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Building a Sustainable Venture: The Mountain Institute's Earth Brick Machine

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Building a Sustainable Venture:

The Mountain Institute's Earth Brick Machine

Introduction

In the Spring of 2002, Elsie Walker of The Mountain Institute (TMI) visited a leading business school in the United States in search of an entrepreneurial, graduating MBA student. TMI, an international non-profit organization, wanted to investigate launching a for-profit entity to promote a machine for which it had recently received a patent. Using dirt as the main ingredient, this machine makes high-quality building blocks (or bricks) appropriate for construction of homes and other one- and two-story dwellings. Walker and TMI believed the machine was ideal for construction in developing countries, particularly for poor populations, who are often accustomed to using earth in home building. Relative to other technologies serving this market, TMI believed that its compressed earth block (CEB) machine was price competitive, allowed for low-cost construction, and was environmentally-friendly.

Focused on environmental protection and community development, TMI hoped that someone with a business school education would be able to determine if these advantages and other market factors would support a for-profit venture. If so, a for-profit venture could be free of the need to constantly find new grant money and, perhaps, could be a better tool for fostering economic development for developing country populations, a key objective of TMI.

At the time of Walker's visit to the business school, TMI had been field-testing this technology in the Tibet Autonomous Region of China (Tibet) for more than two years. After successfully building two small guest cottages and training a number of Tibetan builders in use of this technology, TMI was preparing to launch its CEB machine on a wider-scale in Tibet. This experience would form the first real market test of TMI's specific machine design and approach.

Soon after Walker's visit, TMI hired graduating MBA student John Buffington. Specifically, Buffington was to assist with continuing Tibetan efforts, develop a business plan for further promotion of the machine in Tibet, and, most importantly, investigate global opportunities. Provided he maintained the support of TMI's staff and board of directors, it had been suggested that Buffington would be offered the lead for any new, formal initiative to promote this machine, whether it became a stand-alone for-profit or developed into a full-fledged program within the non-profit, an option that also offered certain advantages.

After ten months on the job, Buffington had concluded that designing a long term strategy for this project was not going to be as easy as he had originally anticipated, especially since progress in Tibet had been fairly slow and offered limited guidance on possibilities in other markets. Buffington's initial excitement with the apparent value proposition of the machine had become tempered with the identification of a growing number of challenges facing wide-scale promotion and expansion in the developing world.

Expecting a full report in two weeks, Walker poked her head in the doorway to Buffington's office. "What do you think?" she said. "Are we still going into the brick machine business?"

The Mountain Institute (TMI)

TMI (www.mountain.org) works to improve environmental conditions and the quality of life for local communities in mountainous regions throughout the world. Specifically, TMI has program offices in the Himalayas, the Andes and the Appalachians, working on full-time projects in at least seven countries with additional work in another four countries. TMI's annual budget is roughly $3 million. Funding comes from the US and foreign governments and private foundations.

Over the past three years, TMI had begun experimenting with business development efforts in both its Himalayan and Andean programs. Aside from the CEB machine effort, the office in Tibet is also investigating opportunities for economic development through the transfer of dairy processing know-how and promotion of eco-tourism. For these projects, TMI hired outside business consultants to perform market research and venture planning.

For his investigation of CEB machine opportunities, Buffington was also hired as an independent consultant. Throughout his time at TMI, his reporting requirements have remained fairly loose. For initial work involving Tibet, Buffington reported to both Elsie Walker, Director of the Peak Enterprise Program (which oversees all TMI activities in Tibet) and Gamesman Balachander, Director of TMI's Asia/Himalayan Program. For exploration of machine use in other geographies, Buffington reports to TMI's President and CEO, Catherine Nixon Cooke. (see Exhibit 1 for TMI's organization chart) Meetings for this purpose, however, were infrequent and sporadic.

Since Buffington began work for TMI, expenditures for promotion of the CEB machine have been limited to ongoing work in Tibet and Buffington's compensation. As of Spring 2003, Buffington's compensation remained the only substantial expense involving the machine effort. This compensation was taken from limited, general funds that have not been earmarked for other specific purposes. It was anticipated that new funds would need to be found by the end of 2003 to continue work with the CEB machine. Buffington, who works out of TMI's Washington headquarters, is free to seek input from other TMI employees. Buffington, however, is the only person dedicated to machine promotion.

Overview of Earth Building

The use of earth in construction has been significant throughout human history. In addition to the creation of simple shelters, many of the world's great feats of construction involved the use of mud or dirt. The Great Wall of China (246-209 BC) was built of earth along most of its route. Hannibal's watchtowers, built with compressed earth in Europe in 300 BC, stood for more than 600 years.

In both ancient times and today in many developing countries, builders have relied on two primary earth-building techniques. One, commonly referred to as "slip-form", involves the building of walls in place using frames. Mud is packed into a long rectangular form to create a section of wall. Once it dries and becomes hard, the form is used again to place another section of wall on top of it. In this manner, the structure is built from the bottom up in a series of two- to three-foot high sections. The horizontal lines left by this approach are clearly visible in housing throughout the world. A second technique involves the use of

forms to make individual blocks, which harden and are then stacked into place once construction begins. Due to the low cost and the fact that these techniques lend themselves well to building by the homeowner, these types of mud construction have remained popular in many parts of the developing world. It has been estimated that half of the developing world lives in houses that rely on mud during construction.

Earth building was significantly advanced in the 1950's with the mechanization of block production. These compressed earth block machines (or CEB machines) are either manually operated or engine driven, and rely on high pressure for block making. Manual machines utilize a large lever that can be pulled by one or two people to compress blocks. The CinvaRam was the first manual machine and has been used in Central and South America as a low cost way to build higher quality structures than previously used earth building techniques.

Engine-driven machines use a hydraulic ram for block compression. The high pressure improves the strength and durability of the bricks and the structures they create. Before the 1980s, however, engine-driven machines were not used as widely as manual machines due to cost and the frequency of machine breakdown.

The CinvaRam Manual Machine

The Hydraform M7

In the 1980s and 1990s, several higher-quality engine-driven CEB machines were introduced to the market. Some involved a novel feature that reduced construction time and lowered costs. Bricks created with these machines were interlocking, containing "tongues" and "grooves" that allowed the blocks to slide into one another. This feature allows builders to eliminate mortar between rows of blocks. Elimination of mortar can reduce the building costs for simple structures by an estimated 5 to 25 percent in developing countries where labor costs are low. Operations in at least three countries developed improved interlocking block making machines. The most well-known is Hydraform in South Africa, which developed not only a durable machine, but also obtained certification of their blocks under South Africa's National Building Regulations, increasing credibility and world-wide acceptance.

Nearly all CEB machine producers have central manufacturing operations that ship machines to their international customers. Today, the most basic engine-driven machines typically retail from between $10,000 and $15,000, not including the shipping price. Manual machine can retail anywhere from $375 to $2,000, depending upon the quality of the machine and the size of the block that the machine creates.

Typically, earth building uses soil at the site of construction, eliminating many of the material and shipping costs that occur with other building techniques. In addition, building with earth block requires less skill than most other building techniques, further lowering costs.

Since the introduction of mechanized machines, most manufacturers have recommended the use of a “stabilizer” in the block production process. A stabilizer improves block strength and resistance to water damage. The most common stabilizer is Portland cement, which can typically be purchased even in remote developing country settings. Additional stabilizers include fly-ash (a byproduct of burning coal and other industrial processes) and lime. A stabilized block will contain 5 to 15% of stabilizer, by weight. Although the use of machines and stabilizers increases costs compared to traditional earth building methods, modern CEB construction still keeps costs low relative to other building techniques and it greatly increases the durability of structures built with earth.

TMI Reinvents the CEB Machine

In February of 2002, TMI received a U.S. patent for its machine, designed by TMI board member Jim Underwood. Like many other machines, TMI’s machine produces interlocking tongue and groove blocks. Unlike other machines, TMI’s is intended for manufacture in simple, developing country machine shops. When he designed the TMI machine, Underwood believed that existing machines, particularly engine-driven machines, were not appropriate for the populations that needed them the most. They were “unnecessarily complicated and difficult to repair in places without appropriate materials or training.” Of his design, Underwood said the following:

> *Our machine resulted from an effort to design an interlocking block machine that was safer, lighter, more portable, ergonomic in use, less expensive, adaptable to local power sources, and capable of local manufacture and repair. In essence, this machine was specifically designed for use in developing countries, with an emphasis on simplicity and engagement of local populations*. (see Exhibits 2 and 3 for more background on TMI’s Compressed Earth Block Machine)

The machine’s primary components are a steel mainframe with a ramming chamber and two sets of hydraulics. With engine, axle and wheels included, the machine weighs roughly 500kg. It can be operated by six or seven workers, of which two should be skilled or semi-skilled. One person operates the machine controls; two or three people mix soil for block making; one person monitors the hopper (where the soil is placed in the machine for block making) to ensure that the soil mix falls into the ramming chamber consistently and appropriately; and two more people remove blocks from the machine and stack them for curing. The tongue and groove blocks made by TMI’s machine can be stacked directly into the structure being built, saving time and labor cost.

Soil is mixed with cement and water either on the ground or in a large metal tumbler. Depending upon the specific characteristics of the soil used and the particular inclination of the builder, 1 part of cement is used for every 11 to 15 parts soil. The bricks achieve 70 percent of their total strength after a week of curing, the chemical process by which cement becomes hard. Interlocking CEB blocks may, however, be stacked into a wall directly from the machine. Bricks reach their full strength after four weeks of curing. After curing, blocks weigh roughly 10 kg and are 220 mm wide x 115 mm high x 50 to 240 mm long, making them equivalent to three to five traditional clay bricks.

When asked why he decided to design an engine-driven machine rather than a manual machine, TMI's Jim Underwood sited the following: (1) manual machines do not achieve the compression strength and, therefore, block quality as engine-driven machines; (2) Tibetan builders did not want to buy manual machines; (3) the per block production speed is typically two to three times slower than engine-driven machines; and (4) the blocks produced are half to a third the size of blocks produced by an engine-driven machine.

A number of staff members at TMI's Washington office felt that TMI's new CEB machine could potentially support a stand-alone, self-sustaining enterprise. The argument was based on the apparent value proposition that the machine would offer to any manufacturing partner and customers who would use this machine for building projects.

The Market for CEB Machines

While some interest has been shown in the United States in the use of CEB (and other alternative or green building techniques) in the past few years, the need for and familiarity with low cost, earth building appears far greater in developing countries. In the developing world, the United Nations Centre for Human Settlements (UNCHS) has estimated that 1.1 billion people are living in inadequate housing conditions in urban areas alone. UNCHS also estimated that approximately 21 million new housing units are required each year in developing countries to accommodate the expected growth in new households during the time from 2000 to 2010. An additional 14 million units would be required each year to end the existing housing deficit by the year 2020.

Examination of Low-Cost Housing Markets for India and Mexico

In preparation for promotion of its machine outside of Tibet, TMI has investigated opportunities in both the Indian and Mexican markets. According to the 1991 Census for India, 3.41 million households are without shelter and 10.31 million households are living in "unserviceable" houses. Thus, the total housing shortage was 13.72 million in 1991. It has also been estimated that another 10.75 million houses would be needed to cover the population growth from 1991-2002, an annual growth rate of 0.89 million homes. By extrapolation from the available data, it can be estimated that there is a deficit of 24.5 million homes in 2002.

According to the State of Mexico's Housing, a report by the Joint Center for Housing Studies at Harvard University, during the 1990s, the total number of new households in Mexico grew by more than 3% per year. This figure does not include replacement or repair of existing homes, which could push the percentage of new home construction sites as high as 6 to 10% of the total number of houses. The majority of growth in Mexico was focused on low-cost building materials of higher quality, a movement fueled largely by the increase in total wealth of Mexican populations over the last 30 years. During the period from 1970 to 1995 the share of houses constructed of block, brick or stone rose from 44.2% of the total housing stock to 75.7%. The share of adobe (traditional earth) houses fell from 30.1% to less than 15%.

To date, stabilized CEB has gained only a very small percentage (far less than 1%) of the housing market. Worldwide, CEB machine sales are estimated at less than 3,000 per year.[1]

[1] Due to the difficulty in obtaining information on sales in developing countries and the need to aggregate estimates from a number of different sources, these sales figures rely heavily on anecdotal information and educated guesses from people in the field. In India, the current market for CEB machines is estimated at roughly 250 to 300 machines per year ($700,000) and growing from 25 to 40 percent a year, according to Development Alternatives, a nonprofit organization that promotes use of sustainable technologies. In Mexico, the market for CEB machines has been estimated at 150 machines per year ($1.2 million) with a growth rate of roughly 30 to 40 percent, according to Ital Mexicana (a manufacturer of CEB machines).

Market resistance to CEB is expected in certain developing country regions due to its association with low-quality, traditional adobe. In Peru, for instance, building materials are classified into "noble" and "non-noble" categories. Noble materials include stone, concrete and brick. Adobe (non-stabilized earth) is in the non-noble group of materials. Anecdotal experience suggests that, without significant market education, stabilized CEB would be treated as a non-noble material even though its quality and even its appearance may lead one to think it deserves noble distinction. In Tibet, builders exposed to stabilized CEB initially assumed that it was of lower strength than concrete block, although this has not been determined scientifically and any minor differences in laboratory strength may not be meaningful in actual use.

The following groups have purchased CEB machines:

- *Nonprofit organizations*—Although the total percentage has not been calculated, nonprofit organizations are thought to purchase a large proportion of CEB machines sold. They may purchase directly for their own development projects or may purchase on behalf of local operations, helping to encourage local development and entrepreneurship.

- *Local Developers/Construction Companies*—As is expected to be the case with other developing countries, the Indian and Mexican markets have a large population of small- and medium-sized builders. Typically, these builders use oven-fired clay brick or cement block, but have expressed some interest in CEB machines.

- *Governments (Local, National and International)*—Government bodies have also purchased a number of CEB machines, particularly in response to natural disasters, such as after earthquakes in India. In Tibet and mainland China, TMI has received significant interest from a number of government entities concerned with housing. TMI expects the rammed earth effort in Tibet will also benefit significantly from China's interest in modernizing the region.

- *Development Agencies*—Several development agencies have used CEB machines for assistance projects, such as the United Nations Development Program in India. Other organizations that have expressed an interest in the technology include the Asian Development Bank, the Inter American Development Bank, and the World Bank.

Sales of machinery that make building material for low-income housing are typically driven by machine price, cost of use in the construction process, interest of the housing market in the material produced, and ability to service the machine. Significant resistance has been shown over the last twenty years against manual machines, which builders and homeowners assume are lower quality than engine-driven machines.

TMI expects its machine will be priced between $4,000 and $6,000. Buffington's research suggested that this price range is competitive with other engine-driven CEB machines as well as with equipment used for most other mainstream building materials, such as concrete block and clay brick.

Competition with Other CEB Machines

TMI's new machine will compete against a number of for-profit and nonprofit CEB manufacturers (see Exhibit 4 for a comparison of key competitors). Like other machines, TMI's machine makes blocks out of dirt (which can be taken directly from the building site), water and a stabilizing agent (such as Portland cement, industrial fly-ash, or lime). Even in countries where use of CEB machines has been greatest, it has been estimated that no company or organization selling this product has captured more than one percent of the total market for construction of low-cost housing.

Hydraform

Hydraform, a privately held company based in Johannesburg, South Africa, is likely the most well-known and largest producer of machines that make stabilized earth blocks... Hydraform machines have been sold in Argentina, India, South Africa, and several other African countries. Like other companies serving the market for engine-driven CEB machines, Hydraform manufactures at two central location and then ships, often internationally. In 1995, Hydraform launched a manufacturing operation in India. According to Development Alternatives, a nonprofit organization that promotes the use of appropriate technologies, Hydraform India sells roughly a dozen machines a year at a price of roughly $9,000. Hydraform appears to market largely on the social benefits of the machine. Of its customer and operations, Hydraform India has said the following:

> *Hydraform works in tandem with international/multilateral aid and development bodies who consistently look for effective, efficient and professional organizations to work as channel, technical, and implementation partners for various rehabilitation, shelter, employment and social/economic empowerment programs.*

Development Alternatives has estimated that a builder using the Hydraform machine can make roughly $6,500 in profits per year (not including the initial cost of the machine), allowing for capital payback in the second or third year of use. Although this profit seems attractive, Development Alternatives has suggested that the initial price tag severely limits Hydraform's ability to sell machines to homebuilders in the Indian market. The high price tag could be particularly burdensome for small- and medium-sized builders.

<u>Ital Mexicana, S.A.</u>

Located in Mexico City, Ital Mexicana is a manufacturer and distributor of building equipment, primarily concrete block machines. Ital Mexicana began to sell hydraulic CEB machines in the late 1990s. Since 2000, the company has sold roughly 150 machines, primarily to projects focused on creating social interest housing. CEB sales represent a very small percentage of Ital Mexicana's total sales. The more high-end of the two machines, which makes upwards of 1,500 blocks/day, sells for roughly $20,000. For many social projects, however, this machine has been sold at a discount of 30%. A low-end machine, which makes roughly 600 blocks/day, sells for roughly $6,000.

Auroville Building Centre

The Earth Unit at Auroville Building Centre, located in Madras, India, sells a number of manual CEB presses. As with other CEB machine manufacturers, the vast majority of these

sales go to humanitarian organizations, particularly for rebuilding of disaster areas. Auroville machines have sold on a limited basis in other parts of Asia, Africa and Europe. These machines have interchangeable molds that allow for a wide variety of block shapes and sizes. Auroville sells the basic frame for roughly $1,000 and then the individual molds for anywhere from $300 to $900 apiece. Although the Auroville machines have made some headway, selling as many as 100 units a year, Development Alternatives says that builders have a strong bias against manual presses in India. The primary reason for this bias is the poor quality associated with the machine, real or perceived. This bias also exists in the Mexican market, according to Ital Mexicana.

ApproTec

The nonprofit organization ApproTec sells a manual machine in sub-Saharan Africa called the Action Pack for $375. Four workers can make roughly 1 block per minute using the machine. Blocks made using this machine do not include a tongue and groove feature, so mortar must be used between rows of bricks for construction.

Alternative Low Cost Construction Technologies and Techniques

In addition to other CEB manufacturers, TMI will be competing against a number of traditional machines and methodologies for production of low-cost, high-quality building material, such as concrete block and oven-fired clay brick. Although these technologies have tremendous popularity throughout the developing world, CEB appears to offer an equal or greater profit margin in most developing country construction sites and it has a far more attractive environmental profile. For example, builders in Tibet estimated that profits could be as much as 10 to 30% higher using CEB as opposed to other building materials. Similar figures were found after analysis of conditions in Mexico and India.

Adobe (Traditional Earth Building)

Adobe (or molded mud), produced by a variety of methods, is commonly used throughout the developing world. Unlike compressed earth, adobe does not use a stabilizing agent such as cement. Typically, adobe is made in block-form (similar to stabilized CEB) or using the slip-form technique (where forms or frames are placed atop a building's foundation and mud is smashed in-place from above to form walls). Adobe blocks made by machine are typically considered of higher quality than adobe made by slip-form or some other technique involving frames.

Adobe machines sell for roughly $500 in Tibet, which appears comparable with prices in India and Mexico. In both India and Mexico, adobe machines are sold by large equipment manufacturers for the commercial construction industry and by smaller, local operations (which often imitate machine designs of the larger equipment manufacturers). Compared to stabilized CEB, adobe has a lower density and lesser resistance to water. Thus, adobe is more susceptible to damage from flooding and weathering, and typically requires frequent repair. Adobe is predominantly used by small, rural construction companies or individuals building their own home. Construction companies tend to favor machines; individuals forced to build their own homes typically must rely on the use of forms. In Tibet, manufacture of an

adobe block (using a machine) costs roughly half of what it costs to manufacture a compressed earth block, due primarily to the cost of cement. Five laborers are typically required to operate an adobe block machine. Due to the quality limitations of adobe, most developing country builders and homeowners tend to consider it an inferior product. Those who can afford another material typically do not buy adobe.

Theoretically, handmade adobe can be stabilized with Portland cement. However, the process is very difficult and tends to produce low-quality blocks. The problem with stabilization of traditional adobe lies with the difficulty in thoroughly hand mixing the cement and mud, which must contain significant moisture in the absence of the high compression strength offered by a CEB machine. To avoid this problem, mud and cement can be mixed by machine. However, mixing machines can cost several thousand dollars. With a CEB machine, the soil is relatively dry and easy to mix with cement.

Clay Brick

Oven-fired clay brick is used extensively throughout the developing world for affordable construction. Brick making in both India and Mexico is a traditional, unorganized industry, generally confined to rural and suburban areas. Like CEB, clay brick can be used for simple construction with little or no need for reinforcement in areas that are not seismically active. Brick is also commonly used for non-load bearing walls in apartment buildings and other larger construction projects. Although individual bricks are more likely to cost less than CEBs, a number of factors affect the total cost comparison. For example, a single clay brick occupies roughly 1/3 the wall space of a single block from the TMI machine. In addition, clay bricks are usually created at a specific location, requiring transportation to the building site.

According to Ignacio Landa, a developer in Monterrey, Mexico, once these factors are considered, stabilized CEB can be cost competitive with or even cheaper than brick. According to TMI's building contacts in Tibet and Jack Blanchette, Coordinator for Construction and Appropriate Technology at Habitat for Humanity Asia, building with CEB will typically be cheaper than building with brick. Total costs for use of brick, however, will vary widely from market to market.

Throughout the world, clay brick is also under fire for its poor environmental performance. In developing countries, the ovens used for baking bricks typically burn highly polluting fuels, such as high-sulfur coal, industrial waste, and wood. This contributes to local air pollution and total amount of greenhouse gases in the atmosphere. A number of regions in China are now banning the use of oven-fired clay brick due to environmental concerns. Several other local and national governments have discussed adopting similar regulations or manufacturing restrictions.

Concrete Block

Concrete block is widely used in construction of affordable dwellings throughout the developing world, particularly Africa and Latin America. According to Chumpe Tsering, one of TMI's development contacts in Tibet, concrete block construction is slightly stronger than CEB construction. Dan Brundage, an engineer who works on building issues for TMI, feels that CEB construction is the stronger technique. Brundage believes Tsering's statement to be an assumption based on knowledge of adobe. Nevertheless, any small difference in strength

between the technologies appears to have no structural significance, says Brundage, particularly in non-seismic areas.

According to Tsering, after factoring in the costs of materials in Tibet, building with CEB could offer a larger margin than building with concrete block. A separate building contact in Tibet, Wang Du, offered a cost comparison between CEB and concrete block in terms of the total construction cost divided by square meters of development. According to Du, concrete block construction costs US$148 per square meter, while CEB construction costs US$86 per square meter. In Mexico, concrete block machines sell for between $400 (for the simplest units that produce roughly 500 blocks/day) and $2,500 (which can produce as many as 1,200 blocks/day). The Mexican figures for machine cost and output appear fairly consistent with figures for Indian machines.

Like clay brick, concrete block has significant environmental impacts. Cement manufacture is very energy intensive, resulting in local air pollution and high greenhouse gas emissions. Cement also requires mining of limestone and other materials used as raw ingredients and mining of coal for fuel use. Mining occupies valuable land and harms local ecosystems. Jim Underwood, the designer of TMI's machine, has estimated that use of CEB that is stabilized with cement reduces total cement use by 50% compared to use of concrete block.

The Tibetan Test Case

TMI began testing use of the machine in Tibet in 2000. Early efforts involved three prototype machines manufactured in the U.S. and shipped to Lhasa. The machines were used for the construction of two cottages in Tibet's second largest city, Shigatse. This construction served as training for 10 to 15 small and medium-sized developers interested in learning about building with CEB. After the training, the machines were loaned to two of the developers who attended. Since the initial building, several additional structures have been built by these developers (see Exhibit 5).

In August of 2002, TMI transferred the ability to manufacture and sell the machine to a small machine shop in Lhasa. This operation expects to be able to expand its business with this new capability. Under a three-year licensing agreement (to be reviewed in 2005), the machine shop has full liberty to set its own price and primary responsibility for generating new sales leads. For each sale, TMI will be paid a fee of 10 percent of the total sales price. Buffington sees this fee as somewhat high, but feels it is a necessary charge to help cover both the technology development and assistance with market development. TMI offers connections and know how that can help drive initial machine shop sales to other non-profit organizations operating in Tibet.

Due to concerns over market potential and political sensitivities in Tibet, this operation will remain part of TMI's non-profit activities. TMI has a number of projects in Tibet that would be affected if any one program offended local authorities. For this reason, TMI's policy in Tibet is to avoid confrontation in order to preserve program development. Therefore, the arrangement with the Lhasa machine shop will only concern TMI's for-profit aspirations to the extent it can inform new sites for manufacture and promotion.

Manufacturing cost for the machine shop in Lhasa, including the cost and shipping of hydraulics and attachment of a trailer and diesel engine, for the first few machines was

roughly 17,200 RMB ($2,100). The labor portion of this cost (just under 20% of the total) is expected to fall as much as 25% as workers gain experience. The machine shop has decided to make inclusion of the Chinese-made diesel engine and an axle with wheels and a trailer hitch standard with each machine. This adds a total cost of roughly $400 to each machine ($125 for the axle and $275 for the engine), which is recognized in the $2,100 figure above. Although readily available and extremely cheap compared to diesel engines available in developed countries, the Chinese engine can break down frequently requiring repair or replacement.

For the Tibetan effort, the hydraulics for the machines are being purchased from Chengdu in mainland China (see Exhibit 6 for a map of TMI's operations in and related to Tibet). TMI was not able to identify a hydraulics manufacturer in Lhasa capable of producing the high-quality hydraulics selected for use in the machine. A TMI volunteer, who covered all of his own travel expenses, spent several days with this hydraulics manufacturer to ensure that the new products met the intended specifications.

To attract interest, the machine shop has agreed to offer a two-year warranty on the sale of its first dozen machines. This warranty does not cover the engine and will not cover instances where it has been determined that damage occurred from improper use or abuse of the machine, which can often be detected by inspection. The hydraulics, the most expensive item covered under the warranty, have an estimated useful life of 5 to 7 years.

To transfer the manufacturing capacity and set-up the necessary business arrangements, TMI relied on a team of several employees and key members of its strategic partner in Lhasa, the Tibet Federation of Industry and Commerce (ICF), a Chinese government agency that oversees development efforts in Tibet. Foreign operation in Tibet cannot occur without the approval and involvement of ICF. All but one of TMI's employees involved in the effort are based in the United States. TMI's local employee, Chris LaDue, acted as liaison for all efforts and was instrumental in selecting the machine shop.

Jim Underwood, the machine's inventor, trained machine shop workers on manufacturer. Buffington arranged the formal agreement between the machine shop, TMI and ICF and began initial sales efforts. One other TMI employee and another TMI volunteer were also involved in the effort. Now that initial experience has been gained in the technology transfer process, Buffington would not expect to use so many different parties to set-up any new site for machine manufacture.

Chris LaDue, program manager of TMI's Tibetan program forecasts sales for the machine shop as follows: 70 machines in Year 2, 110 machines in Year 3, 150 machines in Year 4 and 190 machines in Year 5. These estimates are based on the market for building in Tibet alone. After several months of research on the market in Tibet, Buffington has since concluded that these estimates are probably aggressive. However, having limited marketing data available and no capital for detailed market research, Buffington cannot confidently offer a more "realistic" projection. The machine shop's current capacity is roughly 50 machines per year, and LaDue felt that additional capacity could be added as demand increased.

In Tibet, TMI has focused initial sales efforts on small- and medium-sized developers and foreign non-profit organizations. According to information from the Tibet Federation of Industry and Commerce, there are approximately 300 construction companies in Tibet. The majority of these are small- and medium-sized enterprises. For the year 2000, total revenue for construction companies in Tibet was estimated at 668,737,000 RMB (US$82.6 million)

and total profit was estimated at 86,810,000 RMB (US$10.7 million). The construction industry has grown by roughly 10% per year in Tibet for the past five years. This level of growth is expected to be maintained or increased due to China's "Develop and Open the West" policy, which calls for massive infrastructure development in Tibet over the next 10 years.

If necessary, TMI may choose to use local distributors for product promotion. At least in China, these distributors are little more than independent stores that have been established as the place for certain types of goods. A store that sells construction equipment in China typically seeks a mark-up of roughly 30%.

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At the machine shop in Lhasa, machines are made to order and shipped directly to the customer. The customer will be expected to cover the cost of shipment, both in-country or abroad. With its strong spring-loaded axle, this machine can be pulled behind a vehicle (for local transport) or set in the back of a truck for long distance transport. In order to grow total sales and seed interest in the machine in other regions, TMI has begun talks with several interested parties throughout Asia. International shipment, however, should only be necessary for unusual events or in advance of setting up a new manufacturing operation. In these cases, TMI may choose to cover the shipping costs.

Challenges for TMI's CEB Venture

Armed with the experience in Tibet, Buffington now needed to make decisions regarding the future promotion of the CEB machine. He realized that TMI's work in Tibet provided important lessons on key challenges that must be addressed in order to successfully expand this venture to other locations.

Production

As of late January, 2003, TMI's sales activities in Tibet were on hold while the machine shop works to solve technical glitches with the first few machines produced. The machines have been working well enough to build a few small structures, including a dairy processing plant, but not well enough for the machine shop to comfortably provide warranty support. Problems have included slower than expected block production and overheating, for which improper installation or maintenance of the hydraulics have been suspected as the likely culprit.

Underwood, TMI's machine inventor, and Dan Brundage, a retired naval engineer who volunteers time to TMI, have assured Buffington that these issues are only "small bugs expected with any start-up manufacturing operation" that can easily be solved and avoided in the future. "We should have budgeted for more time to spend with the machine shop working actively with them to solve these problems and to make sure that they could competently train customers on how to maintain their machines in good health," says Underwood. For future instances of manufacturing training, he has recommended an extra month on the ground for debugging. "Unfortunately, our Tibetan partners are not exactly used to self-empowerment. This means that small, solvable problems can take a long time to fix."

Promotion

Looking to borrow wisdom on the challenges facing promotion of "appropriate technologies", Buffington has consulted a number of organizations in the field. One

insightful correspondence was with Martin Fisher, cofounder of ApproTec, which sells manual earth block machines, micro-irrigation systems and other relatively inexpensive products in sub-Saharan Africa. When asked why he does not operate as a for-profit, Fisher said that the products he sells require far too much hands-on marketing and training for the relatively small profit per unit he achieves.

Since ApproTec's products are intended for use by entrepreneurial individuals (rather than an existing business or some other intermediary, as would be done for the rammed earth machine), it focuses on technologies that will retail for $300 or less. Once a technology has been designed, ApproTec teaches a local machine shop or small-factory how to make the technology. This manufacturer is typically located in the largest city of a given sales region. ApproTec then buys the product leaving a profit margin of roughly 25 to 30% for the manufacturer. ApproTec then sells the product at a mark-up of 35% to any of a number of retail outlets, which have been educated by ApproTec on marketing and selling the product. These retailers are rural "general stores" that sell a wide variety of products to local markets. These stores typically receive a margin of 16% on the sale of ApproTec products. Fisher says that his organization can spend up to two to three times what they make in revenue on marketing for a given product.

Piracy

Those involved with the machine effort at TMI have worried that the simplicity of the design leaves it vulnerable to copying by would-be competitors, particularly in the developing country regions where TMI intends to have the technology manufactured and distributed. Buffington also discussed this subject with Martin Fisher of ApproTec. Fisher explained that when a product is novel and unproven to the local population, the marketing burden is high and there is little incentive for someone to try to pirate the technology. As it catches on, however, copiers are expected to emerge. Fisher seemed unconcerned about this. In fact, if the ultimate goal is market development, piracy and increased competition could serve as a measure of success for his non-profit organization's activities.

Licensing Agreement

TMI expects that its licensing arrangements could create an incentive for a local TMI-selected manufacturer or distributor to try to eliminate TMI from sales involvement after initial manufacturing hurdles have been cleared and demand was growing. Buffington hoped TMI could discourage this by building machine shop loyalty and engaging government entities in technology transfer and market development activities. Along with technology transfer, TMI also has the opportunity to improve business practices at the machine shops. Machine shop employees, including managers, typically have little or no formal business training, and may not even have much basic education. These operations could benefit greatly from extending their knowledge on operations, finance, marketing, and other business concerns that are more familiar in developed countries. In past projects, TMI had successfully leveraged participation from government agencies, which have a special interest in assuring that the projects they are involved with run smoothly so as not to lose face.

Managing from Afar

The CEB venture will be headquartered in TMI's Washington, DC, office, an ideal location for networking with socially motivated nonprofits, government entities and international organizations (see Exhibit 7 for a project budget submitted by TMI to the U.S. Department of State for work in Afghanistan). To the extent possible, Buffington is aiming to utilize resources on the ground in developing countries to meet its operational needs, minimizing staff and activities at headquarters. While strategic decision-making and general venture

direction would come from TMI's headquarters, machine manufacture, shipment, training, and distribution would occur in the specific markets of interest.

Lack of a significant local presence, however, could reduce TMI's ability to coordinate with appropriate players. Francesco Piazzesi of Ital Mexicana, which produces CEB machines for the Mexican market, stressed the importance of having relationships with industry, government officials and mortgage loan providers. With several decades of operations, Ital Mexican has built these relationships. For this reason, Buffington thought he might initially focus on those geographies where TMI operations already exist. TMI currently has formal operations in India, Nepal, Peru and the United States and coordinates on efforts in a number of other countries. Relationships with national authorities, industry leaders and other organizations are probably most developed in Peru, where TMI has been working closely with government officials and a number of mining operations.

The Path Ahead

The marketability of CEB machines is greatly enhanced by their potential to contribute to sustainable development. This may be particularly true with the TMI machine. Based on its experience manufacturing and using the machine in Tibet, TMI has estimated that each of its machines, over an estimated useful life of 10 years, could result in $2,600 in profit (assuming no additional costs for marketing) for a manufacturing partner; the construction of 225 homes; and 1,125 people living in these homes.

TMI's simple machine design also allows for manufacture in developing countries, where technical skills may be relatively low and sophisticated machine components may not be readily available. Local manufacture will create jobs for local populations and greatly reduce machine cost for customers. Currently, TMI has made no attempts to quantify environmental benefits or the impact on the local economy, but believes both to be significant.

Looking across his desk at Elsie Walker, Buffington reflected back on what that he had learned over the past 10 months. He still was not sure what the best approach was for TMI. He knew, though, that he had only a few more weeks to put together a plan that charted the path forward for the CEB venture.

Exhibit 1: TMI Organizational Chart

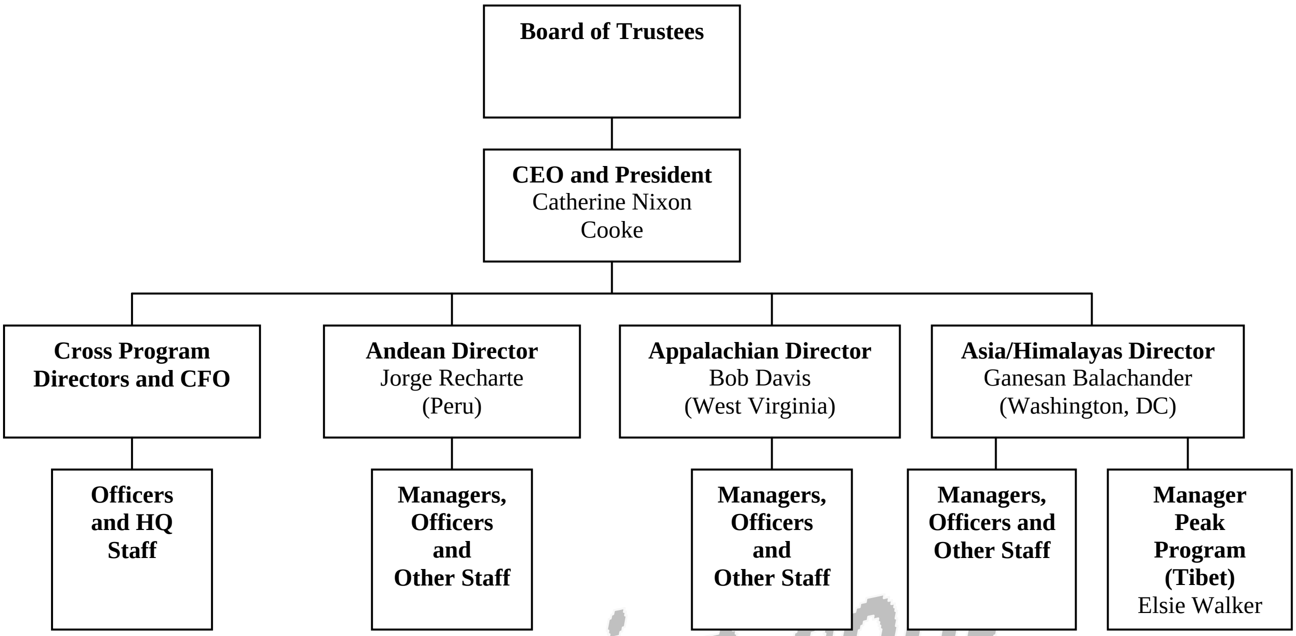

Exhibit 2: TMI's Machine Information Brochure

TMI's Compressed Earth Block Machine

The Mountain Institute (TMI) offers the ideal machine for creating affordable, environmentally-sensitive building material for the developing country setting. Unlike other machines, our patented rammed earth machine was specifically designed for developing country challenges—low incomes, rugged environments and a deficit of skilled labor. Its secret is simplicity! With a minimal number of parts, our machines are low-cost, easy to use and easy to transport. Using dirt as its primary ingredient, compressed earth block keeps building costs low and can replace other building materials whose ingredients may harm local environments.

Aside from offering affordable, reliable housing to communities, use of our machine serves as a tool for economic development. Through partnering, TMI will transfer the ability to make this machine to local enterprises, empowering a new generation of entrepreneurs and employees.

Exhibit 3: TMI Marketing Brochure on Machine Specifics

The TMI Compressed Earth Block Machine

- Interlocking tongue and groove feature on blocks allows for "dry stacking," greatly reducing the need for mortar and costs
- Makes 120 blocks/hour
- Requires 6 to 8 workers, only 1 or 2 need to be skilled
- Weighs ~500 kg and is readily disassembled and transported
- Hydraulic pressure can be easily adjusted to allow for highest quality brick production and flexibility with various soil types
- Designed to provide worker comfort and encourage efficiency
- Blocks meet Universal Building Code standards, with a compressive strength of 4 to 5 Mpa for blocks with 5 % cement
- Can be readily coupled with local power supplies; simple design allows for local production and minimizes servicing
- Block size: 220 mm (width) X 115 mm (height) X 50 to 240 mm (length)

First machine produced in Lhasa, The Tibet Autonomous Region, China.

Exhibit 4: Table of Competitors

Organization/ Company	Price	Power	Output Blocks/hr	Tongue and Groove	Local Manufacture	Axle w/ wheels standard	Engine Used
Private Companies							
Hydraform	$9,000 to $13,000	Hydraulic/ Engine Driven	180	Yes	No (plants in South Africa and India)	Yes	High quality, may not be locally available
Ital Mexicana	$6,000 to $20,000	Hydraulic/ Engine Driven	75 to 190	No	No	Yes	High quality, may not be locally available
Foxfire	~$12,000	Hydraulic/ Engine Driven	180	Yes	No	Yes	High quality, may not be locally available
Eco Brick Systems	$14,250 to $12,375[c]	Hydraulic/ Engine Driven	300	Yes	No	No	High quality, may not be locally available
Nonprofit Organization or Academic Institution							
Auroville Building Center (Academic Institution)	$1,000/ machine + $300 to $900 each for molds	Manual	90 to 180[b]	No	No	NA	NA
ApproTec (Non-profit Organization)	$350 (in Africa)	Manual	90[b]	No	NA	NA	NA

a. Several of the entries listed here have a number of machine types. If only one price is quoted, then the information refers to the organization or company's most commonly sold machine. If a range of prices is presented, then the information for that entry refers to two or more machines or, as in the case of Hydraform, represents geographic pricing differences.
b. Size of manual machine blocks may be 2 to 3 times smaller than engine-driven machine blocks.
c. Eco Brick Systems' prices decrease to a floor of $12,375 depending upon quantity ordered.

Exhibit 5: Building Pictures

Chumpe Tsering in front of house he built using TMI's CEB machine (Shigatse, Tibet, China)

Exhibit 6: TMI's CEB Machine Operations in China

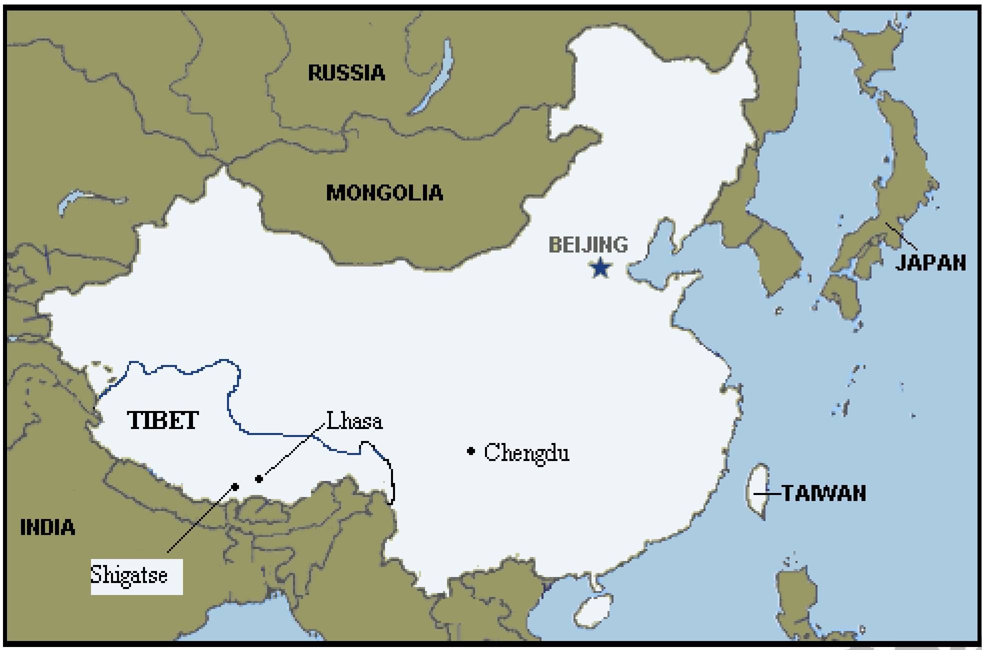

Exhibit 7: Afghan Project Budget (Proposal to the U.S. State Department's Bureau of Population, Refugees and Migration)

Project Management and Facilitation	
John Buffington's Salary (3 Full Months of Project Management)	13,500
Travel Related Expenses	
Airfare (roundtrip)	2,500
Per-diem and Lodging ($65/day for 20 days)	1,300
Translator ($25/day for 15 days)	375
Ground Transportation	200
Coordinator for women's inclusion in project (airfare, lodging, per-diem, translator)	7,200
Total	**25,075**
In-country Manufacturing Training and Machine Shop Marketing Assistance	
Manufacturing Expert (Jim Underwood)	
Airfare (roundtrip)	2,500
Salary ($200/day for 30 days in the field)	6,000
Per-diem and Lodging ($65/day for 30 days in the field)	1,950
Translator ($25/day for 25 days of use)	625
Ground Transportation	200
Shipment of Existing machine to serve as a template	5,000
Material and Labor for Four Initial Machines	10,000
Translation of Machine Blueprints	1,000
Development of Local Language Marketing Brochures	1,000
Correspondence with NGO and Relief Efforts for Machine Promotion	500
Other Machine Promotion Efforts	5,000
Total	**33,775**
In-country Building Training	
Building Expert (Jim Underwood)	
Airfare (cited in Manufacturing Training)	
Salary ($200/day for 60 days in the field)	12,000
Per-diem and Lodging ($65/day for 60 days in the field)	3,900
Translator ($25/day for 50 days of use)	1,250
User Manual Development/Translation	1,000
Building Expenses (Estimates considered conservative, based on info from contacts)	
Labor ($5/person/day for 20 people for 50 days)	5,000
Cement ($6/50 kg bag at 10 bags/building for 15 buildings)	900
Fuel ($10/full machine day of operation for 4 machines for 16 full days)	640
Roofing, doors, foundation material and other ($500/building for 15 buildings)	7500
Total	**32,190**
Office Materials and Supplies	**200**
Legal Fees (currently pro-bono)	
Total Direct Costs	**91,240**
General and Administrative (15% of Total Direct Costs)	**13,686**
Total Costs	**$104,926**
In-Kind Contributions to Project	
Dan Brundage's Airfare, Per-diem, and Lodging	7,200
Machine Donated by TMI for use in Training	5,000
Total Contributions	**12,200**