mothers, are informed and confident about why, where and how the techniques can work. Extensive and careful preparation resulted in the selection of a local brand of ORS sized to common drinking vessels, the organization of repeated visits by health workers, and the incorporation of a number of creative informational/promotional techniques into the program. These included engaging local folk singers, religious leaders, traditional healers, market vendors and schoolchildren in the program in addition to the involvement of mothers. Consequently, a reduction of over 46% in mortality due to diarrheal disease was registered in less than 2 years, and almost 90% of the residents of the project area were conscious of the value of ORT.

Reasons for Success

ORT is only beginning to realize its broader potential, yet the experience to date is quite indicative of a large-scale successful application of appropriate technology. Although certain logistical and technical issues remain, the verdict is unambiguously favorable. The most common factors contributing to the successful realization of these programs are as follows:

- o the technology essentially involves simple actions with tangible results to large numbers of people of all economic and social strata;
- o promotional techniques depend on community support rather than professional expertise or coercive measures;
- o the materials are inexpensive and accessible using existing distribution channels to the fullest extent possible;
- o dissemination strategies are flexible, pragmatic, and comprehensive, utilizing careful planning, multimedia communications, and extensive follow-up and evaluation.

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Water Pumping Windmill Industry

Country: Argentina

Implementing Agencies & Enterprises:

Various Private Manufacturing Companies

Magnitude of Impact

Argentina's water pumping windmill industry is reportedly on its way to becoming the largest producer and exporter of windmill equipment in the world. Although statistics vary, the annual production of windmills in Argentina is approximately 1,500 to 2,000 units per year. This compares to the estimated annual world production total of 5,000 to 10,000 units (Costello, et al., 1982). Argentina is the only nominal developing country with an established viable wind industry and finds itself in an elite league of windmill producers with South Africa, Australia, and the United States.

The Argentine windmill industry has existed in various forms for about 30 years, but only solidified 20 years ago when a design based on a traditional American multiblade fan mill became the standard product. A reported total of over 20 manufacturers of various size are currently engaged in windpump production, and all current manufacture and sales of spare parts and new units originate within the country. One notable Argentine manufacturer, Fabrica de Implementos Agricolas, S.A. (F.I.A.S.A.), is responsible for almost 50% of total Argentine production (Wyatts, 1984).

At present, an estimated total of 60,000 water-pumping windmills are in everyday operation and use in Argentina. Windmill installations are generally located on individually-owned live-stock grazing ranches throughout the Pampas Plains and the Patagonian Plateau, which are blessed by uninterrupted trade winds. Although most of the installations provide water for cattle and other livestock, some of the water is also used for domestic consumption. It would appear that over 300,000 people, a sizeable segment of Argentina's rural people, obtain direct or indirect benefits from these schemes.

Technology Description

Virtually all of the water-pumping windmills produced in Argentina are horizontal axis lift devices closely modeled after the American multiblade fan type windpump design, produced extensively in the U.S. between the 1880s and the 1930s. Specifically, the most common Argentine design is an almost exact copy of the classic #702 Aermotor windmill still produced in the U.S. which comes in rotor sizes of 6, 8, 10, 12, 14 & 16 feet

(1.83 - 4.88 meters) (Aermotor, 1981). Parts are deliberately manufactured to exacting specifications so that they are interchangeable with any of the older windmills manufactured from the 1930's onward.

This class of windmill features a mill unit consisting of the rotor (comprised of airfoil-shaped blades resembling an aircraft propeller), a spring-activated tailvane for turning the rotor out of the face of storm force winds, and a drive mechanism (gears, bearings, pinions, and a pitman arm) for translating horizontal rotation to vertical displacement strokes on the pump rod. The mill unit is firmly attached to a standard 40 foot galvanized iron or wood tower, and the iron pump rod is attached to a standard horizontal displacement piston pump submerged in a cased well at depths ranging from 10 to 1,000 feet.

The key characteristics of this particular windmill design include: the requirement to lubricate the mill unit only once per year; a relatively lighter weight construction than other designs of this type; and a combination of high starting torque with low windspeed.

Smaller size mill units can be simply erected with a gin pole and block and tackle, whereas a boom truck or crane are necessary for the larger size mills. The six foot mill has a rated capacity of 1.2 m³/hour, while the larger units are designed for 1.8 m³/hour. The choice of a given mill is dependent upon factors specific to each site such as average windspeeds and pumping depth.

Complete technical descriptions and operating manuals of FIASA/Aermotor design are available through brochures published by F.I.A.S.A. and Aermotor Windmills in Dallas, Texas (see references). In addition, publications by the World Bank Energy Assessment Office and Intermediate Technology Power, Ltd. present extensive technical performance comparisons of the Aermotor design to the myriad of other designs currently on the market or barely off the drawing boards around the world (Costello, 1982 and IT Power, 1983). The overwhelming conclusion is that while not being the optimal, most efficient mill from the standpoint of mass to output ratios, this type of design is a pragmatic and proven one in many contexts around the world. It requires less precision in manufacture and allows for more leeway in maintenance than many other designs and types.

Dissemination and Funding Scheme

Most efforts aimed at the establishment of windmill programs in developing countries have assumed one or more of the following approaches (Wyatt, 1982):

1. **importation of machines** - this implies introducing wind power by borrowing the experience of the developed world through importing existing commercial hardware. This approach has the advantage of using time-proven

equipment, albeit at often exorbitant prices which do not necessarily positively affect national balance of payments deficits.

2. copy-production of imported models - this is the general approach of the Argentine wind industry, where licensed (and unlicensed) local production largely based on the Aermotor design has resulted in the establishment of a stable windmill industry (further articulated later). For such copy-production to succeed, good industrial capabilities, financing options and relatively strong and secure domestic and/or international markets are essential.
3. production on a village-level of local designs that are inexpensive with high maintenance requirements - this approach strives to achieve the production of equipment which can be produced to the greatest extent possible using locally available materials and rural construction techniques. The low cost machines produced generally require frequent maintenance and attention in order to function properly and efficiently (e.g., Sahores (Africa), Arequipa (Peru)).
4. production of local designs of moderate cost and reliability - this approach strives to produce more efficient and durable machines than the previous category. Their higher cost and more precise engineering often require more developmental time and financial support and often private business or government markets rather than small communities.

In the indigenous small industry approaches, described in options three and four, the need for strong, established markets is even more acute than in the first two options.

The transfer of the American windmill technology to Argentina and the ultimate establishment of a thriving domestic windmill industry can be summarized in three phases. The first phase consisted of an initial widespread importation of windmills from the U.S., followed, about 40 years ago, with somewhat crude reproduction of the basic designs. The Aermotor Company of Chicago, Illinois, seeking to reduce its burgeoning costs in the early 1960's, then sent its general manager to Mexico, Brazil and Argentina to investigate licensing arrangements for the manufacture of components or entire mills.

Argentina was selected for its existing industrial capabilities and large potential domestic market. An arrangement was made with the company F.I.A.S.A. which had previously been producing small farm machinery and FIAT engines under license. F.I.A.S.A. had established a sizeable foundry, milling and manufacturing capabilities and a skilled workforce.

In the second phase, the Aermotor Company provided extensive technical assistance and supervision to the Argentine company. Financing was completely secured through private commercial channels. In the course of several years, production of mill unit assemblies and entire mills (including pump and tower) became the bulk of the company's business. Over 50% of its production was exported under license to the U.S., and then assembled and sold by Aermotor in the U.S. or reexported to third countries.

F.I.A.S.A.'s success spawned imitators and encouraged smaller firms to continue or initiate new work on multiblade fan type windmills on a subcontractural or complete basis for the growing domestic Argentine market. Eventually, F.I.A.S.A. took over the direct exporting rights outside of the United States when the U.S. company began experiencing financial difficulties in the 1970's. (In fact, the U.S. company actually discontinued windmill manufacture for three years in the late 70's, until it was sold to its present parent corporation and moved to Conway, Arkansas).

In the third phase, a form of role reversal has taken place; for the last three years, American windmill entrepreneurs have set up distributorships of Argentinian-made products. Only the mill unit is imported from Argentina, while the tower is fabricated in the U.S.. Informed sources indicate that quality and price advantages are two reasons for the growing competitive edge the imported product appears to have over exporting American products. The Argentinian products, at least those exported to the U.S., have maintained all of the durable features and manufacturing details of the original 1930's design, while apparently the comparable U.S. product has undergone certain minor changes (Wyatt, 1984).

The U.S. distributors importing the Argentine mill unit, all of whom formerly worked for the U.S. company, are carefully checking all inbound shipments and accepting only equipment meeting the traditional standards. This also has a reciprocal effect on the overall quality of fully assembled windmills for the domestic market in Argentina.

Despite import duties and high freight shipping charges, the price of the products constructed with Argentine components being marketed in the U.S. are highly competitive due to their lower labor and production costs. In addition, sales to other developed and developing countries are also picking up as the product's reputation and availability grow. It is not entirely inconceivable that the Argentine success will in turn stimulate copy production efforts in other countries with favorable circumstances.

Economic Considerations

Specific economic assessments of the Argentine windmill are difficult to obtain due to the reluctance of private Argentine companies to divulge company financial information to the public.

However, extensive economic assessments of many commonly available windmills around the world and a good generalized methodology are available in various references (see Costello, 1982, IT Power, 1983, Fraenkel & Kenna, 1983, GATE, 1984, and for the latter, Gingold, 1979).

Current U.S. Aeromotor prices range from \$2,130 to \$11,015, a price which would be prohibitively expensive in developing countries where import tariffs may double the cost. In Argentina, however, prices reputedly are less than 50% of the U.S. prices (Wyatt, 1984). A windmill delivered directly to Haiti (with tariffs excised due to its inclusion as a part of a special development project approved by the government) was shipped at a total, final cost of slightly more than one-half of the price of an equivalent sized U.S. made windmill (Wyatt, 1984).

Until recently, all mill units used in the production of Aeromotor windpumps in the U.S. were manufactured and assembled in Argentina and then shipped to the U.S. Since the mill unit comprises between 35% - 70% of the total unit cost, depending on the size of the rotor, the U.S. distributors for Argentine windmills of this type mainly imported the mill unit and arranged for U.S.-based production of towers on a subcontractural basis (Wyatt, 1984). Exact price figures were unavailable, but the differential between the latter and the importation of a complete Argentine windmill is in favor of the wholly Argentine model at this time, which may indicate a growing trend toward imports in the U.S.

Most of the windmill installations in Argentina (which is also becoming the world's largest consumer of windpumps) are found on private livestock ranches. ITDG explains the economies of scale which have led to this situation: "The value of water for livestock is high because quite modest quantities of water can sustain a sizeable herd. For example, in 3.8 meters/second (14 km/hr) winds, a typical 12 foot rotor farm windmill pump will (at a conservative estimate) sustain a herd of around 70 steers or 500 sheep when pumping from a typical depth of 35 m (115 feet). A windpump of that size will cost typically U.S. \$1,500 to \$3,000 on a 30 foot tower, and will have a life typically in excess of 20 years with only once per year maintenance. The value of 70 steers, even of bush-cattle quality in Africa, is typically in excess of U.S. \$10,000 -- so it is clear that the investment in the windpumps which provides the one most important need not otherwise provided by nature, is not out of proportion. Hence, it is affordable, as the capital sum requirement is typically no more than the revenue to be gained each year from the sale of cattle (assuming a four year growth to sale cycle)." (IT Power, 1983).

Reasons for Success

Apparent reasons for the successful transfer of technology and establishment of a thriving domestic windmill industry in Argentina include:

- o The selection of a proven, durable and easily maintained technology shortcut the need for extensive R&D, prototype testing and market development domestically and internationally;
- o Engineering and small-scale steel manufacturing and entrepreneurial capabilities were well established in the country;
- o Due to the lack of patent and export restrictions, Argentine producers were able to competitively market their products in countries outside the U.S.;
- o Initial technology transfer in the form of licensing and franchising agreements was accompanied by appropriate financial and technical assistance which appeared to be mutually beneficial;
- o Strict export quality standards by sales representatives or components importers in the U.S. positively affected overall quality control of workmanship and production in Argentina; and
- o The existence of highly conducive environmental and agro-economic conditions in the country have created and sustained an active demand for the product (e.g., excellent wind regime, existence of an extensive grazing operation removed from electrical power grids, etc.).

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Bamboo-Reinforced Concrete Water Tanks Project

Country: Thailand

Implementating Organizations and Enterprise:

Community-based Technology and Development Services (CBATDS), an affiliate of the Population and Community Development Association (PDA)

Magnitude of Impact

Since 1979, the Tunngnam Project of CBATDS/PDA has achieved significant success in the introduction and wide-spread dissemination of rural potable water technologies to villages in semi-arid, drought-prone Northeastern Thailand. By the end of 1984, CBATDS had mobilized technical, organizational, and financial assistance for the construction of over 7,000 bamboo-reinforced concrete rainwater collection and storage tanks for individual households (PDA, 1984). The participants in the project contribute their own labor to the construction of the tanks and repay all material costs, plus a small surcharge, into a revolving loan fund. Through this financing scheme, it is projected that a total of between 7,500 and 10,000 additional tanks will be constructed within the next 3 years.

Given the large size and extended nature of families in the vast Northeastern region of Thailand, it can be safely surmised that between 30-50,000 rural people are currently receiving direct benefits from this effort. Within 5 years, this project is likely to provide sanitary drinking water to up to 200,000 people in Northeastern Thailand.

Technology Description

The central technology used in the Tunngnam (Thai for "water tank") program is a bamboo-reinforced concrete cylindrical rainwater tank, which is currently of an 11,300 liter capacity. A woven mesh formed from untreated bamboo acts to increase the tensile strength of the concrete used in tank construction and to reduce the hoop and bending stresses on the base and walls of these structures. CBATDS adopted and improved the designs and construction practices for similar, previously existing rainwater tanks. These earlier tanks were designed and funded by the Thai Division of Sanitation of the Ministry of Public Health in collaboration with Khon Kaen University and UNICEF. The tanks receive rainwater from gutters and drainage pipes attached to the sloping metal roofs which are common in most parts of Thailand.

The construction techniques developed by CBATDS enable a tank to

be constructed in just three days by inexperienced labor assisted by local skilled workers. A square base footing of standard 1:2:3 concrete mixture is poured during the first day of construction. On the second day a round metal slip framework, 1.5 or 2 meters in diameter (leaving 10 cm for wall thickness), is stacked over the bamboo mesh, and the concrete is poured, forming the walls of the tank. On the final day, a tank lid and cement cover, an inlet pipe with by-pass valve, and a water supply faucet at the base of the tank are installed. The entire system is allowed to cure and is ready for use within 30 days.

Three significant technical improvements of the CBATDS program over the previous Thai Government/UNICEF rainwater tank projects include:

- Use of time-saving and material-saving equipment, tools and techniques, such as supply trucks, warehouses, and metal concrete mixing boxes;
- Addition of a bypass drain to divert roof debris and potential contaminants when required; and
- Inclusion of a durable water supply valve and alternative locking mechanism to prevent leaks and theft.

It should be noted that although the short term benefits and success of bamboo-reinforced concrete have been acknowledged, CBATDS and other donor organizations are paying close attention to research into alternative designs, such as ferrocement, interlocking bricks, and reinforced masonry construction, currently being conducted at Khon Kaen University, which may lead to the development of an even more durable tank design.

Dissemination and Funding Scheme

CBATDS was created in 1979 by PDA, Thailand's largest private voluntary organization, explicitly to broaden its extensive national family planning delivery system. Once in place, CBATDS became involved in the generation of broad rural development projects for improving the income and quality of life for rural Thais. In fact, many of the CBATDS programs in water resource development, cottage industries, agricultural extension, etc., are predicated on the participation of the expansive PDA network of family planning acceptors, volunteers and growing staff active in approximately 16,000 villages throughout Thailand (one-third of the country).

The successful and sophisticated dissemination methodology of the bamboo reinforced concrete water tank was largely based on this extensive PDA/CBATDS network. The methodology combines the use of village self-help construction teams with technical assistance and soft loan financing provided by CBATDS.

CBATDS and PDA work on the following premises:

- involving beneficiaries in all stages of project design and implementation;
- providing technical, financial and marketing assistance while maintaining a balance between outside assistance and dependency;
- regarding villagers as the "creators of development" who contribute their own labor, local material resources and their own funds;
- soliciting the cooperation of local political and traditional leadership structures while maintaining the program's integrity and independence.

The actual dissemination scheme for this project proceeds as follows:

- village meetings are held in each village prior to the start of a project where villagers can express their interest and ideas;
- participants are then selected based on need, time commitments, and ability to repay loans;
- after discussing repayment schedules adapted to individual circumstances, contracts are signed;
- self-help production teams of 10-15 people in the community are organized under the supervision of one or more CBATDS technicians and field workers;
- CBATDS delivers all building materials, supplies and construction materials (except bamboo, etc.) to the construction site, which are purchased in quantity at a lower price;
- Construction, finish work, and curing of concrete are then undertaken;
- Follow-up evaluation, trouble shooting, loan collection, etc. ensue.

Several international donors have participated in the development and expansion of the program. A.T. International provided initial assistance in the early stages of CBATDS's development with a \$25,000 planning grant (1979) and \$200,000 in core funding (1980) to help the new PDA affiliate develop its programs. With these funds, CBATDS was able to engage in prototype activities which proved to be crucial for the establishment of the project on a sound basis. The Ford Foundation, IDRC, CUSO, and the Canadian Embassy also supported CBATDS during its developmental

phase. Thereafter AgroAction of Germany provided major infusions of capital (a total of approximately U.S. \$1,440,000) to expand the dissemination scheme. These funds were allocated in the form of a block grant for project implementation which CBATDS invested into the revolving loan fund for project beneficiaries. Given CBATDS capacity to manage and recirculate the funds, this created the potential for a multiple effort beyond the original investment.

Economic Considerations

The large volume tanks cost \$267, a price which would make them inaccessible to most villages if financing were not available from CBATDS. Under the CBATDS program, villagers are charged only \$156, covering materials and a small surcharge, and are required to repay this amount over a two year period without interest. Each participant agrees to make an initial down payment of 10% and monthly payments of approximately \$19. Loan repayments are deposited into a revolving fund administered by three CBATDS field centers to be used to lend to others who wish to install tanks. The same tanks would cost between \$285-\$325 if built by a private contractor. Similar water tanks built by the Thai government cost as much as \$370, and often tend to crack after one or two years due to poor quality control in construction (PDA, 1984).

Environmental Considerations

The average annual rainfall in Northeastern Thailand is 1.25 meters, most of which comes down in torrents during thunderstorms and cyclonic disturbances from May to September. The seven month dry season which follows renders clean drinking water unavailable or difficult to obtain. Prior to the installation of these bamboo water tanks, villages generally resorted to stagnant, communal ponds, dugwells, and small containers for collecting rainwater in order to obtain water for bathing and cooking. Sometimes women and children were forced to bring drinking water from distances of up to five kilometers, or in extreme instances, wealthier families purchased water at exorbitant rates from local vendors (Arbuthnot & Thomas, 1981).

Now, owners and users of Tunngam rain water tanks receive nine liters of clean drinking and cooking water per person daily during the entire dry season. Informal surveys by CBATDS extension workers have shown that families with water tanks have lower incidences of diarrhea than non-tank owners. Adequate security provisions and a bypass valve are intended to help prevent contamination and access to the tanks, although they are not always effectively used by tank owners. Water quality tests conducted inside the tanks have registered low coliform counts and acceptable sanitary standards from the standpoint of the users (PDA, 1983).

The bamboo rainwater tank program has also directly stimulated the installation of over 1500 improved pit latrines and community

ponds in the project area, thus further upgrading the environmental sanitation of the region.

Social/Cultural Aspects

The final design of the rainwater tank arose after a CBATDS-initiated village water survey in 1980 established the important technical, financial, and promotional aspects of the project. A prototype trial dissemination of 50 tanks in 1981 ascertained that village families were willing to invest the time, labor, and money to install large-volume tanks to collect and store rainwater (International Reference Center, 1983). Thereafter the implementing agency, CBATDS, established a strong emphasis on AT "software development" in order to assure that these promotional activities were understood and accepted by the target population and were at the same time flexible and adapted to local customs, organizational structures, and economic circumstances.

Physically, the bamboo-reinforced water tanks are compatible spatially, culturally, and functionally with most rural Thai homes, which generally have corrugated galvanized iron roofs with some form of rainwater collection via gutters and drains for one or more of the roof slopes. In addition, certain materials, such as bamboo for reinforcements, can be collected and prepared by the villagers themselves without outside technical assistance, and many aspects of the work required for the tank construction are compatible with local skills and training.

User Participation and Understanding

After its completion, a family unit assumes full control over their tank. This control is in accord with a signed contract in which the family promises a labor commitment for the duration of tank construction and agrees to a loan repayment schedule. Through active participation during all stages of the water tank development process--from initial discussions through actual construction--users become well versed in the proper use and maintenance of their tank. Furthermore, an owner's manual is being prepared by CBATDS in order to attempt to strengthen local understanding of the relationships between clean water and health.

CBATDS also gives special training in water tank design and maintenance to a selected group of village volunteers so that full knowledge of tank construction is permanently transferred to the village level. In addition, CBATDS leaves behind a stamped card for each owner addressed to the Tungnam project technical staff which is used for reporting difficulties and summarizing services which have been received or are needed.

Reasons for Success

CBATDS pays close attention to maintaining an efficient balance between outside assistance and local participation. CBATDS's primary goal is to act as a catalyst in mobilizing village resources and skills with a minimum of intervention in or disruption of the community fabric. Primary reasons for the ongoing and expanding success of this water tank dissemination scheme are as follows:

- CBATDS's parent organization PDA is a well-known entity which has been involved at the village level in family planning and community service activities for many years. Therefore, villagers have confidence in PDA and are willing to participate in the project;
- CBATDS helps villagers overcome the obstacles they would face in trying to build the water storage tanks on their own by providing credit, technical, logistical and organizational assistance as part of a package. Without CBATDS, few families out of the 4,200 plus who now own tanks could have obtained one;
- The technology chosen was familiar to enough people in the project area to generate a viable threshold of support among opinion makers and eventual participants;
- A comprehensive and participatory needs assessment and technology choice and adaptation process in the early stages of the project paved the way for a solid technology financing and dissemination scheme and effective project management structure;
- External funding agencies provided flexible and responsive financial resources in adequate amounts commensurate with the project's needs at its various stages of growth and development.

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Bamboo Tubewells

Country: India

Implementing Organizations & Enterprises:

Deen Dayal Research Institute
State Governments of Bihar and Uttar Pradesh, India
Local Entrepreneurs

Magnitude of Impact

The bamboo tubewell, a low-cost alternative irrigation technology, has been applied on a massive scale in various parts of India since the first reported installations in the northeastern state of Bihar in 1967-1968. For example, according to recent data, over 60,000 units were installed from 1970-1980 in the Kosi region of Bihar state alone, a dramatic rise from the 330 units existing in 1969-70 (Science for Villages, 1983). In Bihar state, bamboo tubewells were used on approximately 90% of the total 95,500 acres of land irrigated by tubewells, which in turn comprised 58.2% of the total irrigable land in the dry season (Clay, 1982). In a similar development, of the 30,000 tubewells sunk and put into operation from 1977 to 1983 by farmers in the district of Gonda (an area of 2.5 million people) in the state of Uttar Pradesh, approximately 17,000 were the bamboo-type. Additionally, 23,235 privately-owned diesel or electric pump sets (an average of 2.2 tubewells per pump set) were installed to service the tubewells in Kosi in 1977-78, compared to over 10,000 pump sets in Gonda (a 3:1 tubewell-pumpset ratio) by 1983 (Science for Villages, 1983).

The direct rural employment effects of this achievement have also been remarkable. According to Dr. Ed Clay of Sussex University in England, 1972/73 estimates indicated that the fabrication and sinking of 14,000 wells required 300,000 man-days of additional employment, and that 100,000 man-days were required to construct the earth works (Clay, 1980). Dr. Clay estimated that maintaining 40,000 wells would generate 150,000 to 200,000 annual man-days of employment (or approximately 1,500-2,000 jobs), given the average three-to-four-years life-expectancy for bamboo tubewells. Incremental employment generated by tubewell-irrigated farming in general is substantial. In Bihar in 1971-72 such employment was estimated at around 1.7 million man-days (between 5,000 and 10,000 jobs) (Clay, 1972). At that time fewer than 5,000 wells had been installed. By extrapolation one can say that by 1980, when ten times as many bamboo tubewells had been sunk, between 50,000 and 100,000 additional jobs were created in Bihar.

Technology Description

The bamboo tubewell is a relatively simple low cost technology that relies heavily on local labor and local material -- principally bamboo. Essentially, the technology consists of a number of interrelated improvements such as how the wells are drilled, how the pumping mechanisms are used, and what materials are employed to seal the wells and construct the channels.

Before the advent of the bamboo tubewells, government-supported programs offered a technology consisting of pipes with a diameter of 10 or 15 centimeters, sunk to a depth of 45 meters or more using cast iron casing with a base screen. According to Dr. Clay (Clay, 1980), a small number of peripatetic rigs, controlled by the Nimor Irrigation Directorate of Bihar State, sank all the wells, employing a slow and expensive percussive drilling technique. This system had many disadvantages. First, it was difficult logistically to transport the drilling equipment. Second, the wells were equipped with stationary, rather than mobile, pumpsets and thus lacked versatility. Finally, the fact that the pumps relied on electricity, which is not always available, and depended on concrete or brick water conveyance channels meant that slow progress was made in installing tubewell irrigation systems and putting them into operation.

The new technology, which overcame these disadvantages, contained the following technical elements:

Drilling Technology

Wells are drilled by private contractors using a simple labor-intensive "sledge" drilling method. The soft earth strata is penetrated using a hollow rod and an auger and a combination of mechanical and hydraulic action for the excavation. The driller's hand seals off the top of the drilling pipe on the up stroke and is removed on the down stroke to permit overflow.

Well Sealing

Ten- to twelve-foot sections of uniform green untreated bamboo replace the cast iron pipe as casing material. The bamboo sections are sleeved and bound with coir twine. Apparently, green bamboo, if not allowed to dry out, outlasts cast iron and galvanized iron piping, which has a tendency to rust and corrode and is much heavier and harder to handle. Wells may be as deep as 30 meters (100 feet) or more, but only the top 5 meters (15 feet) are required to be of cast iron.

The very high water table and the deep deposits of stone-free sandy alluvia present in many parts of North Central India makes it possible to sink wells 30 to 36 meters and still provide an assured water supply. It must be made clear this technology is only appropriate when aquifers are not very deep and soils are easily penetrable.

Additionally, cheap iron screens are substituted for the more expensive and marginally more effective brass screens in the wellpoint, which in the new system is made of bamboo.

Pumping Configuration

Several wells are drilled in close proximity, and all of them are serviced by a single mobile diesel pumpset which is transported by bullock cart between sites. This technique overcomes the restrictions of a stationary pumpset and means that fragmented land holdings and variable terrain can still be irrigated. The high water table throughout most of the region makes it possible for pumps to operate at field level and for power units to be moved from well to well with efficiency and ease in all but the driest spells. Those pumps are generally rented out at a rate affordable to many local farmers.

Because of the high costs of diesel fuel, an experimental effort is now underway in Uttar Pradesh to substitute a bullock-driven pump for the diesel pumpsets. Based on the principle of the traditional Persian wheel, the pump is activated by the bullocks circular movement which, with special gearing configurations, reportedly has achieved 1,800 RPM, the same speed as a 5 HP engine. Costs of a pair of bullocks and the gears and tackle, which comprise the power unit, are projected to be equivalent to an electrical or diesel engine. The animal-driven system has no recurring fuel costs or complicated repairs and maintenance problems. However, this innovation is still in the prototype stage (Science for Villages, 1983).

Water Conveyance System

Earth conveyance channels of tamped clay (called "Katcha") can be used, rather than the cement channels that represent unprofitable or unnecessary investments for farmers. Given the distribution of land holdings, the uneven terrain and the relatively small amount of land irrigated per installation (less than 3 hectares), this option is highly practical.

Dissemination and Funding Scheme

Dr. Clay (Clay, 1982) has observed that "the invention of the bamboo tubewell was no chance occurrence or isolated act of inspiration but part of a process of induced technical and institutional innovation." This conclusion was based on Clay's extensive interviews with the farmers and private contractors during the early stages of active experimentation to reduce tubewell investment costs.

This bamboo tubewell technology arose after early attempts in the mid 1960s to promote cast iron tubewells as an irrigation option for farmers during the dry season in the grain-producing plains of India. Although the cast iron tubewells showed tremendous productivity-enhancing potential and were feasible technically, their wide adoption by farmers was severely restricted by the

high investment costs of the three major components of the systems -- the well, the pumpset, and the masoned cement channels. Small-scale contractors and farmers began active experiments in Bihar to adapt tubewell technology to local conditions. According to Dr. Clay, (Clay, 1980) "A few contractors and farmers with business contacts outside the region found that they could substantially reduce investment costs by using their own materials, sinking more shallow wells, and using local contractors to install the wells. By privately installing wells, they also cut out the lengthy delays and other hidden costs of credit-financed investment."

In Bihar, the technology apparently spread almost entirely by private, spontaneous collaborations between farmers and small contractors. Expanding rapidly over the course of ten years, a privately-supported and maintained installation, supply, and maintenance infrastructure arose. Key local government officials came around and ended up playing an important role in facilitating the spread of the technology. Despite opposition and skepticism from engineers committed to the more costly metal tube wells, the Deputy Director of Agriculture and the Kosi Development Commissioner pushed to make extension and credit services available to farmers wishing to install bamboo tubewells. This approach is still in effect and expanding to the present day in Bihar.

According to an article in Science for Villages Magazine (1983), in Uttar Pradesh the dissemination process was quite different, although the choice of technologies was virtually identical. Apparently the phenomenon there was generated by a single farmer-inventor named Krishna Duett Shukla who came up with the system through trial and error experimentation working under the severe economic and physical constraints farmers typically confront. The driving force behind the dissemination of this "invention" was a private research institute, the Deendayal Research Institute of New Delhi, which instigated a rural development and cultural project in Gonda District. Apparently, this project involved government subsidies, low interest lending from banks, and extensive outreach and extension work by the Institute.

Economic Considerations

The adoption of the bamboo tubewell system by tens of thousands of farmers in India compared to the much smaller percentage of farmers using cast iron tubewells testifies to the economic and technical advantages of the former system. Cost-savings are distributed throughout the system. In review, these savings include: extended low drilling costs, large savings on casing materials, rental vs. purchase cost of pump to most users of the system, and elimination of concrete/masonry channels (Domman, 1975).

Several researchers have made comparative economic evaluations of different tubewell options in Bihar, Uttar Pradesh and other parts of the Gangetic plains. Domman (1978) reported that the

cost of boring sixty foot bamboo tubewells was Rs 200 to 300, which was estimated to be 10% of the cost of sinking an iron tubewell to the same depth. In a more recent report, Science for Villages (1983) magazine states that the total installation costs of a bamboo tubewell range from a third to a half of the metal one, which is listed as approximately 10,000 rupees (US \$1,000). The two systems were judged to be of equivalent durability.

Reasons for Success

The bamboo tubewell innovation, which has swept across certain areas of the plains of India, has proven to be an unquestionable success in qualitative and quantitative terms. Through largely spontaneous efforts responsive to local farmer demand, this technology has made a substantial contribution to the productivity of Indian agriculture in the areas served by the tubewells. The technology has taken root and spread successfully for a number of reasons:

- o The irrigation technology package addresses local environmental conditions and socioeconomic circumstances (such as local farming systems) in a simple, low-cost, and integrated fashion.
- o In Bihar and Uttar Pradesh, two areas of India where information is available, the use of private initiatives directly involving users, promoters, and installers of the system, with a limited amount of government support, were able to overcome the slowness and inflexibility of the previous government-sponsored technology dissemination programs.
- o Good engineering design principles and economic alternatives were combined with the ubiquitous benefits of optimum reliance on locally-available labor, materials, and skills.

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Labor Intensive Rural Access Roads Programme

Country: Kenya

Implementing Organizations and Enterprises:

Ministry of Transport and Communications (MOTC),
Government of Kenya
International Bank for Reconstruction and Development (IBRD)
International Labor Organization (ILO)
Participation by Bilateral Donors: NORAD, ODA, KFW, USAID,
DANIDA.

Magnitude of Impact

The Rural Access Roads Programme in Kenya is a notable modern example of the technical and economic feasibility of an appropriate technology approach to civil construction. Since its inception in the mid-1970s, the Programme has expanded throughout the country, established a strong organizational base within the Ministry of Transport and Communications (MOTC), and demonstrated its competitiveness with capital-intensive construction methods. In 1983, the Rural Access Roads Programme consisted of forty-two field units located throughout the farm districts and employed over 8,000 laborers, most originating from the area in which road construction was underway. At the end of 1982, 5,885 kilometers of rural access roads had been constructed with 2,223 kilometers of these containing gravel surfacing. By early 1984, over 7,000 kilometers of roadway had been completed (World Bank, 1984).

Technology Description

Road construction basically involves the integration of a number of repetitive tasks which can incorporate a variety of technologies ranging from highly labor-intensive, employing massive work forces and simple hand tools, to highly capital-intensive, engaging expensive and sophisticated machinery. The three major operations involved in road construction, regardless of the technologies used, are: earthworks, production of aggregates, and surfacing. From a technical point of view, most of these operations can be carried out through labor intensive methods to achieve results comparable to those produced by machines.

Over 50 percent of all the costs of road building are in earthworks--the moving and shaping of the surface topography to form a cambered surface suitable for human, animal, and vehicular traffic. The activities involved in earthworks include: (a) the removal of vegetation, embedded roots, and boulders in order to clear a right of way for the proposed road and (b) the excavation, loading, hauling, unloading, spreading and compaction of soil. The Kenya programme chose a system which relies

primarily on manual laborers organized into production units and equipped with simple, locally and nationally produced hand tools such as hoes, shovels, picks, bush knives, and rakes. In addition, one or more intermediate scale tractors and two or more trailers for the earthmoving and compaction operations accompanied each production unit. This technology mix was determined by the project technical advisory staff based on calculations of optimal labor productivity and utilization, while maintaining a wage level at or below the economic break even point, as compared to a capital-intensive technology mix (see next section).

Virtually all of the technical features of labor-intensive road construction have been established over the last century. Actual designs, however, vary according to local economic, social and topographic circumstances. The Kenya program devised appropriate and economical construction methods using simple and easily obtained equipment such as survey pegs, tapes, string lines, camber boards and levels rather than expensive and complicated theodolites. Such equipment can be easily understood and operated, is inexpensive, and produces measurement standards of acceptable tolerances. Thereafter, the bulk of formation of the roadway surface, shoulders, side and miter drains, and placement of precast or cast-in-place structures such as culverts for cross drainage can be accomplished by manual methods.

Originally, it was planned to gravel all of the rural access roads in order to make them suitable for all weather conditions. An engineering criteria for the road site selection established that roads should be located within close proximity (within a maximum of 8 kilometers) of a gravel (murrum) quarry. It was assumed that longer distances would render the cost of hauling and applying gravel too high. The gravel operation involves hand excavation and loading of the gravel along with spreading using tractors and trailers. However, due to various limiting factors, only about 30 percent of the roads are surfaced to date. Such factors include road sitings which are too remote from gravel deposits, the low availability and performance of the equipment used, often due to poor supervision and maintenance, and the lack of spare parts and fuel. In retrospect, the feasibility and relevance of surfacing all roads has been questioned by certain donors and field engineers due to the low daily vehicular traffic of many of the rural access roads.

Dissemination and Funding Scheme

The Kenya Rural Access Roads Programme has undergone a number of different phases and overcome a variety of logistical and organizational problems from the planning of an initial pilot project of 250 kilometers through the execution and maintenance of a full-scale program. Despite earlier skepticism towards labor-intensive methods, the Ministry of Transport and Communications (MOTC) came to see the RARP as a potentially innovative program assisting in relieving the country's pressing

unemployment problems, while at the same time meeting the Ministry's requirements for road construction. As the technical and economic viability of the construction technologies became more demonstrable, the Rural Access Roads Programme also became an excellent means of attracting attention and funds from various international donor agencies.

Initial support from the ILO and NORAD led to the establishment of a technology unit under the Ministry to help determine appropriate technologies and techniques for the program and to set up and monitor field experiences in the Nyeri district in 1975-1976. The technology unit made a significant contribution to the RARP by establishing task rates, site organization, design standards, and nutritional levels for casual laborers and by determining the tools, equipment, local manufacturing capability, labor availability, and administrative and maintenance procedures for the program. In addition, the technology unit helped to organize training programs for the field supervisory staff to help transfer, adapt, and implement these managerial and technological procedures on an ongoing basis. This work was painstaking and slow, but ultimately paid off.

The pilot scheme in Nyeri generated favorable returns in the form of reliable estimates of labor inputs and construction costs which were incorporated into loan applications to the World Bank and a number of bilateral aid agencies, including ODA, KFW, USAID, DANIDA, and NORAD. Donor agencies in Kenya have traditionally divided up the country's regions; in this case close cooperation among the various parties and the Kenyan government and the provision of over US\$50 million combined to create a national scale program with major impact to both local and national economies.

The overall structure of the project has undergone revision in line with operational experience. The organizational structure was decentralized in 1980; three regional coordinators were assigned to manage the activities of the growing number of field units. Originally Ministry of Transport and Communications assigned one engineer per 8 units of 200-300 seasonal laborers, each of which was operating three construction sites and one graveling team. In addition to an engineer, each unit was also assigned two superintendants and one inspector. The communications problems with headquarters and the difficulty in finding capable and committed Kenyans to assume professional roles in rural areas forced important changes. These included the recruitment of younger paraprofessional engineering students, the reduction of the number of units assigned per engineer equivalent, and the integration of RARP into the MOTC. Overall, these various changes eventually resulted in a simpler and more flexible administrative system, and a direct and regular cash compensation for construction and maintenance laborers in the rural areas.

The organization of an effective maintenance system within the program, called the "lengthman system", may prove to be one of

the most critical elements in the Programme's long-term success. Rather than using temporary gangs of laborers, this system, when fully implemented, will allocate responsibility for the maintenance of an average length of 1.7 km of road by contract to a former construction laborer living along the road. Receiving the equivalent of 12 days wages per month, this person is provided with the simple manual tools necessary for maintaining the road surface, shoulder, drains and culverts. This system provides strong incentives and peer oversight by local leaders and users of the roads for local maintenance and is not directly dependent on the availability of vehicles and equipment. Within the next few years it is envisioned that up to 20,000 part-time contractors may be hired under this system to enhance the routine maintenance of low-use roads.

Economic Considerations

Cost comparisons in Kenya between labor-intensive and capital-intensive methods of road construction have shown that labor intensive methods exhibit equal or lower costs and greater productivity than capital-intensive methods. For work carried out in roughly similar areas, the labor-intensive methodology costs about 90-95 percent of the capital-intensive system (World Bank, April 1984). Comparative total costs per Km of road, built in a recent World Bank study, were approximately US\$7,200 for the former system, \$8,300 for the latter. Roads were actually built in Kenya for an average direct cost of \$4,400 (1978 US dollars) per kilometer versus \$4,300 originally estimated, which is low compared to programs in other countries; overhead costs have varied from 20 to 35 percent due to the initial high costs of expatriate personnel, but such costs have displayed a continuously decreasing trend as the "Kenyanization" of the program continues (Coukis, 1983).

A key element in the comparative calculations between labor and capital intensive construction technologies is the relative productivity, investment, and operational costs of machines versus labor. For instance, a \$100,000 bulldozer with a rated capacity of 1,000 cubic meters per day requiring one to three skilled workers to operate may be equivalent in output, costs, and quality of earthworks achieved to 200-300 laborers working in groups of 20-30 each, with up to a dozen supervisory staff (Sud, et al., 1976). Thus, the critical factors in determining the economic feasibility of labor intensive methods are the ability to effectively mobilize and manage labor resources and the concept of the break even wage for unskilled labor. The break even wage level is defined as that wage at which the cost of carrying out a task by labor is equal to the cost by equipment, for a given set of equipment time rates. In Kenya, (and in many other countries) this wage level is between US\$2.00 and US\$4.00 per day, an achievable target in most circumstances. The Kenya program has consistently allocated between 45 and 60 percent of its direct costs to labor, versus 10 to 15 percent in capital-intensive systems (Henriod, 1985).

The World Bank in conjunction with several agencies has determined that labor-intensive appropriate technologies in civil construction, such as those incorporated into the Kenya Rural Access Roads program, have demonstrated high rates of return on investment capital. Programs which effectively produce civil infrastructural elements such as roads, irrigation channels, drains, reservoirs, etc. account for a major part of real domestic capital formation, and, with more labor intensive decentralized methods, can also offer a substantially increased employment potential.

Environmental Considerations

At the field level, the Programme employs local and national resources to the greatest degree possible. Considerable attention is given to proper road siting, drainage, erosion controls, road carrying capacity, and other key environmental concerns. The labor-intensive approach also saves the Kenyan economy the high capital and energy import costs which are an inevitable feature of capital-intensive construction systems.

In addition, due to the recognition that the nutritional status of construction workers has a major effect on labor efficiency, experimental programs combining food and vitamin supplements with the provision of cash incentives to encourage improved nutrition for the rural mobile workforce have been initiated.

Social/Cultural Aspects

The Rural Access Roads Programme has apparently achieved solid and continuing support from the local districts and villages in which it has operated. The most immediate reason for the support has been the employment opportunities offered by the program. Many rural areas have substantial underemployment, which could be alleviated by programs such as the labor-intensive RARP. RARP's pay rates and management structure have been uniform throughout Kenya, thus allaying concerns that it might be displaying favoritism in the country's multi-ethnic society. An additional reason cited for the program's broad-based support has been its involvement with the District Development Committees which are responsible for all district planning activities. These committees are comprised of district officers, local leaders, and government department representatives and have the crucial job of selecting roadsites for the project.

User Participation and Understanding

The optimum application of local skills, labor, and construction materials to rural road construction and maintenance give the program significant advantages over more capital-intensive modes. This includes a greater ability of semi-skilled and unskilled

rural poor workers to participate in the program and comprehend its various facets. Field level staff and hired laborers are more self-reliant and resourceful in confronting operational problems. Additionally, less technical sophistication has resulted in decreased down time and greater flexibility in addressing technical and managerial issues in a more decentralized fashion. A comprehensive training program for field supervisors which stresses decentralized management techniques and alternatives to local social and environmental conditions has been a key element in achieving these results.

Reasons for Success

The Rural Access Roads Programme in Kenya was only one of a number of research and demonstration programs begun in the early 1970s in over a dozen developing countries where labor-intensive road construction methods were not commonly in use. In Kenya and Honduras, the original pilot projects were expanded into nationwide programs, resulting in the institutionalization of labor-intensive construction as a means for developing and maintaining infrastructure works. In certain other countries, however, programs encountered a number of obstacles and sidetracks, resulting in official inertia and lack of continued support. World Bank researchers cited the overriding reason for the successful institutionalization of labor-intensive construction methods as the presence of a clear and consistent commitment by government towards the development and application of cost-effective methods for labor utilization in construction, whether by the contractor or force account system. Without this official commitment, programs all too often became make-work schemes that accomplished little more than the transfer of public resources to inefficiently organized groups of laborers.

Specific distinguishing features of the Kenyan program which have accounted for its success include:

- o mobilization of popular support from local districts and villages by hiring workers from the construction zones and involving local decision-making bodies;
- o establishment of a technical services unit during the pilot phase which developed criteria for site selection, design standards, task rates, and organizational and administrative procedures, and was thereafter integrated into the implementing organization;
- o utilization of para- or sub-professionals to make up for a shortage of graduate engineers;
- o allowance of adequate time (8 years) for the project to develop properly and establish the optimal labor-intensive construction technologies;
- o adequate management tools such as: a) detailed planning

for resource requirements; b) criteria for recruiting and developing staff and providing a suitable organizational structure; and c) realistic targets and objectives;

- o institution of an effective training program for field supervisors, promoting decentralized management techniques; and
- o incorporation of a locally-oriented maintenance system ("lengthman") which effectively decentralizes responsibility and distributes income more equitably in rural areas.

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Women's Pappad Processing Cooperative Enterprises

Country: India

Implementing Agencies and Enterprises:

Shri Makila Griha Udyog Lijjat Pappad

Magnitude of Impact

Shri Makila Griha Udyog Lijjat Pappad, a unique women's cooperative food processing organization, has succeeded in establishing 21 self-sustaining operations throughout India since its inception in 1959. By 1980, over 6,000 active members were engaged in the manufacture and sale of pappad (a popular, nutritious snack food) in their homes or in pre-production centers owned by the organization. Started with an investment of 80 Rupees (Rs) by a group of seven women working with a low income urban community, the group reported gross domestic sales of Rs 30,000,000 (approximately U.S. \$ 3,750,000) and export earnings of Rs 3,900,000 (approximately U.S.\$ 487,500) in 1978-79.

Currently, the members are moving towards creating additional employment opportunities for women through the manufacture of matches, incense sticks, and leather goods, building upon the successful organizational model they have created.

Description of Technology

Lijjat uses a two-stage, labor-intensive processing system for the daily mass production of pappad, a traditional flat sheet of dough prepared from lentils, flour, sodium bicarbonate and spices. For the cooperative, organization both at group production centers and at members homes is the key to producing a high quality product and meeting consumer demand.

Raw materials are bought in bulk in both processed (e.g., spices) and nonprocessed (e.g., pulses and grains) form. They are ground and processed at a Lijjat-owned mill in Bombay in 1/2 HP and 1 HP hammermills according to standards set by the Khadi and Village Industries Commission, an Indian parastatal which provides technical and financial support to small-scale industries.

These ground and processed materials are then transported to and stored in each of the organization's 21 centers, where the dough mixtures are prepared by cooperative members to exacting sanitary and culinary standards. Using manually-operated equipment such as simple hand mixers, portable scales, and stainless steel pots, the ingredients are combined with salt water and peanut oil and formed into large balls of soft dough. By 6 a.m., these prepared and weighed amounts are ready for distribution to members working in their homes who arrive to collect their quota of

dough and to deliver finished rolled pappads from their previous day's work.

Most of the final preparation of the pappads is done in members' homes in what is a form of the dispersed factory system of production. Using simple hand equipment, women roll the ready-mixed dough into round, flat sheets, usually in the afternoon when household tasks are completed and the sun is very hot. The finished sheets are allowed to dry in the sun. After their delivery to the Lijjat center early in the morning, the pappads are sent to the packing section for packaging in polyethelene bags and labeling, prior to distribution by mini-buses to marketing agents and outlets.

Rigid quality control checks are conducted at the various centers, and the finished product is submitted for tests to the Lijjat Central Office in Bombay. There at the Lijjat organization's own laboratory, quality tests for moisture content, salt, sodium bicarbonate, thoroughness in mixing, fibrous texture, etc. are conducted each week on sample products from each of the 21 centers. Based on reports from branch centers and the laboratory, corrective steps are taken by the head office to bring substandard quality production from any given center up to the Lijjat standards. Pappads which do not pass inspection (on an average only 1% of total production) are discarded.

Dissemination/Funding Scheme

Lijjat Pappad was created in 1959 in a congested Bombay district by a group of seven women who were members of a trade community, the Lohanas. The Lohanas have a strong cooperative tradition of assisting any of their people in economic distress and have substantial business acumen and entrepreneurial talent. Women of this community possessed a variety of household food processing and production skills, but were unable to engage in income earning activities because of the traditional taboos on manual labor. They lacked qualifications for white collar employment, which would have been acceptable.

With the assistance of a private voluntary organization, the Lohana Trust, the group seized upon the idea of pappad rolling as a potentially viable income-earning venture. They contacted leading retailers and wholesalers, who, in spite of their initial resistance, were eventually convinced to accept the product of a "small group of housewives." The group's determination paid off. Within several months they were able to recoup their initial investment and expand operations. The group assumed the name Shri Makila Griha Udyog Lijjat Pappad which translates literally as, "Women's Cottage Industries' Tasty Pappads."

The group established an organizational structure based on certain commonly held values such as co-ownership, equality of status, self-reliance, belief in the dignity of labor, and dedication to work -- values of the Gandian social action philosophy.

The emerging organization strove to synthesize the concepts of family, business, and service. Perhaps most important, the organizers chose to prove that women can initiate and manage organizations successfully and independently without the assistance of men.

Contrary to common practice in India, all the managers as well as members in the organization are women, and all members are partners rather than employees. Over the years, Lijjat has become a combination women's organization, public trust, registered society, and cooperative enterprise operating successfully in the volatile open marketplace. After seven years of slow but steady growth, the group received recognition from the Khadi and Village Industries Commission (KVIC). The simultaneous registration of Lijjat as a public trust clarified its role as an institution for "women's welfare through self-help" and gained it an invaluable exemption from income tax.

An infrastructure of district centers arranges for the pre-production of dough, its distribution to the home-based pappad rollers, and transfer of the final product to commercial marketing agents and channels.

Virtually all pappad rolling is done in the women's homes rather than on the cooperative premises, except in a few rural centers, such as Valod in Gujarat, where the members are very poor and do not have adequate space or sanitary conditions in their homes. In this instance, special sheds are set up by the organization where the women can roll the pappads.

Most Indian cooperative organizations rely on official marketing outlets, such as the KVIC. Lijjat, however, elected to pursue strictly commercial marketing techniques from the start. Lijjat organizers set up arrangements with the predominantly male sales agents working on a commission basis who would be directly involved in the sale of pappad.

There is quite a clientele in Bombay and the State of Gujarat for the Lijjat brand of pappads. Devaki Jain in her book Women's Quest for Power attributes the success of Lijjat pappads to the "consistent high quality of the product and the reliable supply line."

Economic Considerations

Financial returns to the home-based producers and the few hired staff are substantial. Each member or household unit pledges to produce a minimum of 3 kilograms of pappad per day. In 1980, this amounted to potential earnings of Rs 4 to Rs 40 per day, depending on time and labor availability per household production unit.

On the average, daily earnings amounted to about Rs 7.20 for 6 kilograms of pappad, with a portion (Rs 1.20 or 20%) deposited in the compulsory savings scheme set up by the organization. Re-

cently, salaries at the centers have ranged from Rs 500 to Rs 1,200 per month (U.S. \$58-\$141), which is somewhat more than most home production workers can earn. In turn, home-based pappad rollers earn at a higher rate (ranging from Rs 100 to 900 per month) than they could earn in other non-cooperative, home-based systems of production.

Lijjat's financial policy is based on two premises -- internal financing of working capital requirements and high profitability. Working capital requirements are kept low by the institution of weekly or bi-weekly production turn around and the receipt of payments from wholesalers and retailers immediately or within seven days of shipment. There are no credit sales. Marketing agents are paid monthly on a commission basis (ranging from 10 to 35 paise per packet sold), with transportation provided by Lijjat or borne by the agents. This assures a constant infusion of capital and a healthy cash-flow situation, which is augmented by the mandatory members savings fund. Funds for the expansion of existing centers, purchase of new equipment for the Lijjat mill and laboratory, and so on are obtained through lines of credit provided by the KVIC's Processing Cereals and Pulses Industries scheme.

The gross profit margin per packet of product (either in 500 or 250 gram sizes) is approximately 20%; net profit is between 5% and 10% of the factory-gate value of the pappad. Lijjat's relatively higher price, compared to other brands, has not reduced its competitiveness and contributes significantly to its commercial viability.

The initial investment for a new center is made by the Bombay head office, after careful assessment of commercial feasibility, labor availability and level of local support and participation. A sample estimate (1977 price) of capital outlays for initial investment in a new Lijjat branch center is shown in Table 1.

Table 1
Costs for a New Branch Center

	Rs
Vehicle	
Minibus	58,675
Delivery Van	51,610
Weighing Equipment	5,000
Furniture	8,500
Rent for Building (6 months)	48,000
Salaries for Staff (6 months)	30,000
Working Capital	45,000
TOTAL INVESTMENT	246,785

Social/Cultural

The Lijjat Pappad rolling enterprise, although started primarily to provide extra income and employment opportunities for women in their homes, now offers other support services which address the individual and collective economic, political, and social needs of its members.

Lijjat membership rules stipulate that any woman above the age of 15 can become a member/co-owner of the organization. As a condition for her entry, she agrees to certain principles, such as devotion to work, cooperation for the maximum benefit of all members, rolling of pappads for Lijjat only, rolling a minimum of 3 kilograms of dough each day, and the subordination of self-interest to the larger interest of the Lijjat organization at all times. As stated in the Lijjat charter, a new member joins the organization as a full-fledged member with all rights of co-ownership and a right to participate in meetings. All members have the power to veto any decision taken by the majority of members.

A management structure, consisting of elective and appointive supervisors and officers, has helped to consolidate and provide continuity and growth to Lijjat operations. Virtually all managers, who serve regular terms at the pleasure of the general membership, have risen from the ranks of the pappad rollers. They receive regular salaries but retain their membership in the organization. They cease to earn remuneration for pappad rolling or other tasks, for which piece-rate payment is made to the members.

To the fullest extent possible, members use consensus-based decision-making for all matters under consideration by the general membership. General meetings are regularly held once a year. The chief representative decision-making body is a 21-member management committee, comprised of elected members of Lijjat centers and appointed advisors. This body in turn selects officers on an annual basis from among their ranks: president, vice-president, two secretaries, two treasurers, and a coordination committee. In addition, each of the centers has its own branch committees for day-to-day management. While these bodies decide issues on the basis of majority rule, they often seek to find consensus positions.

These structures serve to assure that the various critical elements of Lijjat Pappad's commercial activity -- production, quality control, raw material supply, marketing, financing, accounting, payment, and public relations -- are managed and maintained in a responsive, decentralized fashion. Each of the 21 Lijjat centers is in fact an autonomous unit with respect to production, sales, procurement and deployment of financial resources, hiring of staff, and local publicity and is also a discrete accounting unit. Business management is controlled by these centers and, by extension, all of their members.

The organization implements strict accounting procedures and practices and closely monitors productivity and financial performance at all levels. It also promotes schemes to help members and the organization itself achieve financial stability. For example, a compulsory savings scheme has been set up where 20% of member earnings are set aside each month. This fund provide members with individual loans and the organization with financial capital for the purchase of equipment and the establishment of new centers.

Two other important aspects of Lijjat's operation are its skill development and social service functions. Pappad rollers can be promoted to supervisory positions, and various education and training operations are made available for members. The overall organization provides the savings plan, complete with small scale loan options and profit sharing gifts such as jewelry and cash bonuses for all members. Several centers provide social services, subsidizing scholarships for children of low-income families, setting up libraries, and organizing regular field trips and group social gatherings.

Lijjat is currently initiating new economic ventures in areas other than pappad rolling, with the support and encouragement of the Kahdi and Village Industries Commission (KVIC). These ventures follow Lijjat principles of organization, management and production, that have proven to be so successful.

Lijjat offers an alternative to the ordinary dispersed factory system of production which is prevalent throughout Indian and other Asian countries but which often results in extremes of exploitation, domination, and/or sexual harassment by men.

Lijjat's success in running a dispersed factory that is equitable and non-exploitative accounts for its growing appeal among women throughout India. All workers are members and share in both profits and the decision-making process. The shareholders' participation in day-to-day management addresses a major constraint in conventional cooperatives where member participation is usually ineffective and leadership often unaccountable to membership.

Reasons for Success

Shri Makila Griha Udyog Lijjat Pappad has securely established its presence in India as an innovative and successful women's food processing venture with a high degree of participation and equity by members. It provides a unique organizational model for other efforts in India and in other developing countries to create employment for rural and urban poor women. The reasons for the successful establishment and growth of the Lijjat Pappad cooperative enterprise include:

- o The product chosen is familiar to consumers, has relatively uncomplicated and inexpensive technology requirements, and is conducive to combined household and light industrial production techniques.

- o The operating philosophy, which is based on common ownership, cooperation, and individual incentives to production, has effectively mobilized and organized women of lower income and status, a disadvantaged segment of society.
- o The operation was established on a sound commercial basis with well-organized and coordinated systems for procuring materials, supervising production, and marketing the final product.
- o Financial principles and practices are based on self-reliance and self-development.
- o Consistently high levels and standards of quality in production are achieved through an effective sampling and laboratory control system.

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RURAL SMALL FARM IMPLEMENTS COMPONENTS MANUFACTURE

Country: Tanzania

Implementing Organizations and Enterprise:

- Themis Agricultural Implements Company, Pvt.
- USAID/Tanzania
- Ubungo Farm Implements, (UFI) Ltd.
- Tanzania Machinery Testing Unit (TAMTU)
- Other small farm implements enterprises at Mwanza, Iringa, and Mbeya

Magnitude of Impact

A decentralized approach to the production of ox-drawn implements is showing promise of meeting the needs of small farmers throughout Tanzania, where draft-animal power (DAP), generally using oxen, is prevalent in approximately half of the country's 8,000 villages (Allen, 1984). The demand for reliable, low cost equipment with locally available servicing and spare parts is quite substantial; to date, however, draft-animal powered implements have generally been expensive, unsuited to soil conditions and available power sources, or in very short supply (Kajerby, 1983).

The situation is changing with the establishment of two private regional component manufacture and fabrication enterprises in the population centers of Arusha in the north and Mwanza in the northwest, and by the slated opening in 1984 of two more factories: a government-owned facility at Mbeya in the southwest and a parastatal common facility workshop at Iringa in south central Tanzania. These facilities will be staffed and managed by Tanzanians. All will use locally available skills and raw materials as much as possible, relying on the central government for concessionary credit only. The two products which are currently being manufactured and marketed are improved village ox-carts and durable, lightweight toolbar-plow sets.

The two private enterprises employ a production and distribution system that makes it easy for them to reach their market and to avoid high transportation and location costs. In just two years, they have been able to produce quality products in high demand and short supply at competitive prices. Their output has exceeded their production targets in both major categories of production.

Themis Agricultural Implements, Ltd, in Arusha exceeded its 1982 first year targets of 750 ox-carts and 500 toolbar-plow sets, ultimately producing 1,000 of the former and 600 of the latter. In 1983, its second year of operation, the company produced 1,500 ox-carts and 2,000 toolbar-plows (Allen, 1984). It appears likely that these production levels will be maintained or exceeded for the foreseeable future. No difficulties were encountered in mar-

keting these implements, either preassembled or in knock-down kits, and some orders were received from sites quite distant from the factories.

Responding to this apparently dynamic market, in 1984 the existing facility of Mwanza and the soon to open factories at Iringa and Mbeya are gearing up to achieve toolbar-plow production quotas of approximately 5,000, 2,000 and 4,500 respectively (Allen, 1984). These factories will use production techniques and designs similar to those used in the Arusha factory. This level of production will create employment for over 150 skilled workers and bring immediate benefits to at least 20,000 farmers annually. Toolbar-plows are generally used by no more than two farmers; whereas the ox carts are often shared or hired out to several farmers. It is expected that land productivity will increase due to more efficient use of existing land and the incremental land put into production by farmers.

Although they are just gearing up, these factory units show promise for increasing the availability of DAP implements to farmers throughout Tanzania. It is estimated that in the long-term Tanzania could use 30-40,000 ox carts and 10-15,000 toolbar plow sets. To meet this need, several more decentralized production units should be opened up. These units might also develop further product lines.

Technology Description

The decentralized manufacturing process involved in this rural small farm implements program eclipses the actual engineering designs in importance. The two chief products being produced--ox carts and toolbar-plow sets--are based on adaptations of existing designs from Tanzania and Uganda and will be described briefly later. This program responded to the challenge to produce items on a regional basis, which are beyond the technical capabilities of rural workshops and are not being produced in adequate quantity or at suitable prices by large-scale centralized factories in the capital city.

A number of manufacturing units, each with different skill and equipment requirements, were set up in the Arusha Region to produce and assemble as many of the components locally as possible. One moderately-sized enclosed factory in the regional center of Arusha, where electrical power supply and communications are relatively good, was set up to specialize in metal shaping, cutting, forging, drilling, welding and bending. This factory is equipped with metal working machines, such as lathes, milling machines, drill presses, hydraulic presses, grinders, manual cutting, bending and rolling equipment, compressor, welding units, etc. plus various hand tools. A foundry was also installed but later was found to be superfluous. Three much smaller workshops solely employing hand tools and specializing in woodworking were established at well dispersed rural sites further removed from the district capital. The larger unit is

capable of producing both finished commodities and unassembled components (knock-down kits), while the sub-units are strictly assembly and servicing units.

Certain components requiring a high degree of precision and capital intensive equipment, such as the plow bottom parts (mouldboards), are ordered in bulk from Ubungo Farm Implements (UFI), a large parastatal factory located in Dar-es-Salaam. This arrangement provides compatibility of components and relieves a major constraint on the productive capacity of smaller units. The heavily subsidized UFI has the capacity to produce 21,000 plows per year, yet is operating at less than 40% of that capacity and sustaining large losses underwritten by the government.

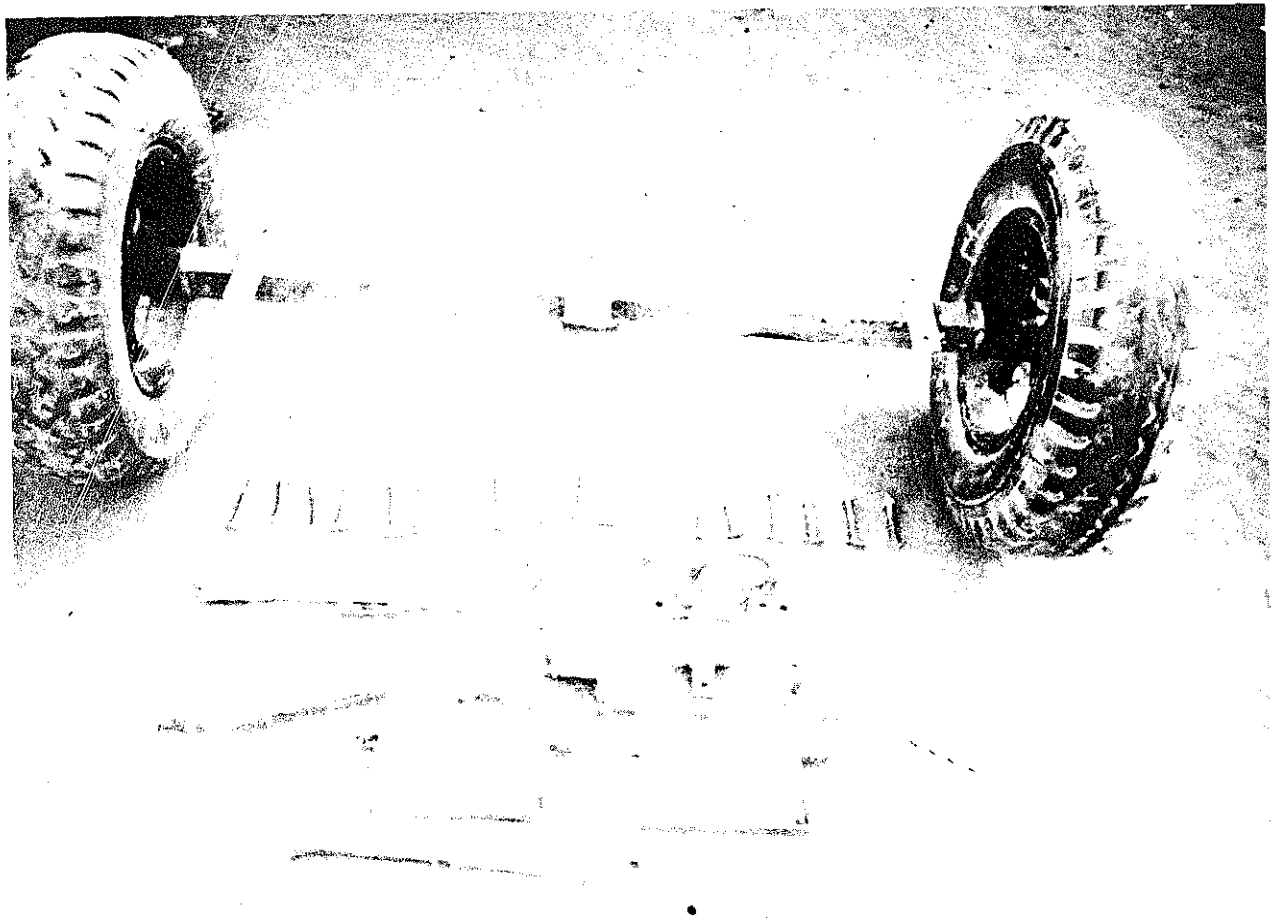
The Design Process

The ox-cart produced in the Arusha unit is almost entirely based upon a standard design devised by the Tanzania Machinery Testing Unit (TAMTU) after extensive research (see Figures 1 and 2). However, TAMTU, which has largely assumed a research and development role in its 20 years of existence, is unable to meet national market demand for these carts due to its limited production capabilities and uneven material allocations. The design lends itself to a division of labor. The metal components of mild steel (axles, wheels, brake units, beam clamps, and hitches) are produced at the large factory in Arusha and then delivered to the sub-units for main assembly with the wooden components or sold as kits directly to farmers at the factory gate. After only two years of production in Arusha, the factory-gate-to-farmer market has exploded. Approximately 1,200 units have been sold as kits and 300 units delivered to the sub-units.

The cart has a carrying capacity of approximately one ton. It uses simple but sturdy wooden bearings and can be equipped with either metal or pneumatic wheels. The latter are preferred for rough terrain, but are more expensive. They usually consist of metal rims and tubes with extremely worn recycled Land Rover tires. Between 25% and 30% of the carts produced in Arusha use pneumatic wheels. TAMTU experimented with using wooden wheels mated to an axle made from water pipe. This alternative, however, proved to be unpopular with farmers (SIDO, 1981).

The toolbar/plow set manufactured at Arusha (Figure 4) is based on the Kabanyolo multipurpose toolframe developed by L. J. Clarke at Makerere University in Uganda in the 1960s. (The Kabanyolo model in turn had evolved from the "UNIBAR" developed and manufactured in the United Kingdom by A.R. Stokes Project Equipment, Ltd.) A toolbar is merely a long frame (a length of pipe or sectional steel) with handles and depth gauges, which can be fitted with interchangeable, detachable implements such as plows, weeders, and seeders. Its versatility allows farmers to perform tillage, cultivation, weeding, and planting operations with one piece of equipment. In practice, most toolbar systems promoted in developing countries are underutilized, with the plow attach-

FIGURE 1



Assembly kit for oxcart with rubber tires.

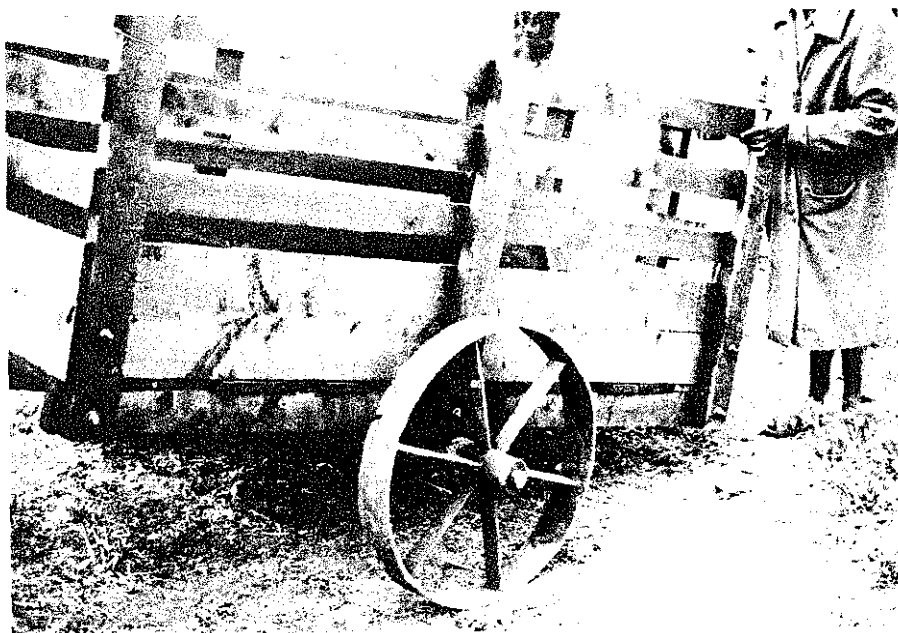


FIGURE 2: Preassembled oxcart with metal wheels.



FIGURE 3: Oxcart with team of oxen.



FIGURE 4: Toolbar plow

ment most commonly in service.

The Arusha toolbar/plow design has been modified considerably from the Uganda-derived Kabanyolo design. In fact, the design is still undergoing revisions and variations as a result of ongoing exchanges with farmer purchasers. Primary modifications have included substitution of a depth wheel for a depth bar, inclusion of a height adjustment mechanism for the handles, the addition of more weeding times, and the strengthening of the draw and hitch system.

As previously stated, the toolbar uses the UFI mouldboard plow attachment and closely matches its overall performance. The critical dimensions of the Arusha toolbar are similar to the UFI product, which is a conventional Ramson-type nine inch mouldboard plow and is now the accepted standard for the country. In other words, the new product is already known and accepted in Tanzania and can tie into the existing spare parts system for the parts most subject to wear and deterioration.

An important difference between the Arusha toolbar/plow and the standard mouldboard plow used in Tanzania is the fact that at present the Arusha design uses a 2.5 inch water pipe rather than sections of rail for the long main frame. This makes the unit significantly lighter and more manageable for either one or two hitched oxen. This change was made on the advice of farmers during the early experimental stages of the program. Current plans are to produce both heavy and lightweight options at the various regional factories and let farmers choose the model that best meets their needs. For example, in sandy soils or friable soils previously cultivated, the light-weight units will be appropriate, whereas the greater penetrability of the heavier model might offer advantages in more compacted soil or marginal lands.

Dissemination and Funding Scheme

A number of efforts to set up rural agricultural equipment factories have been made in the past 20 years in Tanzania. These efforts, however, have generally resulted in either poorly equipped and undercapitalized workshops with uneven production levels or in research and demonstration-oriented units under government auspices (Kjaerby, 1983). The initial thinking of the Arusha Planning and Village Development Project (APVDP), a USAID-funded program, was to favor the latter approach and set up rural small industrial development centers in several villages with a certain amount of commercial activity.

Under the guidance of an expatriate advisor, the small industry development service center approach was scrapped in favor of creating self-supporting regional enterprises catering to specific local markets. The project decided to set up manufacturing and assembly units on a commercially viable basis rather than to collect data about the feasibility of existing and potential economic activities. The underlying assumption of this approach

is that design and production modifications leading to an appropriate product for the specific environment take place more efficiently as a result of production, marketing, and use by the farmer. Facilities using uncomplicated fabrication technologies and equipment were planned at two levels.

Thus, in an unusual arrangement, the Themis Agricultural Implements Company and three small workshop units were started as private ventures in 1981, capitalized by a 2.63 million TSh (Tanzania shillings) (\$270,000 1982 U.S. Dollars) ten-year interest free loan from the Arusha Regional government with funds made available by the USAID APVDP project. Additionally, a three year line of concessionary credit and material procurement services was secured from the Tanzania Rural Development Bank (TRDB). This had the crucial effect of assuring relatively regular supplies of bulk fabrication steel and other raw material supplies (SIDO, 1983).

The managers of the project were selected by interview as a partnership from among 26 other group applications. The seven directors which were chosen come from various parts of the region and bring with them useful knowledge of the farming systems in use. They also represent an unusual concentration of talents, since five have been trained overseas, and two have worked for over ten years in TAMTU. The terms under which the factory was offered were that this group would assume control of the operations of the factory and its production plan and would be responsible for machinery installation, tooling, and start-up. The partners contributed 15% cash equity and after one year's grace period began to repay the capital costs of the factory over ten years.

The fledgling enterprise then targeted for production those implements which farmer market surveys had indicated were in high demand, namely oxcarts and plows. As previously described, the results were extremely promising, with output exceeding production targets in both categories. Several other farm implements have been developed, including planters, ridgers, and weeders, all for use with the original toolbar. Additionally, plans are underway to begin production of an intermediate-scale oilpress, which will require investments into new equipment and the adoption of more rigorous engineering and production standards.

In addition to expanding its range of products and increasing its output, the company carries out an informal extension program in which modifications to the designs are regularly tested in communities within fifty miles of Arusha. This activity, held in the district townships, is combined with a sales effort in the monthly rural cattle markets and is supported by the government, which supplies transport and the services of the Regional Agricultural Mechanization Officer.

The success of the Arusha enterprise has helped create new markets and production models which the existing facility at Mwanza and planned facilities at Iringa and Mbeya are eagerly emulating.

Although the products and designs slated for production at these existing or planned rural enterprises may vary, the production processes and distribution and maintenance systems will be similar to those demonstrated at Arusha. Financing for these ventures will also include concessionary credit for capital costs and preferential raw material allocations from the Tanzania Rural Development Bank and other government agencies.

Economic Considerations

Large numbers of farmers are willing to purchase the oxcart and the toolbar for cash up-front because they know these implements will increase their productivity. An important aspect of both products is their complementarity. Both ox carts and toolbar-plows dramatically increase the amount of land that can be put under production, as labor is a serious constraint in many areas.

Under normal circumstances, labor is abundant in the rural areas, but the relatively short time available for cultivation and planting before the rains means that the amount of land that can actually be put in production is limited. While one person takes about four days on the average to cultivate one acre, two people using a team of oxen can cultivate up to two acres in one day. Thus, labor productivity at this critical time can be increased by a factor of four. Additionally, since the supply of inputs (fertilizer, seeds, irrigation, etc.) increases by a similar factor, under optimal conditions, augmenting the overall use of draft animal power to increase the capacity of farms in such tasks as transferring and handling produce is also crucial. In both the input and output ends of farm operations, ox carts become useful productivity enhancing tools. In fact, farmers in Tanzania are beginning to rent their carts for 100 TSh a day (\$8.00 U.S. on the official rate of exchange) to their neighbors (Allen, 1984).

The economic impacts of improved ox-drawn equipment in Uganda, specifically the Kabanyolo Toolbar, the antecedent of the equipment being produced in the Tanzanian rural production facilities, were described by Dima and Amann (1975). According to these authors, a sample survey of farmers who had adapted this improved technology found that 75% of the farmers had learned to operate the equipment quickly and had expanded the acreage of food and cash crops under production. The Ugandan program faltered, however, due to political instability in the country and the fact that, unlike in Tanzania, the government failed to establish production plants in rural areas to manufacture the draft-animal powered equipment and to provide repairs and spare parts for local farmers.

In Tanzania today, comparing the cost of the carts and plows with farm commodities provides a more realistic view of the incentives farmers have to obtain them. In early 1984, steel-wheeled carts with brake levers retailed for 4,275 TSh at the factory gate and over 8,000 TSh assembled. Translating these costs to commodity

values, the oxcart unassembled is worth about six hundred-kilogram sacks of maize, the average annual production for a one acre holding. The assembled oxcart is worth twelve hundred-kilo sacks of maize, the average annual output of two acres. From this comparison, one can see that even a slight increase of new land put into production in one or two seasons, above and beyond the 6 to 7 acres per farm national average, would amortize the cart investment. A toolbar-plow set currently priced at 2,200 to 2,500 TSh is an attractive investment of 3.5 to 3.8 sacks of maize or the yields from less than an acre (Allen, 1984). It is not at all surprising that there is a great demand for the ox-carts and plows. A 1980 survey in Arusha Region revealed that only about 20% of the demand for plows was being met and less than 5% of the demand for ox-carts (SIDO, 1981).

Environmental Factors

The use of draft animal power systems in general, the decentralized production process, and the designs of the implements being produced in the rural Tanzanian factories address various macro- and micro-level environmental concerns. A national workshop held in May 1983 in Dar-es-Salaam on the topic of sustainable agriculture attended by cabinet level officers, agricultural extension workers and representatives of the Rodale Research Center of the U.S.A. emphasized draft animal power and implements as key means of restoring and maintaining soil fertility and productivity (Rodale, 1983). Given Tanzania's precarious energy situation, increased use of animal power does appear to signal a hopeful trend and has the potential for helping to reduce dependence on fossil-fuel-based energy resources.

The enhanced capacity to put more land under cultivation implies possible problems as well as opportunities. Thus, a strong need exists to assure that the opening of marginal lands to crop production is achieved in a non-destructive and ecologically sustainable way.

User Participation and Perspectives

As previously mentioned, this initiative has relied heavily on the perceptions, preferences, and priorities of the local farmers using the new farm equipment. The choice of technologies was based on detailed needs assessments and market surveys in rural villages. The designs eventually chosen were familiar and did not represent radical departures from what was already known and accepted. In order to produce appropriate, useful equipment on a continuous basis, the linkages between farmers and enterprises were purposely kept as close as possible. In this way the production centers were able to use feedback and criticisms from the users to improve existing designs and/or to increase available options.

Reasons for Success

This commercial approach to the production and dissemination of small-scale draft animal power agricultural implements has generated favorable results through increasing the availability, sales, and production of this equipment and through augmenting the number of DAP farm implement production enterprises . Success can be attributed to the following factors:

- o the favorable financial and technical packaging of the enterprises;
- o strong political support for the program at the national and local levels;
- o the selection of high quality technical and managerial personnel;
- o an appropriate choice of products geared to local needs and production capabilities with proven high demand among farmers; and,
- o integration of one major product (oxcarts) in a manufacturing system dependent on dispersed producers adding final and substantial value at the village level.

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