CHELSEA CENTER FOR RECYCLING AND ECONOMIC DEVELOPMENT
UNIVERSITY OF MASSACHUSETTS

RBED Report

FEASIBILITY STUDY OF HOSPITAL BED AS PRODUCT FOR INNER CITY REMANUFACTURING ENTERPRISE

June 2001

80 Everett Avenue, Suite 221 Chelsea, Massachusetts 02150
Tel: (617) 887-2300 Fax: (617) 887-0399 www.chelseacenter.org
Cover Printed on Recycled Paper Manufactured in Massachusetts

Feasibility Study of Hospital Bed as Product for Inner City Remanufacturing Enterprise

Douglas Ling, Director Economic Development
Asian Community Development Corporation
Boston, MA

Chelsea Center for Recycling and Economic Development

Community Economic Development through Recycling Program

June 2001

This project is funded by the University of Massachusetts' Chelsea Center for Recycling and Economic Development, through the Executive Office of Environmental Affairs and the Clean Environment Fund, which is comprised of unredeemed bottle deposits.

The Chelsea Center for Recycling and Economic Development, a part of the University of Massachusetts' Lowell Center for Sustainable Production, was created by the Commonwealth of Massachusetts in 1995 to create jobs, support recycling efforts, and help the economy and the environment by increasing the use of recyclables by manufacturers. The mission of the Chelsea Center is to develop an infrastructure for a sustainable materials economy in Massachusetts, where businesses will thrive that rely on locally discarded goods as their feedstock and that minimize pressure on the environment by reducing waste, pollution, dependence on virgin materials, and dependence on disposal facilities. Further information can be obtained by contacting the Chelsea Center for Recycling and Economic Development, 80 Everett Avenue, Suite 221, Chelsea, MA 02150, 617-887-2300.

TABLE OF CONTENTS

Acknowledgement

This feasibility study is an extension of the *Remanufacturing Enterprise for the Inner City* study, conducted by Prof. Robert. T. Lund, Prof. William M. Hauser, and the Asian Community Development Corporation (ACDC), in the summer of 2000. Both studies were funded in part by the Chelsea Center for Recycling and Economic Development. The author wishes to thank Jennifer Capuano, Director of Economic Development Program of the Chelsea Center for her support and interest in this project. The advice, support, and vision of Prof. Lund, and Prof. Hauser are also gratefully acknowledged here.

This study could not have been possible without the generous offer of time, equipment, and space, by Mr. Shyue-Ling Chen, Director of Medical Engineering, and Mr. Edward Sacco, at the New England Medical Center.

The author would also like to acknowledge the contributions of Mr. Xin-Rong Liu, who carried out most of the disassembly of the test bed; Mr. Yi-Cheng Ye, previously Secretary of the Corporation for Trade Promotion and Exhibits of Guangdong province, who provided market information, personal contacts, and many useful discussions on China; and Ms. Annie Chin-Louie, who updated the pro forma financial statements for the Inner City Medical Corporation business plan for this study.

The Inner City Medical Corporation concept for Chinatown is partially an effort to create meaningful manufacturing jobs and business opportunities to people like Mr. Ye and Mr. Liu – those with a wealth of manufacturing and trade experiences, but found their new life in the U.S. (with a new language) lacking in opportunities to take advantage of their expertise. The project is part of the sustainable economic development strategy initiated by ACDC in 1999.

I. Introduction and Summary

This feasibility study was a follow-on to the Remanufacturing Enterprise for the Inner City study conducted by Prof. Robert T. Lund and Prof. William M. Hauser of Boston University, in conjunction with the Asian Community Development Corporation in the summer of 2000. The previous study proposed a remanufacturing enterprise (the Inner City Medical Corporation, or ICMC) as an economic development vehicle in the inner city. Specifically, the study focused on the dental chair as the primary product. The study was particularly relevant to the Asian Community Development Corporation (ACDC) because of the existence of two healthcare facilities (Tufts Dental School, and the New England Medical Center) in the Chinatown neighborhood. Surplus equipment from the two would be readily available to a community-based venture. An ACDC survey also showed that close to 50% of the Chinese workers sampled had some experience in manufacturing before emigrated from China to the U.S. The clustering of medical facilities and the clustering of skilled manufacturing workforce both point to the feasibility of a remanufacturing venture for Chinatown as a natural sustainable economic development strategy.

This study continued the previous feasibility study but focused on the hospital bed as a second product for remanufacturing. The hospital bed is characterized by higher availability of cores (surplus beds) and similar to the dental chair in terms of mechanical complexity. However, the value of the finished product is found to be lower domestically due to its high supply, and lack of modern features. At a list price of about $1,100, the profit margin would be low, especially if dealers are involved. However, as an inner-city venture aims to provide much needed manufacturing jobs and job training opportunities, the lower profit margin may be acceptable. The growing nursing home or assisted living sector may prove to be a more suitable market for refurbished beds. Keeping remanufacturing costs low and selling direct may be the only solution.

Markets in developing countries, while expanding in general, were found to be problematic for hospital beds. While import barriers for refurbished equipment were few, low-cost local alternatives (e.g. non-adjustable beds costing only $100-200 in China[1]) would sway procurement decisions towards other high-value refurbished equipment such as CT-scanners and other diagnostic instruments. Secondary markets such as Vietnam and Indonesia may prove to be suitable for ICMC because of the smaller demand, less developed domestic manufacturers, and devalued currency.

Adding hospital bed to the ICMC product line might ultimately achieve the goals of providing more workers with meaningful and productive jobs. However, the bed market appeared to be too competitive to add much to the bottom line or profitability of the venture.

This report covered the work done largely during the month of June, 2001.

[1] Private conversation; information from medical staff at Wei Zho City Hospital, Wei Zho, Guangdong, China

II. Technical Analysis

The Greater Boston area is home to many world-class hospitals. Among the top 25 hospitals (by patient revenue) in Metro Boston, there are about 4647 licensed beds[2]. While the number of beds may fluctuate with economic cycles and corporate consolidation over 10,000 beds may be in service in Eastern and Central Massachusetts at any one time. It is estimated that at least 750 beds may be replaced or discarded in any particular year, and may be available for remanufacturing.

Region	**No. of beds***
Metro Boston	4,647
Metro South (incl. Plymouth, Cape Cod)	1,856
Metro West (incl. Worcester County)	1,632
Metro North	1,434

Table 1 Number of licensed hospital beds in Eastern and Central Mass. (*among top 25 hospitals by patient revenue)[3]

A. Hospital Bed Disassembling

The New England Medical Center (NEMC), a 300-bed teaching hospital for Tufts University, has been using various versions of the Borg-Warner hospital beds procured over the past 15 years. A new generation of hospital beds, with built-in weight sensors, self-drive system, and the ability to be integrated into the hospital's patient monitor and communication systems, are currently being evaluated as replacement for the aging beds at a cost of over $3 million. Faced with the prospect of having to deal with the disposal of the older beds, NEMC became interested in the Inner City Medical Corporation venture. An Alpha Model-3 bed manufactured by Borg-Warner Health Products, Inc. (serial number 6831-04AG) was offered by the Department of Medical Engineering for this project.

The work was conducted on-site at the New England Medical Center, Department of Medical Engineering. Approximately 300 square-feet of space was used for the process. An intern, Mr. Liu, who had substantial manufacturing experience in China, disassembled the test bed without much prior preparation and assistance from the NEMC staff. The time it took for each major step was recorded and presented in Table 2. The time it would take for a trained worker to perform the same disassembling task was estimated. The actual process of disassembling and re-assembling the bed took two people 1.5 days, including ample time for discussion and documentation. The tasks were deemed to be relatively easy, requiring only a small number of hand tools.

[2] Boston Book of Lists, *Bos. Bus. J*, 2000
[3] *Boston Book of Lists*. BBJ, 2000

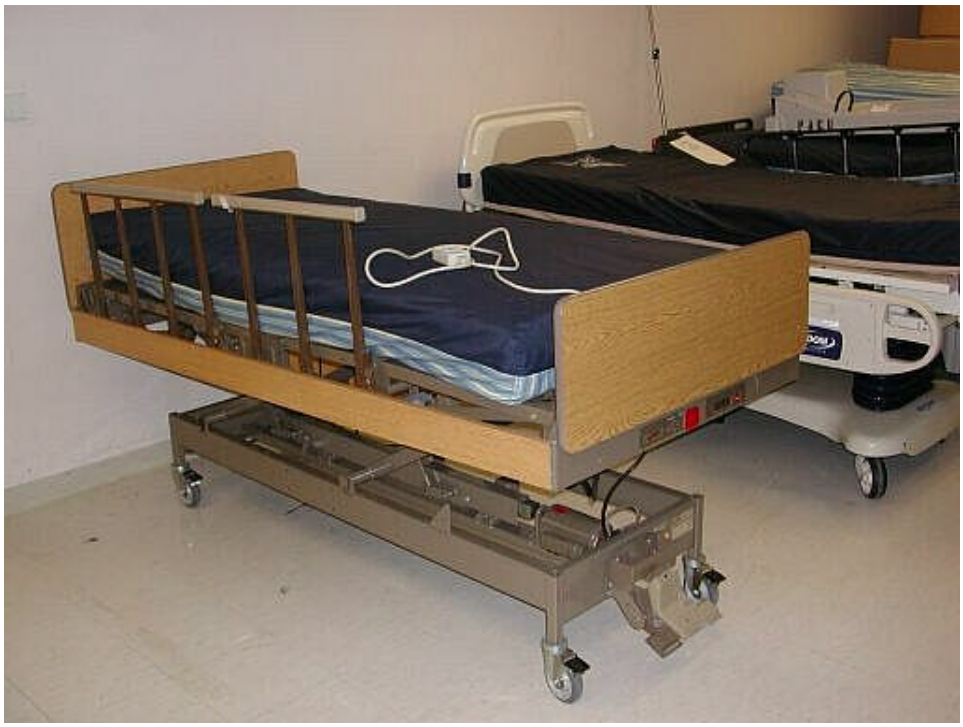

Figure 1
Borg-Warner Alpha Model 3 bed with a current-model Stryker bed in the background

Task	Time took this study (minutes)	Time for a trained worker (minutes.)
Removal of hand rails (4)	20	10
Top section – knee and foot panels	15[4]	15
Top section – drive motors (2), power panel	5	5
Lower section – drive mechanism	30	15
Lower section – foot pedal assembly	20[5]	15
Casters (4)	N/a	10
Total	**90**	**70**

Table 2 Time study of the disassembling process

[4] back panel not removed due to semi-permanent rivet-attachment
[5] draw bar motor and foot pedal linkage not removed due to semi-permanent rivet-attachment

Figure 2
Test bed lifted for disassembly

- ❑ Big Joe 1500-lb electric fork lift
- ❑ Socket wrench
- ❑ Mallet
- ❑ Adjustable wrench
- ❑ Screwdrivers
- ❑ Needle-nose pliers

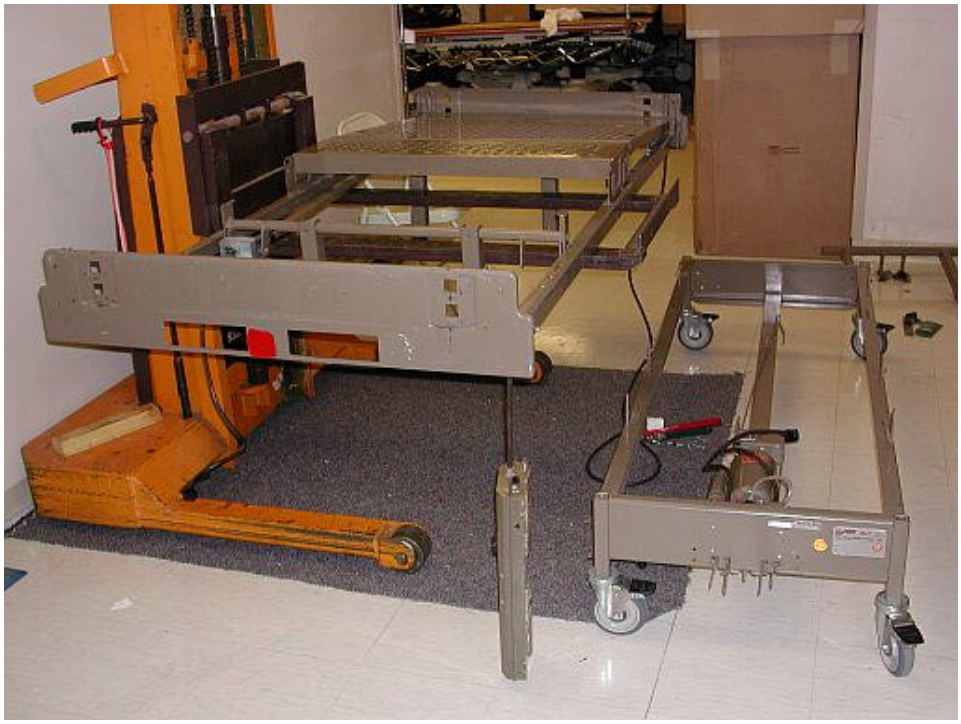

Figure 3
Test bed separated into top and bottom frames

B. Bill of Material

The complete parts list for the Alpha Model 3 contains 106 indexed items[6]. In addition, the air mattress cover ("Pressure Guard") is manufactured separately by Span America Medical Systems of South Carolina. Several observations were made:

- The parts were found to be in good condition despite having been in service for over 10 years. The paint job on the frame appeared to be durable. Liquid stains and dirt were evident where the frame and the decorative panels met.
- A mix of fasteners used, including many different sizes of hex head, Philips pan head, and flat head screws, required frequent tool changes and slowed down the disassembling/assembling process.
- Use of different push nuts, retaining rings, and rivets not only increased the parts count but also slowed down the process.
- The motors and attached gearboxes were inspected and showed little sign of wear and tear, nor any lubricant loss or contamination.
- The electronic control contained simple discrete components although one capacitor (part #05/41-0001) was listed at $28.
- The foot pedal assembly was the most complicated to disassemble. Small retaining C rings in very tight spaces made for an awkward and time-consuming operation.
- The safety sides (arm rails, figures 3 and 4) were molded from high-impact plastic for strength and electric non-conductivity. They were attached to the bed frame with 0.25-inch shoulder screws, rubber and metal washers, and lock nuts. It was reported that this was one of the most easily broken part of the Alpha Model 3 bed. The rails were used often as handholds when the beds were moved. The safety sides typically broke where it was pulled and bent against the side decorative panel – a condition probably not anticipated by the designers. Replacement cost of each set of safety sides was listed at $75.

A sample parts disposition chart (Table 3) illustrated the likely refurbishment tasks necessary.

Part no.	Description	qty	Notes	Required		Disposition		
				clean	inspect	as is	repair	replace
04/00-5554 04/00-1050	Pivot stud, 1-inch dia	4 of ea.	Attached via screws to frame	✓	✓	✓		
03/00-8257	Upper frame	1	General stain from liquid, especially behind side panels	✓	✓	✓		
03/00-1776	Lift yoke, foot	2	Molded high-impact plastic; one broken on test bed	✓	✓			✓
04/00-7614	Motor assembly (incl. Gear box)	2	Foot and head panel control		✓	✓		

Table 3 Sample parts disposition chart

[6] Service Manual, Borg-Warner Alpha I Model 3 hospital bed

Figure 4a
Safety rail disassembled

Figure 4b
Safety rail in installed position with bed side panel

Figure 5
Foot pedal damage

Figure 6
Upper frame surface blemishes

Figure 7
1-inch pivot stud for back and foot panels

C. Remanufacturing Considerations

From this study, it is clear that the "last generation" of hospital bed tends to be relatively well made and easy to remanufacture. The weight and size of the frames do make the operation more demanding than that for a dental chair. For the most part, the mechanical linkages and pivots were durable and easy to clean. Broken pieces such as foot pedals and arm rails need to be replaced. If no spare part is available, most of the parts can be machined using metals or composites. However, that would add to the cost. Table 4 outlined the complete refurbishment process. The direct labor cost was estimated to be between 7.5 to 8.4 hours, or between $90 to $101 (at a labor rate of $12 per hour). Refinishing costs can add up to another $280 per bed. The final maximum estimated direct cost for each refurbished bed was therefore $381.

	Task Description	**Minutes**	**Mat'l cost**
1	Identify bed, model, locate parts list and instructions	5	
2	Disassemble bed, prepare parts for subsequent operations	70	
3	Inspect and clean pivots and joints (may aggregate from several beds and batch process)	20	
4	Powerwash frames and dry	30	
5	Inspect frame for paint damage; determine need for refinishing	10	
6	Inspect and clean drive mechanisms (lead screws, bearing blocks) and small parts	60	
7	Test electrical system	5	
8	*Optional*: replace transformer for international usage	(10)	
9	Inspect mattress; discard or retain	15	
10	Inspect and replace side panels	15	
11	Disassemble, inspect and replace safety sides	15	
12	Replace and repair broken parts	60	$75
13	*Optional*: prepare frame for painting (sandblast or priming; including packing for transporting to paint shop	(45)	$10
14	*Optional:* refinish bed frames	Outsource	$180
15	Re-assembling bed (use new screws)	90	$5
16	Test bed operation	10	
17	Affix labels, serial number, etc	10	
18	Prepare for shipping	20	$10
19	Documentation and	15	
	Total time, not including outsourced and optional tasks	**450 min**	**$90**
	Total time, including optional tasks	**505 min**	**$280**

Table 4 Labor estimate for the Alpha Model 3 bed

The following observations were made:

- Refinishing of the bed is likely to be required because most of the frames are exposed. The size and heft of the frame would present problems for refinishing although only basic enamel-based paint would be needed. Preparation of the bed frames and surfaces would likely demand the most amount of time. Sandblasting and painting of the frame may cost up to $220 per bed if contracted out. The trade-offs and economy of having an in-house paint booth should be carefully weighed and considered.

- Cleaning of most of the pivots, lead screws (drive mechanisms), and other lubricated parts should be routine using some sort of solvent bath. Re-lubrication would be done using factory-specified or better lubricants.

- For export markets, the ability to switch between 110V/50Hz and 220V/60Hz may be important. This may be accomplished by changing the transformer in the existing control box, which has room for such modification. Some engineering design may be needed for specific beds.

- Storage and transportation costs may also be a concern because a hospital bed, before and after remanufacturing, occupies a lot more space than a dental chair. More workspace is also needed than the dental-chair-only venture concept.

- The hospital is not considered to be medical equipment but furniture. While the US Food and Drug Administration (FDA) still designates the hospital bed a Risk-Level-II device, internationally, the furniture classification allows hospital beds to bypass many cumbersome medical equipment certifications. As the previous dental chair study indicated, FDA registration and reporting are required for refurbishers but not enforced. In the "absence of adverse events", the de facto regulatory burden should be low[7]. In any case, proper labeling, packaging, and manufacturing process would be kept to the high standards required of an original equipment manufacturer.

[7] Pro Forma Business Plan: Inner City Medical Corporation, pp 40-41

III. Market Study

Domestic Market

The U.S. market for used and refurbished hospital beds is somewhat limited due to recent technological advances. Current bed designs contain many innovations such as integrated monitoring and sensing electronics. Major technological changes in the last 10-15 years have reduced the recoverable value of a hospital bed by remanufacturing. While a new bed may cost more than $5000 each[8], the cost of a refurbished 15-year-old Borg-Warner Alpha 1 is listed only at about $600 to $900 through specialized distributors[9].

Which these older beds are considered obsolete at major hospitals, the growing number of nursing homes around the country may represent a potential market for refurbished hospital beds. As of 1998, there were an estimated 11,459 assisted living facilities (ALFs) nationwide, with approximately 611,300 beds and 521,500 residents[10]. With an aging population, the demand for ALFs will continue to rise. Simple remanufactured adjustable beds like the Alpha Model 3 may offer just the right cost-benefit for these facilities, which house 53 beds each, on average.

Export Markets

a. China

Healthcare industry in China has been growing steadily in the past 10 years. Industrialization, improving economy, and a burgeoning metropolitan population have pushed personal medical expenses by 20% to $27.7 billion in the past three years[11]. With increasing demand for modern medical service, new hospitals and healthcare facilities have been built or expanded. While domestic manufacturers of medical equipment have also grown, import of medical products is still significant. In the first 4 months of 2001, North American import totaled over 15 million dollars, although the amount still far lagged that of Japan ($89 million). American medical products, despite their higher cost, are well regarded for their quality, value, and innovation. While there is little data on the Chinese market for hospital beds, at least at the 400-bed Wei Zho Hospital in Guangdong province we contacted, there is currently a plan to replace some of the beds.

Conversations with professionals in the healthcare industry and international trade agency in Guangdong province confirmed that there is little barrier to entry for hospital beds, which are classified as furniture. Most hospitals, even major ones with 1000 beds, continue to use simple steel-frame, non-adjustable or manually adjustable beds that are perhaps 20-years old. They are durable, easy to maintain, domestically produced, and cost only $200. Bunk beds are occasionally used for non-critical patients in order to accommodate more patients. Imported beds are rare except for major “showcase” international hospitals. Procurement budgets tend to favor diagnostic and surgical equipment rather than furniture since there are no low-cost alternatives

[8] www.medical-beds.com
[9] 800.beds.345; www.medical2u.com/800beds.htm
[10] Hawes, et al, 1999
[11] MOFTEC data, April, 2001

for the former. In order for a U.S. remanufactured bed to be competitive in the market, the price is likely to have to drop to $500 or lower! It is no surprise that there is virtually no restriction on the importation of refurbished hospital beds.

Discussions with Chinese trade experts also revealed that there is a special classification for recycled or refurbished import products that requires documentation on the environmental protection benefits. (While China is not necessarily known for environmental protection - mainly due to images of its out-dated coal-fire power plants, there is an on-going movement toward environmental protection and conservation). Whether the special classification is an incentive for, or barrier to recycled products, is being investigated. Our expert, however, felt that any such new initiatives would likely mean excessive paperwork and delays at the customs at this time.

b. Vietnam

The total number of hospitals in Vietnam is approximately 800, providing about 40,000 beds[12],[13]. There are also another1,000 clinics and medical stations that make up the healthcare system. Since 1999, over 1,500 hospital beds have been added or planned. The Ministry of Health and local provinces operate most of the hospitals in Vietnam, although private hospitals and clinic, often with foreign joint-venture partners, are beginning to appear. The 1997 government budget for medical equipment was $12 million with an estimated annual growth rate of 10% .

While there is still substantial red tape, currently, there are no special import duty, nor restrictions for medical or related equipment such as hospital beds. Refurbished hospital beds and dental chairs may find eager customers in Vietnam.

c. Indonesia

Like many other Southeast Asian countries that suffered dramatic devaluation of their domestic currencies, Indonesian government and industries found their purchasing power plummeted. In April 2000, the Ministry of Industry and Trade issued decree no.129/MPP allowing the importation of second hand capital equipment[14]. This decree opens the door for foreign refurbished equipment. No special tariff for used or refurbished equipment. Both used and new equipment is assessed a tariff from 5% to 10%, with a VAT of another 10%.

Regardless of government action, private hospitals are not controlled by the Ministry of Health and can therefore directly purchase used and refurbished equipment[15],[16]. If the economic woes continue for Indonesia, the demand for used and refurbished equipment will continue to grow both in the public and private sectors.

---

[12] Industry Sector Analysis Report on Vietnam: Healthcare Services, US For. Comm. Serv., US Dept. of State, 09/01/98.
[13] compiled from US & Foreign Commercial Service reports 12/27/00, 12/07/99, and 02/03/00; US Dept. of State
[14] "Import of Second Hand Capital Equipment", International Market Insight (IMI), US & Foreign Commercial Service and US Dept. of State, 5/22/00.
[15] "Hospital Seek Used Equipment", IMI, US & Foreign Commercial Service and US D. o. State, 5/14/99.
[16] "Demand for Used Medical Equipment", IMI, US & FCS and US D. o. State, 02/18/00.

Both Vietnam and Indonesia have also expressed interest in refurbished dental equipment. There relatively small market (compared to China) may also play to ICMC's advantage as it may be possible to direct import the refurbished equipment without going through a dealer who can aggregate bigger orders.

IV. Discussion: Impact on Inner City Medical Corporation Business Plan

Quantitative comparisons between the hospital bed and the dental chair as products for ICMC can be summarized as followed:

	Hospital Bed	**Dental Chair**
Core availability (annual; local sources only)	750	200
Value (new)	$ 4000 - $6000	$ 3000 - $5000
Dealer Price (refurbished)	$ 900 - $1,500	$ 1,500 - $2,500
Labor cost of refurbishment (direct + indirect*)	$ 180	$ 248

* not including cost of refinishing (outsourced)

The difference between a dental chair and a hospital bed, in terms of their remanufacturability, was clearly caused by more substantial advances in technology for the hospital bed. As the beds become obsolete for the typical hospital with modern systems, their post-remanufacturing value decreases.

While hospital beds may be available in larger quantity than dental chairs, the value of a remanufactured bed prove to be disappointingly low. Adding hospital beds to the product line would not necessarily improve the bottom line of the business but may offer more employment opportunities for the community.

In the previous business plan, worker productivity was low in years 1 and 2, at 40% and 85% respectively[17]. That was due largely to the limited availability of dental chair cores. The projected excess capacity (about 2400 man-hours in year 1) may be fully utilized to remanufacture about 200 beds. If we assume that 750 cores may be available in one year in Massachusetts, that would allow two additional workers at ICMC to be productively engaged. A higher job creation potential has been one of the goals of the Asian CDC Board as it considered the feasibility of starting up ICMC. The business plan is being revised to reflect the scenario of having both the dental chair and the hospital bed as products.

It is clear, at least for the moment, that more complex but refurbished imaging equipment are the most sought after in foreign markets. For the long-term, more profitable products other than the hospital bed need to be identified. NEMC has offered infusion pumps, infant incubators, among other medical equipment for our consideration and experimentation. With good planning and execution, ICMC should be able to gradually increase the technical complexity of the product-lines as worker skills are improved.

[17] Pro Forma Business Plan: Inner City Medical Corporation, pp 45

V. Conclusion

This study helped expand our understanding of the market and technical issues surrounding remanufacturing of medical equipment. While the one-month grant period did not allow in-depth research into many promising areas (e.g. nursing home procurement pattern), research will likely continue at ACDC.

APPENDIX

REFERENCES

China Trade Information

- Ministry of Foreign Trade and Economic Cooperation (www.moftec.gov.cn)
- State Council (www.cei.gov.cn)
- General Administration of Customs (www.customs.gov.cn)
- Personal contact: Guangdong Province Department of Trade Promotion, Office of Business Development, Guangdong, China
- Personal contact: Wei Zho Hospital, City of Wei Zho, Guangdong, China

U.S. Foreign Trade Information

- International Trade Data Network www.itdn.net
- Industry Sector Analysis and International Market Insight reports: www.tradeport.org

Domestic Hospital Bed Remanufacturers/Resellers

- www.medical-beds.com
- www.medicalresourceusa.com
- www.medical2u.com/800beds.htm

Publications

Alpha I Model 3 Technical Manuel, Borg-Warner Health Products Inc.

Boston Business Journal 2000 Book of Lists: Area's Largest Hospitals; pp208, Boston, 2000.

Remanufacturing Enterprises for the Inner City (Final Report)
Hauser, W.M., Lund, R.T., and Ling, D.C., submitted to the Chelsea Center for Recycling and Economic Development, September, 2000.

Pro Forma Business Plan: Inner City Medical Corporation (Supplement to Manufacturing Enterprise for the Inner City)
Hauser, W.M., Lund, R.T., and Ling, D.C., submitted to the Chelsea Center for Recycling and Economic Development, September, 2000.

A National Study of Assisted Living for the Frail Elderly: Results of a National Survey of Facilities; Hawes, C, Rose, M., and Phillips, D.M., Myers Research Institute, December 14, 1999.