WHEELCHAIRS FOR THE THIRD WORLD

Appropriate Technology International

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Appropriate Technology International wishes to acknowledge the wheelchair makers in Jamaica, Malawi, Mexico, Nicaragua, Paraguay, Peru, the Philippines, and the USA, who contributed to many design improvements in the ATI-Hotchkiss wheelchair.

PREFACE

ATI PHILOSOPHY: To encourage the participation of the poor in their own economic development by encouraging technologies that are appropriate not only to local conditions but also appropriate to the people themselves.

To many people, appropriate technology means providing technology appropriate to the local resource endowment--availability of capital, raw materials, skills of the labor force, market access, etc. Appropriate Technology International (ATI) perceives appropriate technology as embodying an additional dimension: contributing to the beneficiaries' sense of well-being. The project described in this paper reflects this philosophy.

The idea that technology can be made appropriate to the people it serves (recipients/beneficiaries and workers) is not new. It is an outgrowth of the Utopian ideal of a society where technology would be adapted to the workers, rather than the traditional approach of demanding that the workers adapt to the technology. However, it was not until the early 1970s that the philosophy of improving workers' productivity by improving conditions in the workplace gained widespread support, first in Japan, then in Europe, and later in the United States.

Providing mobility to handicapped persons living in the Third World is the obvious goal of the ATI-Hotchkiss Wheelchair Project. Two additional concepts embodied in the project design--providing employment opportunities and credit facilities for the handicapped--testify to ATI's holistic approach to appropriate technology. The wheelchair was designed so that handicapped persons can participate in all aspects of the production process; from blueprint modification, to welding, to fabricating the final product. ATI now is encouraging the local project partners (sub-grantees) to experiment with employment practices which enable the workers to repay the credit extended to purchase their own wheelchairs. Thus, the ATI-Hotchkiss wheelchair project not only will free many Third World residents from the confines of their homes, but will also increase their self-confidence and self-esteem, and will contribute to their overall sense of well-being and happiness.

— Ton de Wilde
Executive Director
ATI

INTRODUCTION

Most disabled persons living in the Third World who need sturdy wheelchairs--suited to the world in which they live--must do without. This severely limits their options. Many are confined to their homes; others, lacking adequate mobility, find it very difficult to obtain an education or compete in the job market.

Good-quality imported wheelchairs are available but very few people can afford the $600-$1500 price tag. Some disabled urban dwellers are able to obtain quality wheelchairs from rehabilitation centers. However, throughout the Third World,and especially in rural areas, the demand for sturdy, flexible, totally mobile wheelchairs far exceeds the supply.

Owning a wheelchair does not necessarily mean smooth riding. The foreign-built chairs usually are not strong enough to withstand the rough surfaces common to much of the Third World, even in urban centers. In some Third World countries, locally-made wheelchairs are available--at a reasonable price. However, these tend to be poor copies of the imports and are far heavier and confining than state-of-the-art wheelchairs.

For the past four years, Ralf Hotchkiss, an engineer who himself uses a wheelchair, has worked to develop an alternative wheelchair that would be appropriate for conditions in the Third World . This work has been undertaken through two Appropriate Technology International development grants. After three years of field testing, the Hotchkiss technology is now being disseminated within Latin America. The design has been fixed and a production system has been established to permit small metalworking shops to manufacture the ATI-Hotchkiss wheelchair.

The Hotchkiss design results in a very lightweight folding chair that is extremely well balanced and is adaptable to individual fitting. The ATI-Hotchkiss chair, which has 26 fewer welds and 82 fewer fasteners than standard chairs, is of simple, yet rugged construction. At primary stress points, it employs heavier components than standard prescription designs. Almost all of the materials and components used in the manufacture of the chair are available in Third World countries. It can be produced in these countries at 1/8 to 1/4 the cost of imported wheelchairs and its price is competitive with other locally-produced folding wheelchairs. The production system is labor intensive; 30-40 hours of work are required to produce each chair. Welding skills and routine mechanical aptitude are the principal labor skills required.

The Hotchkiss design has the potential to alleviate the shortage of wheelchairs in the Third World. The challenge lies in transferring this technology to the countries where it is needed and in assuring the establishment of independent manufacturing capabilities. To help achieve these goals, ATI has sponsored workshops and technical exchanges, and is writing a production manual, which will contain detailed descriptions of the design and a set of instructions for the production system.

EVOLUTION OF THE TECHNOLOGY

Organizacion de Revolucionarios Desabilitados (ORD)

The Hotchkiss design was initially tested in Nicaragua in 1982. Members of ORD (Organizacion de Revolucionarios Desabilitados--Organization of Disabled Revolutionaries) wanted their advocacy group to become financially self-sustaining. These young Nicaraguans, who had been disabled either by polio or in the recent Civil War, decided that an ideal way to accomplish this goal would be to open a wheelchair manufacturing and repair shop.

The ORD wheelchair factory was organized and outfitted over a period of 18 months. Participants located and purchased inventory and various essential tools, such as an acetylene torch, and set up shop in the living room of a small house. After Hotchkiss trained the ORD members, they soon began repairing chairs for the public. Within the first five months, the shop had completed more than 1,000 repairs.

When the project closed in early 1983, the workshop was fully established as a repair and production facility. Several ORD members were competently trained in wheelchair repair and design.

In addition to producing and repairing wheelchairs, the ORD accomplished something else: training and employing disabled people--both men and women --in a nonpatronizing program staffed by other disabled people. Disabled women still suffer a greater stigma than disabled men. Working in and with the ORD has helped some Nicaraguan women to escape from the confines of their homes.

Workshops in Jamaica, Peru, and Costa Rica

In an effort to introduce the Hotchkiss design to more countries, ATI organized a series of two-week workshops held in Jamaica, Peru, and Costa Rica. These workshops trained a total of 31 people from 12 different countries to construct the ATI-Hotchkiss wheelchair. The majority of these participants now have either opened their own small wheelchair-manufacturing businesses or are employed in a wheelchair production facility.

The first workshop, held in Jamaica in October 1983, provided an immensely productive forum for the exchange of information among its participants. Seven mechanics and wheelchair makers represented small businesses and disability groups from Jamaica, Guyana, Trinidad, Paraguay and Malawi. Each participant built a complete wheelchair from scratch, using locally available materials with one exception: the pneumatic front wheels.

All the participants fabricated hub-drilling jigs to take back to their home shops and two participants made a set of cross-brace jigs. Everyone left with a complete wheelchair, one hub-jig and a few tools.

The workshops in Peru and Costa Rica in 1984 were similar, although Hotchkiss placed greater emphasis on jig-building. The workshop organizers, however, changed the criteria for selecting participants. These participants had to be experienced wheelchair makers; the organizers thought that if they began using the Hotchkiss design, then more ATI-Hotchkiss-type chairs could be produced in a shorter amount of time. The organizers also believed that the feedback the experienced wheelchair makers could provide would better help solve the remaining production-design problems.

Ten participants registered for the Peru workshop; additional people joined later. Five of the participants from Paraguay, Bolivia and Peru represented small businesses. Four people from the Dominican Republic, Colombia, Ecuador, and Peru represented social service and rehabilitation agencies. A member of an indigenous Peruvian organization, Peace and Justice, also attended. Five participants in the Costa Rican workshop represented vocational training centers in Guatemala, El Salvador, Honduras, and Costa Rica and three people represented small businesses in Mexico, El Salvador, and Colombia.

The new selection strategy for workshop attendees proved successful. A few days after the Peru workshop, Hotchkiss visited a group of participants in Lima--four disabled men who owned their own wheelchair production shop. They were well on their way toward completing three more wheelchairs using the Hotchkiss design.

In these new models, the Peruvians had changed the fitting of the x-brace onto the frame. The new method was a little more complicated but the end result was more attractive. Moreover, this method only required three sizes of metal tubing to build the frame rather than four. Locating and stocking all four metal tubing sizes had always been a problem. This reduction streamlined the operation and reduced the probability of supply shortages.

Technical Exchanges

In addition to the workshops, AT International funded a series of technical exchanges between Hotchkiss and wheelchair manufacturers in Latin America and Asia. Several mechanics visited Hotchkiss in his Oakland, California, workshop. He, in turn, visited Third World workshops where he observed their work and shared his expertise. His visits to the Philippines were particularly beneficial.

The 22 disabled persons who worked in the Tahanan Walang Hagdanan wheelchair factory in the Philippines had built more than a thousand wheelchairs during the first four years of the factory's operation. When sufficient materials were available, they were able to complete as many as 50 wheelchairs a month. Hotchkiss first visited Tahanan in 1981 to demonstrate the construction of his then-current chair design. The mechanics there had criticized the practicality of that design and sent Hotchkiss back to the drawing board.

Hotchkiss again visited Tahanan in 1984. The changes he now suggested would save time, cut costs, and enhance the maneuverability of the Tahanan chair. He showed the workers how to standarize measurements for the upholstery and handrims, thus cutting production time, making the parts interchangeable, and simplifying manufacture and repair. He introduced tools that cut production time even further and enabled the workshop to take advantage of his new design for the footrest, fork and brake.

All these changes streamlined the wheelchair manufacturing process. Fewer parts, fewer welds, and less subcontracting were required. The total production time dropped and the weight decreased by nearly 25%. Steel used in the chair is sold by weight, so the weight reduction meant a considerable savings in cost.

DESIGN APPLICATIONS FOR THE THIRD WORLD

Several international relief and rehabilitation agencies, concerned about the short supply of wheelchairs specifically designed for conditions in the Third World,[1] have devoted funds to developing ingenious low-tech chair designs that provide a good measure of mobility at a minimum cost. These chairs use wood and bicycle parts; thus they can be built in rural or village settings.[2] Because these low-tech wheelchairs are equipped with

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1. World Health Organization, "Disability Prevention and Rehabilitation," 1981.
2. AHRTAG, (Applied Health Resources and Technology Action Group, Ltd), Personal Transport for Disabled People, 1984.

large drive wheels at the front and a single caster wheel at the rear, the mobility of the rider is seriously compromised.[1] Additionally, the heavy construction of these chairs and their inability to fold make them quite difficult to transport by taxi, bus, or burro.

Hotchkiss believes that these low-tech wheelchairs seriously hamper the integration of the disabled into the very competitive work world. In the U.S., it had long been accepted that the benefits of providing a state-of-the art wheelchair to a disabled worker far outweigh the costs. However, the best U.S. chairs cost $1,500 apiece--a price which is far too costly for Third World countries. Hotchkiss, and the ATI staff, felt that a top-quality wheelchair could be built at a price close to that of the cheapest metal wheelchair. Hence ATI's goal: to build the best, most cost-effective Third World wheelchair possible.

Physical Adaptations

A wheelchair that will function optimally in typical Third World conditions must be as stable as possible without being excessively wide. For this reason a four-wheeled chair is preferable to a three-wheeled model. The chair can be expected to encounter soft or rough ground, hills, steps and curbs. A chair with the drive wheels at the rear can handle these obstacles much more effectively than one with the drive wheels at the front.

An optimal chair is both sturdy and flexible. The footrest, caster, and drive wheel need to be strengthened to absorb severe impacts. The frame of a four-wheeled chair needs to flex so that it can move over rough terrain without losing traction. A lightweight, foldable wheelchair can also be more easily transported--either in a taxi or atop a bus. A foldable chair can also be neatly stored --essential in cramped living quarters.

The chair should be as narrow as possible, in order to allow maximum maneuverability in homes and workspaces. The armrest should be removable or low enough to permit safe lateral transfers in and out of the chair. The resulting mobility is particularly important in architectural environments that present barriers to disabled persons. An optimal wheelchair should be fully equipped with parking brakes for safe transfers, metal handrims for efficient propulsion, a foldable footrest for close access, and push handles for obtaining assistance.

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1. David Werner, "Rural Rehabilition," 1985. (Proposed title for a not-yet published article).

Economic Adaptations

Third World poverty imposes another set of design adaptations. Many parts in the standard wheelchair are formed in a heavy press, an expensive and often wasteful technique in which a part, for example, the hub or caster fork, is pressed out of heavy sheet metal by a unique die. Parts can be made very quickly in a press, but the initial investment in the press of (U.S.) $30,000 to $50,000 is far beyond the financial resources of most Third World wheelchair builders.

If Third World countries want to produce a standard wheechair without investing in these capital intensive operations, they are forced either to import certain parts or to fabricate them by hand. However, imported parts are far too expensive and copying press-formed parts by hand is very time-consuming.

The best design for each part would permit the part to be made quickly and easily by hand. Good designs for some handmade parts are already available, but they have been out of use for 30 years or more.

Other Design Criteria

In addition to physical and economic constraints, the wheelchair design had to meet several other critera. The new chair had to be safe, comfortable, dependable and, as the "chair you wear," it had to be attractive. Moreover, each design change introduced to fulfill one goal--be it lower weight, lower cost, or easier manufacture--also had to fulfill every other. The evolution of the design represented a continuous set of trade-offs. The end result is a wheelchair that for the first time directly meets the needs of the most active and independent disabled people in the Third World. (See figure 1 on page 8 for a drawing of the current prototype of the ATI-Hotchkiss chair.)

THE ATI-HOTCHKISS WHEELCHAIR

The frame of the current Hotchkiss model is made entirely of electrical conduit--cheap, sturdy tubing that is easy to shape. The unique swing-away footrest and curved armrest are also made of this material. The chair folds with a simple tubular frame made from half the usual number of parts. Standard automotive bearings and standard bicycle wheels are used; the seat is canvas. The narrow chair fits through almost any doorway, and weighs only two-thirds to three-fourths as much as the standard model.

Design Features

Several of Hotchkiss's innovations, including his new brake, armrest, and footrest, represent significant advances in wheelchair design. These already are being copied and incorporated into design work in the U.S. One of the most original developments is the footrest.

The swing-away footrest was originally designed to allow maneuvering in very tight spaces and close access for difficult transfers. This feature is especially useful in negotiating architectural barriers, yet its cost and complexity are prohibitive.

The swing-away footrest Hotchkiss developed has half as many parts and weighs 50% less than most commercial models. Each separate footrest is composed of one moving part that swings away from the front of the chair. As the footrest swings, it turns the footplate sideways into the plane of the side frame. This permits the chair to fold without the footrest getting in the way. (See figure 2, on page 8.)

Another unique feature of Hotchkiss's chair is the armrest. A curved fender bar has replaced a removable armrest which was bulky, expensive and difficult to construct. Because the bar follows the shape of the tire, the armrest does not hinder transfers into the chair. The chair's folding mechanism has also been altered to allow the fender bar to serve as a structural element of the sideframe, further reducing the chair's weight and complexity.

Construction Methods: Transforming the Hub

In designing each of these new features, Hotchkiss had to carefully consider the kinds of tools, techniques, and materials required in the manufacturing process. Each change was evaluated in terms of simplicity, cost, and the necessary production time. Changes in the hub design illustrate this process.

Large U.S. wheelchair companies produce their own hubs with expensive press-forming techniques which are too costly for developing nations. An alternative technique, proposed by a workshop in the Philippines, called for the use of bicycle hubs. However, although these hubs are cheap and readily available, they are unreliable because their axles bend easily and may sometimes snap under impact. Redesigning the hub presented a major challenge.

HOTCHKISS WHEELCHAIR

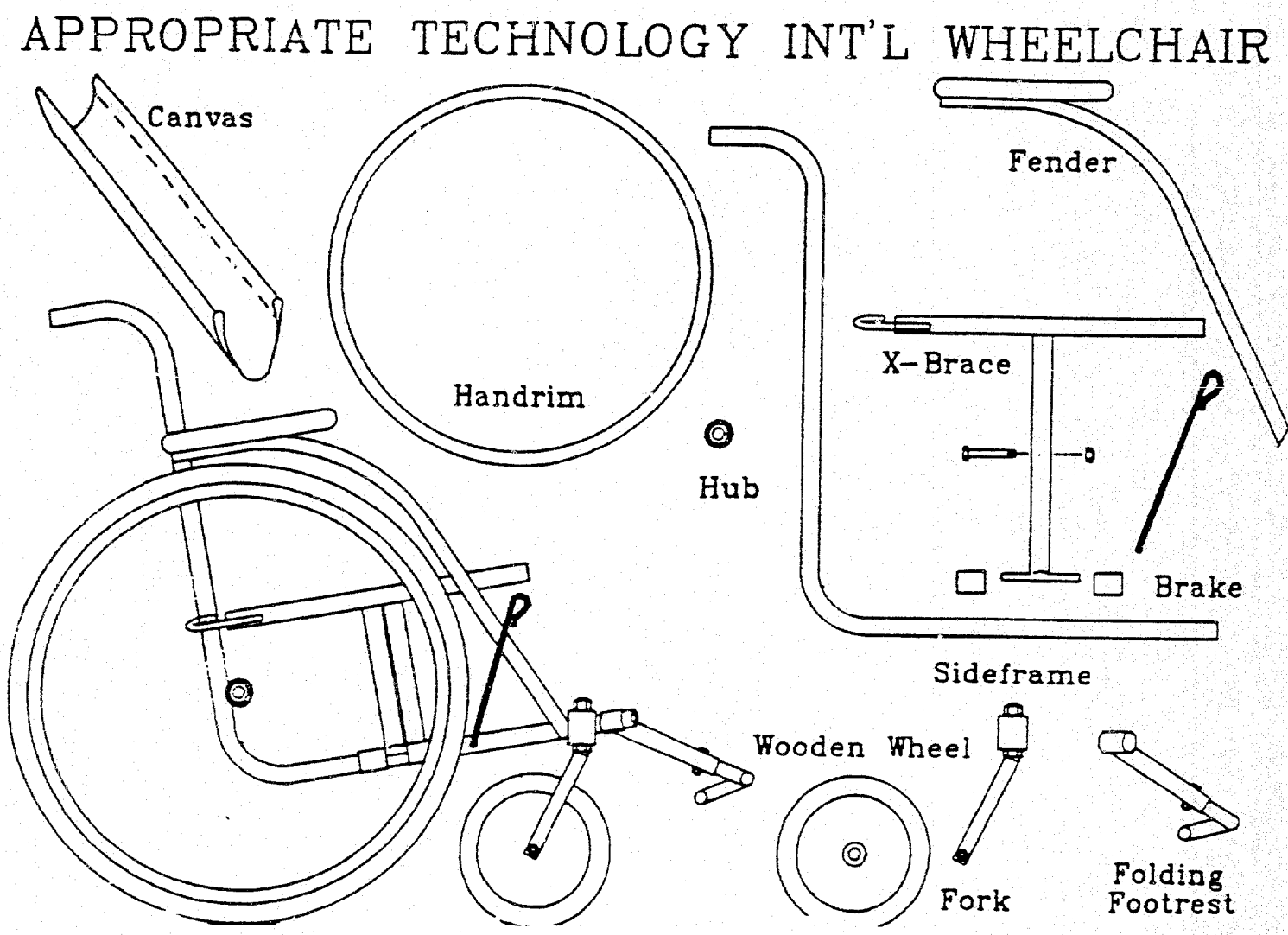
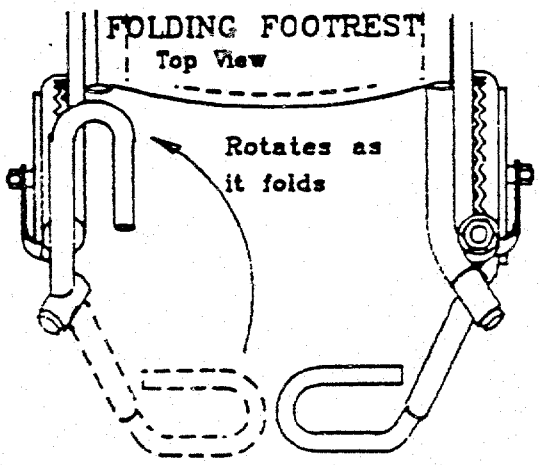


Figure 1. ATI-HOTCHKISS WHEELCHAIR

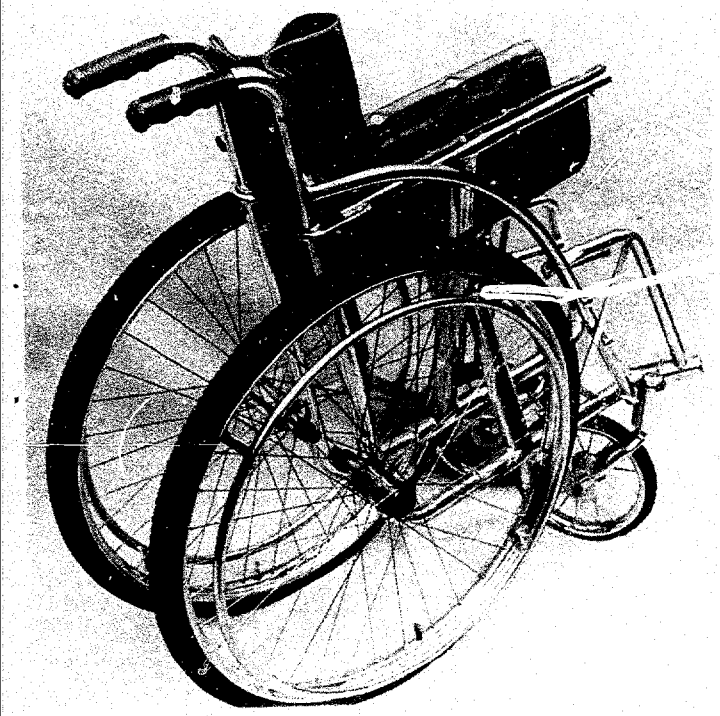


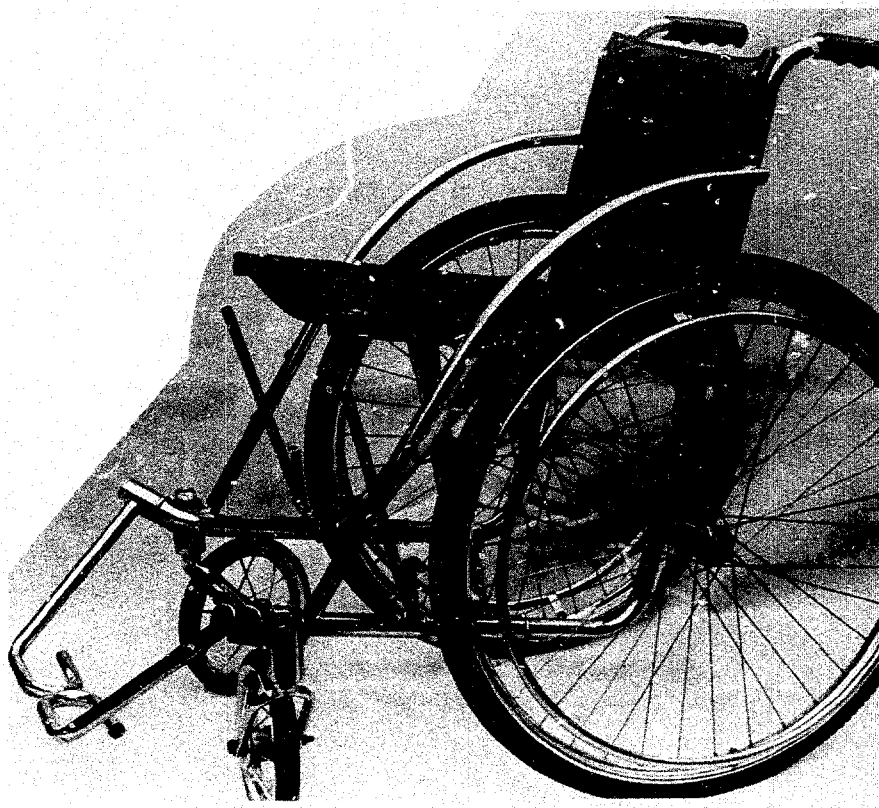
FOOTREST DESIGN

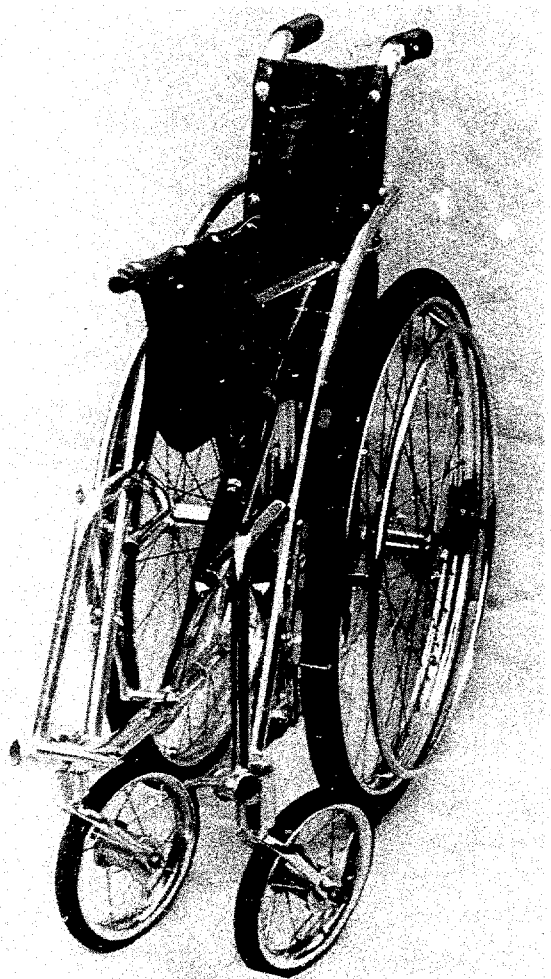
Figure 2. SWING-AWAY FOOTREST

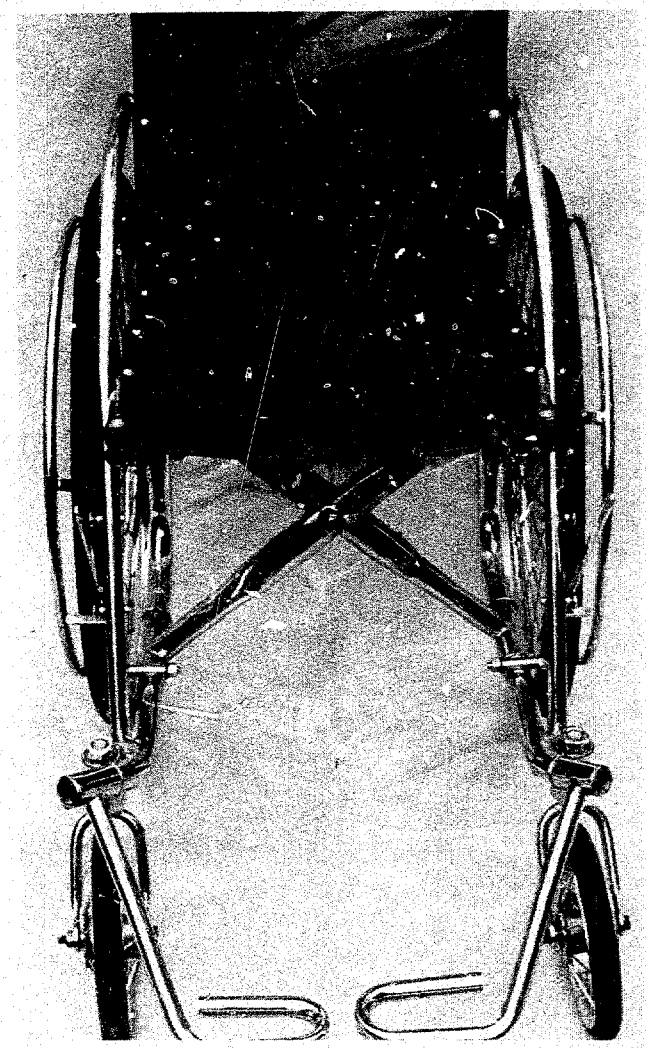
FIRST COMMERCIALLY PRODUCED ATI-HOTCHKISS WHEELCHAIR

PARAGUAY









The standard hub consists of a metal tube with formed flanges at each end to which the spokes are attached. How could the flanges be made other than by using the expensive press forming method?

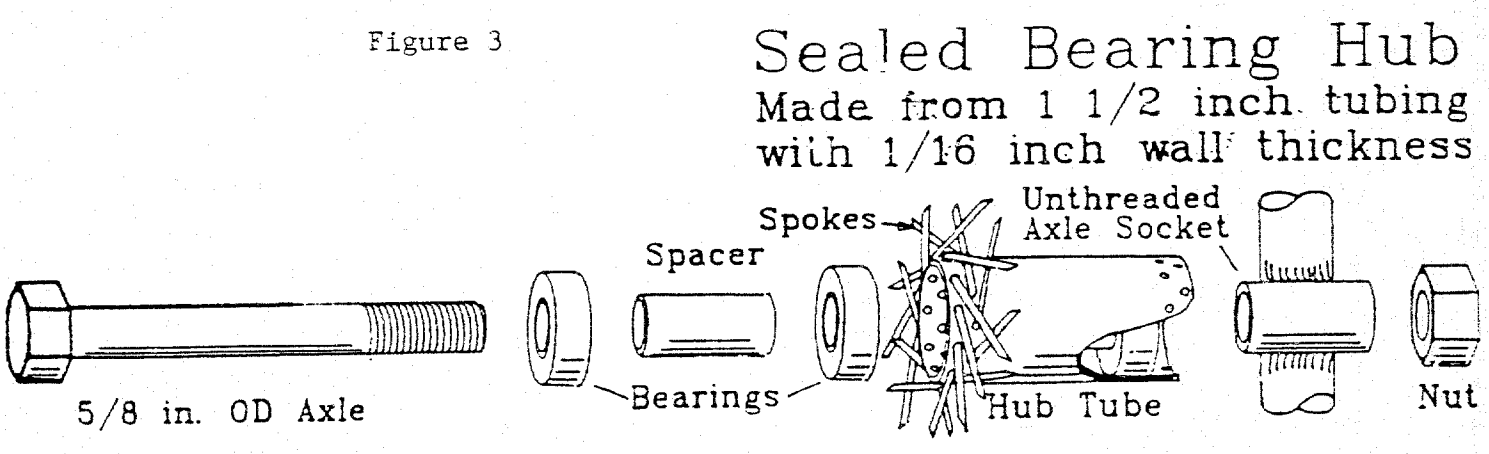
Hotchkiss first tried replicating the standard model using less expensive machinery. This method was very time-consuming. It took more than an hour to complete a pair of hubs--and although the machinery was less expensive, it still stretched the means of most small producers.

An overseas wheelchair company suggested attaching the spokes directly to the hub, eliminating the flanges entirely. (See figure three below). This method was attractive because it could decrease the production time and complexity and required only simple tools. But it demanded straight spokes, unavailable in many Third World countries. The problem was solved by attaching the spokes to the sides of the hub tube, thus allowing standard bent spokes to be used.

While this work proceeded, the search continued for sturdy and cheap bearings for the hub. A new, dependable source was found in an auto parts store: used automotive bearings. These new bearings decreased the hub's cost by two-thirds.

Together all these changes cut production time for the hub to only five minutes and decreased its cost to (U.S.)$2.00. Better yet, all the parts were available in most Third World countries. The manufacture and assembly techniques were simple and required only a few inexpensive tools. Because the construction methods are simple, this design can be replicated with minimal guidance.

Figure 3



RESULTS

The first AT International project plan called for designing a wheelchair that could be fabricated at a cost of $365; less than half of its parts would need to be imported. The current model costs between $60 and $80 for parts, plus the labor of one skilled mechanic for five days and the overhead of a production shop for that time. In Paraguay and Nicaragua the factory sales prices range from $175 to $200. In the Philippines, it is $150. The lower prices in the Philippines are possible because the workers have chosen to pay themselves less than the Philippine minimum wage.

The continued design changes have decreased the need to purchase ready-made parts beyond ATI's original expectations. The current version of the chair requires ready-made front and rear tires, tubes, rims and spokes, all bought from bicycle dealers at a competitive price. People who have some mechanical skill can learn the subtleties of this simple design in a two-week workshop.

This prototype has the potential to provide low-cost, dependable mobility for many disabled people in the Third World. Using this chair, they can attend school, hold jobs, and participate in the social and economic development of their countries.

The new ATI development grant will support the dissemination of the Hotchkiss technology on a regional scale within Latin America. Five sub-projects in Peru, Colombia, Guatemala, Honduras, and the Dominican Republic channel technical and financial assistance to a minimum of 12 micro-entrepreneurs engaged in the production of the ATI-Hotchkiss wheelchair. These small-scale enterprises have annual production capabilities ranging from 100 to 300 units.

Under this new grant, Ralf Hotchkiss's work will shift from design and development to production. His efforts will focus on: making minor adaptations in the basic design in order to respond to local resource constraints; locating collective sources for materials and components; establishing and enforcing quality control standards; designing tooling alternatives (special attention wil be paid to jigs and dies); and resolving specific production problems.

ACCESS TO THE HOTCHKISS TECHNOLOGY

Any reputable institution or enterprise wishing to provide a low cost wheelchair to users in the Third World countries will have access to the Hotchkiss technology. ATI can provide one or more of the following:

The Production Manual Ralf Hotchkiss's production manual is scheduled to be published in spring, 1985, and distributed by ATI. The manual, written in easy-to-understand English, and clearly illustrated, will contain a complete, detailed description of the design and a set of instructions for the production system. The primary audience is expected to be engineers and mechanics who are capable of interpreting mechanical drawings.

The Basic Tool Kit: Tooling to produce the ATI-Hotchkiss chair consists of tools which are usually found in a reasonably well-equipped small metalworking shop and unique tools that have been developed for the production of the ATI-Hotchkiss wheelchair. The Basic Tool Kit--the special tools--includes a jig set consisting of 19 jigs and 3 sample parts, a bending set consisting of 8 dies and a handpowered bending frame, and a set of 5 hard-to-procure measuring tools. These Basic Tools will permit small shops to copy the Hotchkiss designs at tight tolerances and still keep their labor costs competitive. The basic tool kit can be purchased at a cost of approximately (U.S.)$1,000 FOB Washington, D. C., USA.

Access to the Hotchkiss Network All enterprises engaged in producing the ATI-Hotchkiss wheelchair will be able to share information and experiences on design modifications and sources for materials and components. Twice a year a bulletin, edited by Hotchkiss, will be mailed to all network members. Specific problems will be answered individually, in writing, by Hotchkiss.

Access to Production Sites Any institution/person may contact ATI to arrange a visit to an existing production site. ATI will also recommend enterprises where apprentices may receive training.

INVESTMENT REQUIREMENTS AND COSTS OF PRODUCTION

Experience in Latin America indicates that where there is no local competition the ATI-Hotchkiss chair can be produced profitably by a one man shop. However, significant economies of size and much more precise quality control can be achieved in a four-worker shop. The following investment schedule and production cost data are based on four-worker shops operating at 80% of a production capacity of 200 chairs per year.

Investment Requirements: (see page 14 for details)

Based on ATI's investigations in Colombia, Paraguay, and Peru, an investment of approximately $9,700 is required to establish a four-worker enterprise to produce the ATI-Hotchkiss wheelchair.

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Plant	assumed to be rented
ATI Basic Tool Kit	$1000
Normal Complement of Tools and Equipment[1]	$2900
Start-up costs	$ 800
SUBTOTAL INVESTMENT IN EQUIPMENT AND PLANT	$4700
Operating Capital[2]	$5000
TOTAL INVESTMENT	$9700

[1] These are hand tools and equipment such as a drill press and an oxi-acetylene torch that any well-equipped metalworking shop should possess.

[2] Assumes that a two-month production inventory must be financed.

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On a cash basis the investment could be reduced to as little as $5,000 for an already established shop that turned over its inventory on a monthly basis.

Costs of Production: (See page 14 for details)

ATI's investigators in Colombia, Paraguay, Peru, and Costa Rica indicate that the direct cost of producing the ATI-Hotchkiss wheelchair will range from $114 to $140 per unit and that indirect costs will range from $40 to $131 per unit depending on interest rates and the percent of plant capacity employed. Taking the data available in Colombia, a unit production cost of $180 ($114 direct, $66 indirect) was established for a shop that was operating at 80% of capacity.(200 chairs per year)

The most critical factor affecting the production costs is the procurement cost of materials and components. Great economies can be achieved by purchasing in large lots. Generally, the costs of financing large lot purchases are more than compensated by cost savings.

CONCLUSION

The Hotchkiss design is an engineering achievement that unquestionably meets a serious need in the Third World. Its ultimate success depends, however, on the ability of wheelchair manufacturers to go it alone--i.e. manufacture and distribute the ATI-Hotchkiss chair at a profit.

AT International has endeavored to make this possible by providing training and information exchanges, technical assistance and credit to local workshops. ATI continues to support research on ways in which to better adapt the wheelchair and its fabrication to Third World conditions.

THE ROLE OF RALF HOTCHKISS

Ralf Hotchkiss has been designing alternative wheelchairs for nearly two decades. After he personally became disabled as a result of a motorcycle accident, he found that the standard wheelchair was easily broken, unnecessarily confining, and lacked many features he deemed essential. Hotchkiss began prowling around junkyards. He found scraps of old bicycles and other machines, and started putting together wheelchairs with the features he wanted.

Hotchkiss, who has worked as an engineer in the aerospace industry, also has invented a wheelchair that climbs stairs and allows the user to stand up and another with four-wheel drive. He has written books and articles on wheelchair design, product safety, and auto safety, lectured in the United States and abroad, and testified in courts of law and Congressional hearings on each of these topics.

Hotchkiss' engineering background led him to believe that the standard wheelchair could be cheaper, sturdier, and more useful to its rider. And he knew it could be done simply, by individuals or small businesses. Hotchkiss's persistence as an engineer, coupled with his commitment to alternative technology as both viable and necessary, account for much of the success of the AT International Third World wheelchair projects.

Hotchkiss Wheelchair, Four LA Countries
Comparative Direct Costs Per Chair
Comparative Investments

Country (Location)	Colombia (Medellin)	Costa Rica (San Jose)	Paraguay	Peru Lima
DIRECT COSTS/UNIT				
Material	$75	$72	$82	$98
Labor	29	33	23	32
Finishing	10 1/	20 2/	20 2/	10 1/
DIRECT COST/CHAIR	$114	$125	$125	$140
INDIRECT COSTS MONTHLY (does not include depreciation)				
Rent	$200	-	-	$100
Administration	160	-	171	-
Services	20	-	163	-
Transport	40	-	-	50
Other	30	-	11	70
	$450	-	$345	$220
INVESTMENT				
Plant	see rent	-	-	see rent
Basic Tool Kit	$1000	-	$1000	$1000
Tools & Equipment	2930	-	2600	3110
Start-up Costs	800	-	600	500
Subtotal Cap. Inv.	$4730	-	$4200	$4610
Operating Capital	$5000		$5130	$5480
TOTAL INVESTMENT	$9730		$9330	$10090

1/ Nickel plating $10 per chair subcontracted Colombia price.
2/ Chrome plating $20 per chair subcontracted Paraguay, Costa