2015 WPI/IIT Project Center: Annual Report

Kamand, Himachal Pradesh, India
March 15—May 3 2015






History and mission of the India Project Center

In 2013, the Indian Institute of Technology (IIT-Mandi) and Worcester Polytechnic Institute (WPI) from Massachusetts, USA, established the India Project Center on the IIT's new Kamand Campus in the beautiful hills of Himachal Pradesh. The center unites 3rd year undergraduate students from each institution to collaborate on projects that engage the intersection of environment, technology, and society. The genesis of the Interdisciplinary Socio-Technical Practicum (ISTP) comes from two facts: One, the development of useful products and technologies requires an understanding of the socio-economic context in which they will be used; and two, the introduction of a technology often changes the society. Thus, it is essential that scientists and engineers understand the complex interaction of society and technology. Students learn that ethical and sustainable innovation can best be catalyzed through shared learning and open engagement between the end users and the designers.

Over the course of two months, our student teams investigated opportunities featuring urban and rural infrastructure, community resilience, public health, micro-economies, sustainable shelters, and regional communication technologies. They worked long hours to identify key stakeholders, conduct interviews, administer surveys, and build and test innovations for both process and product improvements. To that end, we wish to offer our heartfelt thanks the mentors from IIT Mandi that volunteered to guide each team through these processes. The constant support and encouragement of these mentors ensured that their respective projects operated smoothly and with all available resources throughout the term. We also wish to acknowledge our visiting WPI co-advisor, Dr. Lorraine Higgins, for her tireless work with each of the teams to streamline content and writing, and for spearheading the efforts to create this booklet. With the guidance and effort of the mentors, these 9 ISTP reports will pave way for our students to achieve critical learning outcomes that will shape their approach to science and engineering problems.

Finally, the WPI students and faculty are deeply grateful to our generous hosts at IIT Mandi. In particular, the Director, Prof. Timothy Gonsalves, the Dean of Academics, Prof. Ramesh Oruganti, and all involved faculty and staff for their warm welcome, and for ensuring that we had a most enjoyable stay. We are overwhelmed with the kindness shown to us during these two months.

Dr. Venkata Krishnan and Dr. Ingrid Shockey, Project Center Coordinators

Greetings from the Director of IIT-Mandi

Fifty years ago, WPI crafted a unique project-oriented undergraduate engineering curriculum. Five years ago, IIT Mandi devised a curriculum with a similar project-oriented flavor. It is destiny that has brought these two institutes in distant corners of the world together in the ISTP. The cultural diversity of the IIT-WPI project teams results in novel perspectives and solutions for the problems of the Himalayan villages. The cultural diversity of their team-mates enriches the education of the students, making them better engineers for the future globalized world.

I wish the students all the best! I hope that some of the ideas that have emerged during these ISTP projects will help to transform rural Himachal in years to come.

Timothy A. Gonsalves, Director, IIT-Mandi

The reports on pp. 1-100 of this booklet represent the work of WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its website without editorial or peer review. For more information about the projects program, see:

http://www.wpi.edu/academics/ugradstudies/project-learning.html

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Investigating the Kangra Valley Tea Industry

Abstract

In recent decades, Kangra Valley tea production has declined by 50%, predominately among farms less than a hectare in size. Our goal was to investigate small-scale tea production in this region and to develop suggestions and technical innovations beneficial to small estates. Stakeholders were interviewed and site visits were made to identify industry vulnerabilities. We designed a mechanical harvester to improve efficiency and reduce labor costs, and we recommended policy and marketing strategies to revitalize the Kangra tea market.

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Understanding Tea and its Decline in the Kangra Valley

Tea, the second most consumed drink in the world, is obtained from the *Camellia sinensis* plant. India is the second largest tea producer after China, and grows and processes over a billion kilograms every year, pre-eminently in the states of Assam and West Bengal (ITA, 2015). Though less well-known than other tea cultivating states, Himachal Pradesh has 2,000 hectares of land being used for tea agriculture (Figure 1). However, in recent years, Himachal Pradesh noted a significant decline in production.

Figure 1. Kangra Valley tea estate.

Most of the state's tea grows in the Kangra Valley, known as "the valley of gods". This Himalayan region produces black orthodox tea and green tea, considered some of the finest in the world (ibid). While Himachal Pradesh boasts a large area of land dedicated to tea estates, only half this land is currently in active production. Numerous challenges over the last century, including changing government policies, declining markets, climate change, and labor problems have burdened the farmers. According to the Tea Board of India, growers find it increasingly difficult to sustain their estates.

These concerns have caught the attention of the Tea Board of India and Indian Institute of Technology Mandi (IIT-Mandi) because tea production in the Kangra valley is closely tied to the economy of Himachal Pradesh. Therefore, the goal of this project was to investigate small-scale tea production in the Kangra Valley and suggest innovations beneficial to these small tea farms. The goal was achieved by first documenting the Kangra Valley tea industry; second, identifying strengths and vulnerabilities in small tea estates and in tea production processes; and third, developing criteria for implementing appropriate technology, and suggesting modification of existing government policies in relation to the tea industry.

Kangra Tea: History, Scope, and Production

In 1849, Dr. Jameson, the Botanical Gardens superintendent of North West Kangra, planted the first tea seedlings in Northern India. Three years later he established a commercial plantation near Palampur, which sprouted the tea industry in the Kangra region (Guar, 2008). There are currently over 5,000 registered tea growers in Himachal Pradesh, out of which only 1,200 are active according to government records. The majority of farm owners cultivate a hectare or less of land for tea. These tea growers and Kangra tea processing factories still use orthodox methods.

The tea process begins with the cultivation of the tea plant. It takes four years for the tea plant to fully mature before workers can pick the leaves. Once mature, the tea estates harvest the leaves approximately every two weeks. These harvesting periods are called flushes. The first flush, harvested in April, produces the most desirable tea (ibid). To harvest the leaves, workers pluck the tea branch's tip, removing two leaves and the apical bud (Figure 2). This allows the plant to continuously grow buds and ensures the youngest leaves are always picked.

In several large tea estates, automatic harvesters have modernized plucking, but in many cases workers still pluck by hand. Estates owners claim to pay 8 to 15 rupees to workers per kilogram of green leaf, or at a flat rate of about 200 rupees a day. Tea plucking is a time-consuming process and strains farmers and workers physically, introducing musculoskeletal issues in the hands and wrists from repetitive motion (Dihingia & Dewangan, 2012).

Figure 2. Freshly picked leaves and a bud.

After tea harvesters pluck the bushes, the leaves are processed. The orthodox tea method for black tea includes withering, rolling, fermentation, and drying, while the green tea method includes withering, steaming, rolling and drying (Figure 3). The lack of fermentation in green tea preserves the polyphenols, increasing the health benefits and market price (Suzuki, 2012, 88). While packaging tea, workers sometimes combine black with green tea to create a unique blend.

Unlike large estates and factories that use machines, small growers chiefly process tea by hand. Large estates and processing facilities can afford electric harvesting shears, withering troughs, rollers, and dryers to increase productivity and efficiency. Many factories process thousands of kilograms a day, while small tea estates struggle to produce a fraction of that. For example, factories use machine rollers that evenly apply pressure to the leaves for 30-45 minutes (UPASI, 2014). These machines can roll about 120 kg per load. In comparison, hand rolling requires small estate workers to roll leaves between their hands or to use bamboo mats, capable of producing 500 grams in 15 minutes (Sato, 2007, 1).

Some farmers with under a hectare of land sell their leaves to processing facilities. The facilities grade the quality of the leaves, paying the farmers accordingly. Processing facilities are currently not subject to regulated pricing.

When small estates process their own tea, farmers struggle to market their product. Kangra tea is not a well-established brand, and most of the tea goes into auction in Kolkata. Auction prices widely vary, which makes tea production an unreliable source of income. As a result, some farmers have abandoned their estates or only produce tea for their personal use.

In this project, we took into consideration the background information and problems noted in the cited literature and further explained to us by officials from the Tea Board. Exploring the similarities, differences, and relations of large and small tea estates enabled the team to

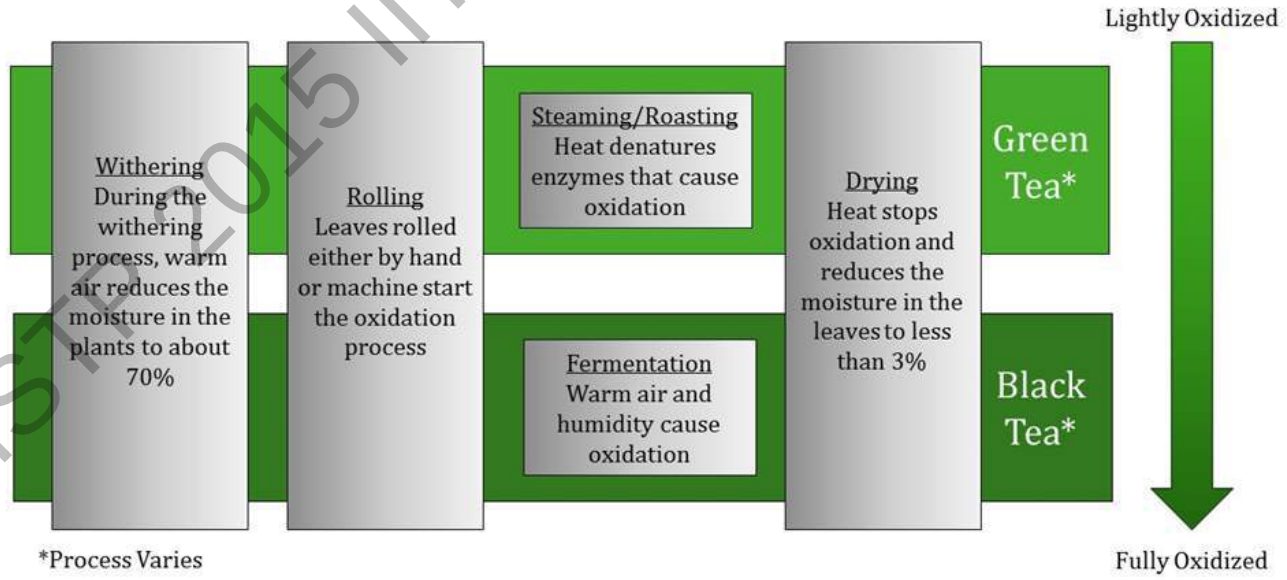

Figure 3. Green and black orthodox tea process.

understand the larger context of the Kangra tea industry before engaging in field work to study the industry in more detail.

Methodology: Strategies for Investigating the Industry

The goal of this project was to investigate small-scale tea production in the Kangra Valley and suggest innovations beneficial to these small tea farms. In order to accomplish this goal, we established several objectives:

- Documenting tea production and estates in the Kangra Valley
- Identifying strengths and vulnerabilities in small tea estates and in tea production processes
- Develop criteria for implementing technology and policies

We implemented several research strategies to meet each objective (Figure 4).

To begin documenting the tea industry, we first met with the Deputy Director of Himachal Pradesh from the Tea Board of India. This representative provided us with an overview of the processes in tea production and helped us establish contact with tea estates and facilities in the Kangra Valley. To collect additional data on the industry, we visited two larger estates and three processing facilities. During the visits to the large estates and factories we conducted semi-structured interviews with the owners and managers regarding the production process, and took photos of the estate and equipment.

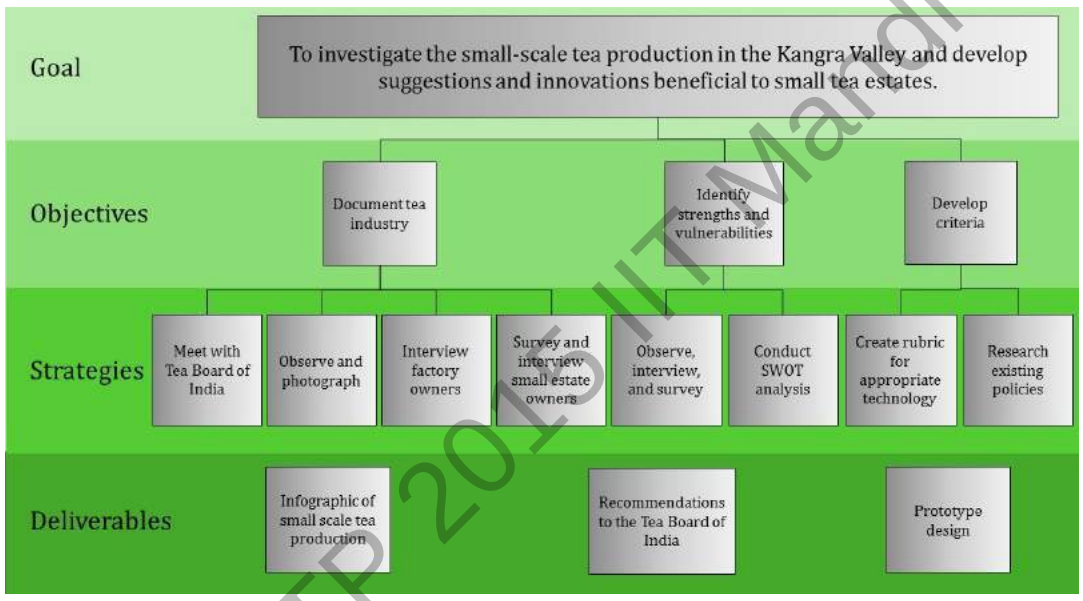

Figure 4. Methodology for project.

We then set a goal to meet with 30 small tea farms (approximately 3% of total growers), and actually met with 34 farmers. Using a directory of small growers provided by the Tea Board, seven villages were randomly selected from four blocks in Kangra district (Figure 5). Then we randomly selected six farmers from each village, allowing us to get a spectrum of representation. We selected more farmers than our goal, assuming some farmers would not be available. We used a survey to record demographic information, data about the farms and practices, and their perceptions on the role of the Indian government in tea production and the challenges they perceived in their work. The team split into small groups to interview the farmers. Interviewers (IIT students) recorded the farmer's answers on a paper survey and later translated for the team. During the documentation and interview process we took photographs of the small-scale tea production processes and the estates. Some of the interviews were audio recorded for reference and later analysis. Data was stored in a safe and secure location during and after the research was completed. During the whole process, farmers were disassociated from the data by using numbers instead of names to protect their identities.

Data was analyzed based on age, land size, location, and if growers sold or processed tea to

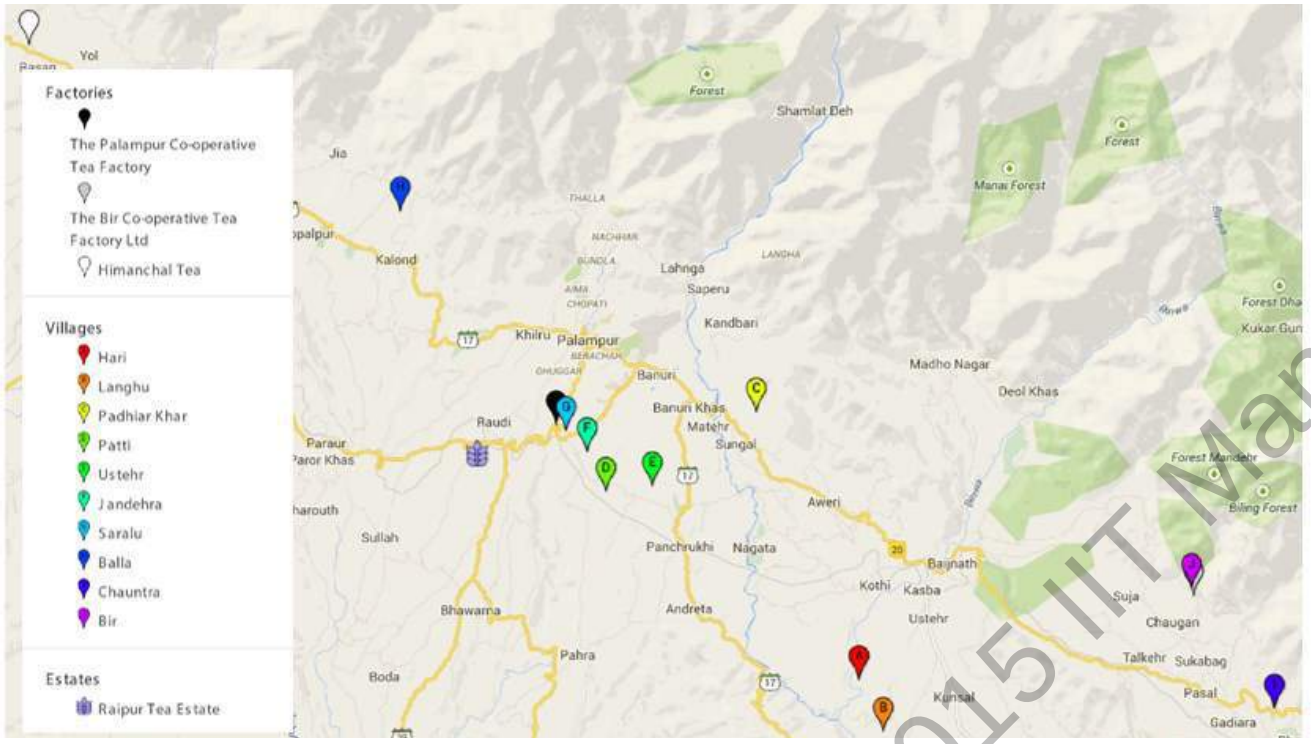

Figure 5. Map of sampled tea estates, factories, and villages.

see if these factors played a role in the processes they used and vulnerabilities they faced. A SWOT (strengths, weaknesses, opportunity, and threat) analysis of the data was used to identify major strengths and vulnerabilities affecting small tea estates.

Finally, we identified possible technological prototypes that could address these needs, and created a rubric of criteria for the prototypes design based on the above data collection. These criteria included not just practical and technical considerations but socioeconomic ones as well. We also created suggestions for the Tea Board, using the above analysis, policy research, and our insights about the biggest constraints for the growth of the Kangra tea industry.

Results and Discussion

Documenting the Kangra Tea Industry

The team began documenting the tea industry at two large estates and factories on the Raipur Tea Estate, and one factory in Sidhbari. Each estate was well-maintained and the factories were clean and sanitary. On average, the factories hired 8 workers, and each factory had the capacity to produce 5000 kg of tea a day.

We observed estate laborers harvesting leaves using two methods. To produce a higher quality tea, the laborers hand plucked tea leaves. Hand plucking ensured that the harvested crop primarily consisted of two leaves and the bud. For a lower grade tea, the workers used machine harvesters, which enabled two operators to collect 100 kgs/day. However, the harvester cost 26,000 rupees, was loud, and required fuel. It also gathered waste leaves (Figure 6). To increase processing yield, the

Figure 6. Workers use machine harvester to gather tea.

factories also bought plucked leaves from local tea farms. For example, the Sidhbari factory bought and transported sacks of leaves from ten separate farms by truck.

All three factories produced green and black tea. The exact protocol varied on the factory and type of tea, but each factory used large machinery to process the leaves. Standard equipment included withering troughs and fans for withering, rolling machines to twist the leaves, and conveyer-belt dryers and wood furnaces to dry the tea. These machines cost several lakh (100,000) rupees, and had a capacity of 125 kilograms per batch.

The factories sold their tea using two different methods. One owner sold to the Kolkata auction, the primary wholesale auction center in India. The owner informed the team his product was blended with tea from other states. The other owners created their own brands, Himalayan Brew and Himanchal Tea, within the past ten years and marketed their tea independently. Himalayan Brew targeted the national and international market, while Himanchal Tea focused on domestic markets. Although the large estates and factories were not included among our stakeholders, touring these facilities gave the team an overview of Kangra tea.

Small tea growers were our primary stakeholders, so data collection focused on field visits to 34 small estates in Hari, Langhu, Padiahar Khar, Patti, Balla, Saralu, Jandhera, and Ustehar. Interviews revealed diverse situations. The average garden size was 0.89 hectares, and the range was 0.005 to five hectares. Six out of 34 farms were inactive, overgrown with weeds, and the plants under maintained. Twenty-seven farmers actively harvested tea to produce at home or sell to a factory. While some owners regularly pruned their bushes, others estates lacked consistent maintenance. In several cases, bushes were uneven, making plucking difficult. In one circumstance, an estate leased land to another farmer to maintain and collect leaves. Due to labor and maintenance cost the estate owner did not profit from the lease agreement (Figure 7).

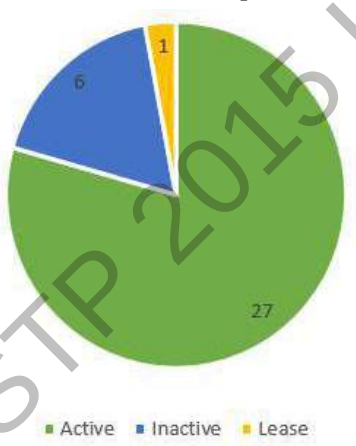

Figure 7. Small-scale estate activity.

Except for three farmers, tea growing was not the primary source of income. The majority of estate owners were retired mostly from government service jobs, and the mode age was 60 (Figure 8). The majority of owners were over 60. They relied on their family or laborers to tend crops and pluck leaves. Twelve out of the 27 farmers hired laborers to pluck the leaves for an average rate of 9 rupees per kilogram or 230 rupees a day.

Every active farmer interviewed produced tea at home in some capacity. Only four produced green tea; however, several farmers expressed interest producing green tea if given educational training. With the help of their families or laborers, the majority of estates plucked the tea by hand. One farmer claimed to use

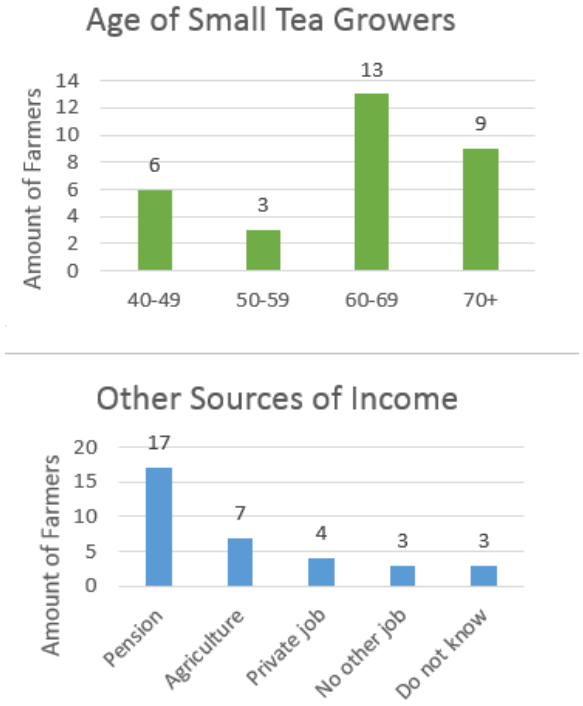

Figure 8. Estate owner demographics.

shears to harvest the leaves while another had a diesel-powered harvester he used when he did not hire laborers. The withering process took place inside a cool room or in the shade. After withering, the leaves were hand rolled with cloth or a bamboo mat. In Langhu and Ustehar, several tea growers sent their tea to a nearby factory to have it rolled. The factory charged 175 rupees per batch (70 kg) for rolling and additionally 200 rupees for transport. In many estates, fermenting and drying were simultaneously done. Farmers placed the rolled leaves on a mat on their roof and left the leaves for several hours.

Since tea was generally viewed as unprofitable by small farmers, 41% of active farms produced tea for personal use only, though in the past have sold some tea to auctions. The rest sell the leaves locally for an average rate of 200 rupees/kg.

Strengths and Vulnerabilities of Small-scale Estates

During our fieldwork, the team identified strengths and vulnerabilities that affected small estate owners. An immediately apparent strength was the quality of Kangra tea. The orthodox method for black tea produced a unique flavor and richness, as tasted firsthand at the homes of many farmers. Furthermore, the Kangra green tea process preserves high levels of polyphenols and antioxidants, increasing health benefits.

Although the situations in each village differed, farmers reported consistent vulnerabilities (Figure 9).

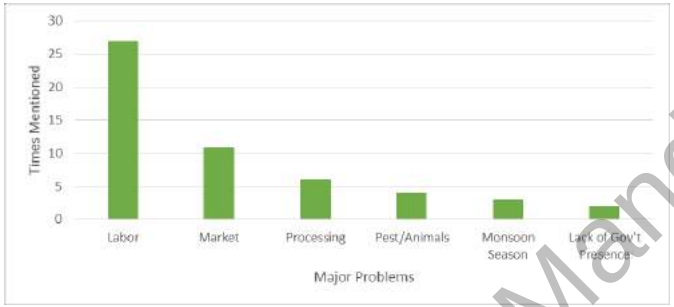

Figure 9. Vulnerabilities in small-scale tea production.

The farmers most frequently complained about labor costs. Several expressed that they could not afford laborers to maintain and pluck their gardens because the profit margin would be small. Tea growers also often complained about the market. Although some farmers sold to the local market, the biggest market for Kangra Tea was the Kolkatta auction. Auction buyers purchased tea at wholesale price, which rendered small-scale tea production undesirable due to the small quantities.

The other major complaints included processing problems and unwanted pests or animals. Withering and drying during the monsoon season is difficult, because farmers rely on sun drying. In this case, farmers are forced to sell the fresh leaves to factories for low prices. Rolling is time consuming and labor intensive when done by hand, producing small batches at a time. With regard to pests, several tea estates did not have fencing, which enables stray animals to eat the tea leaves. Furthermore, all the farms were organic, increasing crop loss to bugs and weeds.

A notable problem was the reported communication between farmers and government. When asked, the majority of farmers suggested that they received limited information from state government regarding schemes beneficial to tea growers. The Tea Board, however, had more positive reviews from farmers, particularly over the past few years with the appointment of a new deputy director for Himachal Pradesh (Figure 10).

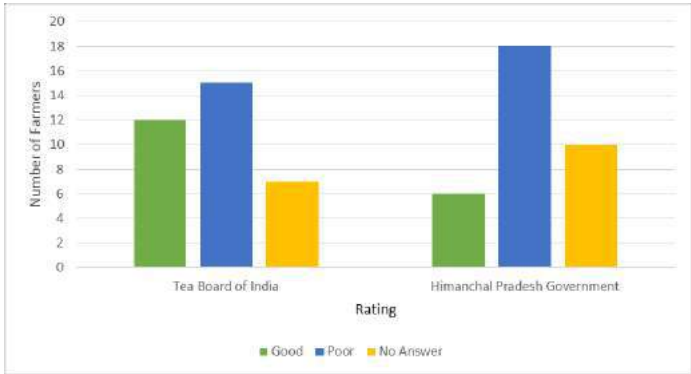

Figure 10. Small-scale farmers rating of existing schemes and government aid.

After identifying strengths and vulnerabilities, the team organized this information into a SWOT chart (Table 1).

Table 1. SWOT analysis.

Strengths	Weaknesses
-Taste -Organic, orthodox processed and high quality tea -Active Tea Board -New brands arising from large factories -Available land	-Divided, small-scale estate community -Inactive farms -Poor communication between estates and government -Labor cost and availability -Labor intensive, manual tea plucking and production -Lack of local market and marketing strategy
Opportunities	**Threats**
-Domestic and International Marketing -Self-help group expansions -Technology for small estates plucking and processing -Government schemes towards self-help groups and technology subsidies	-Unwanted pests and animals -Monsoon season -Aging owners

Developing Criteria for Policy and Technology

Because 27 farmers mentioned harvesting as a problem and all complained about labor time and cost for collecting leaves, mechanization of plucking was chosen as a focus. To properly address this issue, we researched and developed an appropriate technology criteria rubric for the small tea estates. We noted criteria related to size, cost, material selection, stakeholder perceptions, human factors, efficiency, and output effect (Table 2).

This criteria rubric informed our design process. We assessed existing plastic shears with an unattached bag and eliminating many existing design features, including the shears. The design needed significant improvements in material selection, efficiency, and human factors because the tool was unbalanced. Additionally, the shears needed more efficient way to toss the collected leaves into a larger container.

Discussion: A New Leaf for Small Growers

The Kangra Valley holds immense opportunity for thousands of small tea farms to flourish and produce high quality, organic tea from one of the most beautiful corners of the country. Small-scale production allows for careful control of the process and results in a distinctive product, strengthening the commercial value as well as market demand.

Small growers realize this potential; when asked, 100% replied favorably to the idea of starting a Kan-

Table 2. Appropriate technology criteria rubric for small tea estates.

Category	1	1/2	0
Size	Appropriate to site of application.	Size is manageable for site of application.	Size is not manageable or appropriate for site of application.
Material Selection	Locally attainable materials properly chosen to fit role of product.	Materials chosen to fit role of product, may be difficult to obtain for manufacture	Materials chosen have no relevance to role of product, not locally available,
Ease of Maintenance	User can fix and repair by self.	Requires some outside help to repair	Must send to manufacturer to repair.
Usability	Intuitively used by any person.	Requires some instruction to understand.	Lots of instruction and training required to use.
Efficiency	Productivity has gone up. Product is an appropriate use of resources	Productivity remains the same and resources used are somewhat wasted.	Productivity goes down and resources are completely wasted.
Stakeholder Perception	Praise or like product.	Indifferent towards product.	Dislikes product.
Cost	No to low cost for stakeholder.	Subsidized and/or reasonable cost. Manageable expense.	Product is too expensive for stakeholder to purchase and make a profit.
Human Factors	Product has no negative human factors or effects.	Has some negative human factors or effects but none that are severe.	Causes major problems for humans; Although innovation is good device does not reduce negative effects
Effect on Output	Output quantity has increased. Quality is better.	No change in output quantity or quality.	Output quantity or quality has decreased.

gra brand. However, they are not equipped with the financial support or marketing skills that large estates have to do this.

Even if farmers have means for purchasing processing machinery, few inexpensive designs exist for tea production on such a small scale. They also have space constraints. Moreover, the most time consuming part of their business, plucking, has few affordable and ergonomic alternatives to standard shears. If harvesting equipment could be efficient and cost-effective, it would be the first step in boosting production and profits of their exceptional tea.

The trend in decline of tea production in Kangra Valley has been dramatic; an alarming number of farms have been abandoned. Because farmers have other occupations, their motivations to continue growing tea are minimal. Without incentives for the farmers, the risk of the small-scale Kangra tea industry disappearing is an actual possibility. There is great opportunity for government involvement, especially from the Tea Board of India. Many extremely beneficial schemes are currently in place, but are primarily targeted at major tea producing states like Assam and are difficult to scale down to Himachal Pradesh. For example, the Tea Board defines a small estate as under 10.12 hectares of land, but nearly all the farms surveyed and those listed in the directory of tea growers were under a single hectare. This indicates that government schemes do not currently take into account the site-specific constraints of these relatively small farms; however, these farms constitute over 98% of farms in Kangra district.

Project Outcomes

The approach for tackling problems affecting tea production in Kangra Valley can be broken down into four categories: labor, communication, policy modification, and market creation.

Addressing Labor Issues: Prototype Design

To tackle the labor problem, we developed a prototype using the rubric for appropriate technology (Figure 11). This new design for a plucking tool was designed to speed up the plucking process and reduce labor costs. The tool features a 10 inch square box, which is small enough to handle by a single worker and accurate while plucking the leaves. The prototype could be made out of several locally available materials including metal, plastic or wood. The box design is simple to use, and the few, nonelectric parts would make it inexpensive and easily repairable. Also, the device is expected to be accepted by farmers because several farmers expressed the need for mechanization during the interviews. Currently, the team is unaware how the prototype would affect efficiency, workers, and the crop. Field-testing of existing devices against the proposed prototype needs to occur to understand these factors.

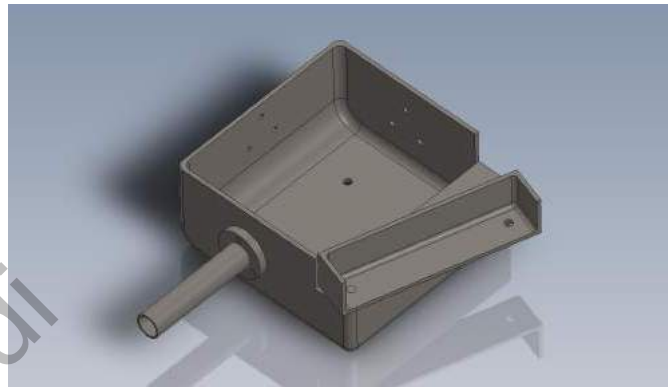

Figure 11. Prototype design for a manual plucker.

Communication Improvements

A mobile-based Agricultural Advisory System (AAS) is currently under development by the IIT-Mandi to address the need for better communication between farmers and the Tea Board. The AAS would function as an online database of tea growers' information, and also operate as a call center to help farmers with concerns or questions. We suggest a few specific features be added. First, a list of processing facilities and their current price listings for green leaves as well as any other services they may offer. This will provide transparency between factories and farmers who choose to sell their fresh leaves. Second, a listing of all available schemes should be put on the AAS website;

these are currently difficult to find, and, according to farmers, not advertised effectively. A way for farmers to apply for these schemes online or to begin the process on the phone would be helpful as well.

Policy Change and Market Creation

Changes to existing schemes could greatly improve the output of the entire Kangra district. Many schemes are available for farmers through the Tea Board of India, but none are tailored to the state of Himachal Pradesh, which is different from other tea growing states. Small farm size, uneven terrain, and lack of local markets provide a specific set of challenges for tea growers in the region. A report of recommendations for the Tea Board of India and tea farmers in Himachal Pradesh has been generated as a supplement to this study to target policy changes and market creation. It includes suggestions to expand personnel, increase the amount of information available online, provide training for green tea production, and most notably modifying of the self-help group (SHG) scheme. The SHG scheme allows at least 20 farmers with a minimum 20 hectares of land to join together to apply for subsidies for farming equipment, and we propose the following changes:

- Decrease the minimum collective land size
- Focus subsidies on processing so a group of farmers can produce tea of the same quality
- Provide programs for green tea processing
- Provide subsidies for initial marketing to kick-start local brands

For the survival of Kangra tea, a niche market can be created in order for the industry to prosper. Because the amounts produced are low, the tea should not be sold in auction. The first step is ensuring that enough tea can be produced with the same level of quality to sell under one brand. One strategy that can be utilized is the formation of collectives of farmers who process their leaves in the same place and with identical methods. The tea can be sold in tourist locations through local vendors including Himachal Pradesh Horticultural Produce Marketing and Processing Corporation LTD. (HPMC), an organization that sells local products throughout the state. The HPMC and Tea Board could promote Kangra tea to the public through educational campaigns. Using infographics and advertisement, the consumer could be introduced to the uniqueness of Kangra orthodox tea making it more appealing (Figure 12). Using the SHG scheme is a way to approach better marketing, and tea growers should be encouraged to apply to these programs.

Conclusion

Problems facing the Kangra Valley small tea estates are multifaceted and complex. The study revealed several processing, socioeconomic, marketing, and policy issues hindering the tea growers from producing tea at full potential. We developed several suggestions to begin addressing the challenges facing the industry. We present a mixture of technological and social deliverables because a single solution is not the answer to the complex situation in the region. Many small steps need to be taken to revitalize the Kangra tea industry, involving a collective effort from tea growers, the Indian government, and the consumers .

The team achieved the project's goal. However, the scope of the study was extremely broad, and further research can be done to enhance each of the respective outcomes. Future ISTPs and IQPs could focus on a single, unique problem pertaining to the Kangra tea industry. For example they might develop a small-capacity and cost-efficient rolling machine or drying mechanism, or they might investigate the implementation and effect of modified government schemes. This project and future projects have great potential to bring lasting change to the region.

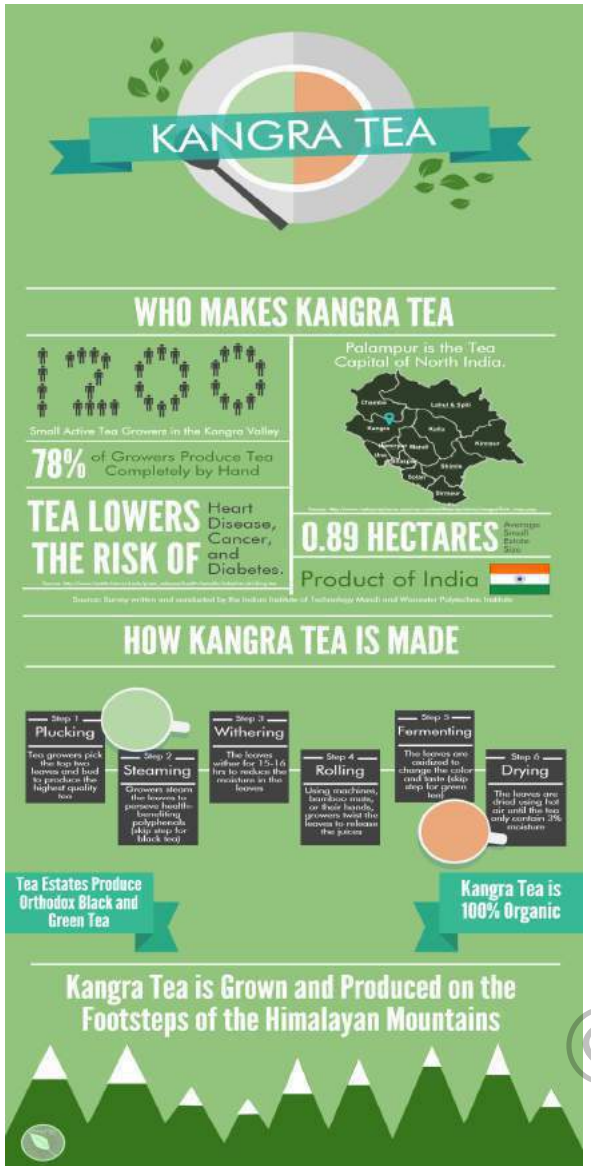

Figure 12. Kangra Valley promotion infographic.

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- All the tea farmers interviewed for their hospitality and making our research possible

Supplemental Materials for this project (raw data, calculations, research instruments, and additional project outcomes) can be found at http://www.wpi.edu/E-project-db/E-project-search/search, using key words from the project title.

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Assessing Gharats of the Kamand Valley

Abstract

This project assessed the challenges facing traditional Himalayan watermills known as gharats. We conducted site assessments at 21 gharats and interviewed both mill owners and local grain farmers to explore the social, technical, economic, and environmental reasons for mill abandonment. Additionally, we examined the factors causing diminishing demand for gharats' services. We developed recommendations for watermill owners, and initiated a pilot renovation on an abandoned mill to test innovations that can maintain the gharat's tradition.

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An Interactive Qualifying Project/ Interdisciplinary Sociotechnical Project submitted to:

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Indian Institute of Technology Mandi

The Decline of Gharats in the Himalayan Region

The District of Mandi resides in the northwestern Indian state of Himachal Pradesh. A predominantly rural state, Himachal is home to just under seven million people (Census of India, 2011). The region's high mountains and narrow roads discourage the import of goods, resulting in a need for locally produced food. Consequently, agriculture dominates the state's economy, contributing about 30% to the state's gross domestic product and providing employment for nearly 71% of the population (Himachal Pradesh Department of Agriculture, 2015). Since the region's primary crops are wheat and corn, the need has always existed for a method to process these foods. Small, individual watermills, known in Hindi as "gharats", were developed to fulfill this purpose (see Figure 1). Harnessing energy from the many streams and rivers that cut through the mountains, gharats have been in operation for centuries, processing grains into flour using a large grindstone connected to a turbine that spins with the flow of water.

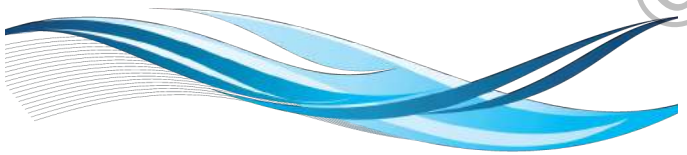

Figure 1. Himachali gharats

This simple technology harnesses natural resources into energy and income for families, and is thought to produce a higher quality of flour than modern alternatives (Abhik Ghosh, 2008). Unfortunately, fewer of these water mills are in operation every year. Many factors are contributing to the gharats' decline, ranging from environmental changes to lack of technological innovation (Vashisht, 2012). The goal of this project was to build an understanding of indigenous milling methods in Mandi District and to create recommendations that can improve the industry's longevity. To accomplish this, our team set three objectives: conducting baseline site assessments, interviewing stakeholders, and collaborating with stakeholders to create innovate mill improvement strategies.

Indian Gharats: Operation and Challenges

Before completing our on-site fieldwork, we conducted preliminary research to gain both a historical and a technical understanding of gharats, as well as to identify the broad challenges that they face.

Operation

The Himachali gharat (Figure 2) has remained technically unchanged for centuries, using an ancient technique developed around 100 B.C.E. to grind wheat into flour (Hellmans, 2004). Water is first diverted from a nearby river or stream into stone or earthen canals. These canals guide the flow toward a chute, which is placed above the gharat in order for the water to gain momentum as it falls toward the turbine. Debris is removed from the flow through the use of makeshift wooden filters. The gharat's turbine and chute have classically been constructed of wood, but recent years have seen a trend to replace these components with metal counterparts (Vashisht, 2012).

A funnel with a slow release mechanism is located on top of the grindstone, gradually depositing grain into the stone's center.

Centrifugal force pushes the grain outwards, crushing it into flour. The flour is released through the edges of the grindstone where it can be collected by the gharati.

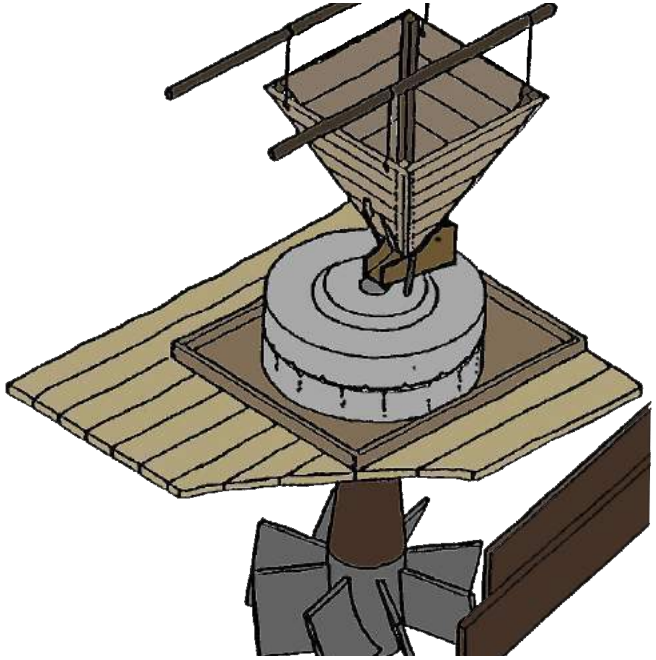

Figure 2. Basic structure and mechanism of a gharat (Gurudev, 2015).

Contemporary Challenges to Gharats

Thousands of gharats in Himachal are still functional and used on a regular basis. However, given the unique location requirements and remote nature of some gharats, there are numerous factors that contribute to the abandonment of the mills (Vashisht, 2012). To address these topics more completely, we evaluated the mechanical, environmental, and social challenges that determine a gharat's success.

Mechanical Factors

Rainwater picks up rocks and dirt as it flows down the steep mountainsides that flank the rivers of Himachal Pradesh, saturating them with small particles. Crude water filtering techniques (see Figure 3) are inefficient in removing most of the debris, resulting in significant erosion damage to the mill mechanism. Wooden turbines and blades are the most affected, and must be frequently repaired or replaced.

Figure 3. Common canal filter comprised of vertical sticks..

In addition to wear on the turbine, friction generated during the milling process slowly smooths the surface or the grindstone. It must be frequently roughened in order to maintain its milling efficiency (Ghosh, 2008).

Human and Environmental Challenges

The gharat's location also poses unique challenges. Although the rivers that power the gharats are fed by snowmelt and glacial runoff, rainfall is the driving factor behind their flow rate. In monsoon season, 70% of the average annual rainfall in Himachal falls during the months of July, August, and September, with just a small amount of precipitation in the winter months (Meoweather, 2014). This uneven rainfall causes the water level of rivers and streams to vary wildly over the year, creating unreliable conditions for the water diversions necessary to power the mills (see figure 4).

Figure 4. Water diversion from river.

In addition, alterations in the flow of water sources upstream from the mill may render it inoperable, and can occur due to floods, landslides, and human interventions. Increased absorption of water into the ground due to extensive deforestation in the region is also a factor, and can result in a reduction in the flow of mountain streams (Agarwal, 2009).

Challenges in Supply and Demand: Tradition vs. Technology

Finally, the introduction of modern alternative milling techniques in rural communities has greatly reduced demand for the gharat's services. Some local farmers have turned to more convenient processing methods, such as installing diesel-fueled or electric mills in their homes rather than transporting up to 30 kg of grain to and from the gharats (Ghosh, 2008). This shift towards electric milling is thought to carry a negative health effect. When subjected to the high temperatures produced by electric mills, fat inside grain becomes rancid and many of the vitamins are destroyed (Aubert, 1989). The low grinding rates found in gharats distribute nutrients much more efficiently, and also increase levels of vitamin B_1 (Moritz and Jones,

In order to research more into the challenges facing gharats, we conducted on site fieldwork and interviewed millers near IIT Mandi's Kamand Campus.

Methodology

The goal of this project was to build an understanding of indigenous milling methods in Mandi district and to create recommendations that could improve the industry's longevity. In order to meet this goal, our group established three objectives:

1. Gather basic site information, including the location, operations, and quality of mills.
2. Obtain stakeholder knowledge about mill operations, usage, and challenges to the industry.
3. Collaborate with local millers to develop strategic improvement scenarios.

The methodological approach that our team used is summarized in Figure 5.

Objective 1: Site Evaluation

In order to conduct effective site evaluations, we identified gharats on the basis of local recommendations and recorded their GPS locations. We developed a site assessment checklist that aided us in documenting key technological and geographical traits of the gharats. Information points of interest included whether the gharat was operational, its proximity to the road, the character of the terrain between the gharat and the road, the mill's turbine design, and the current water flow conditions. Since our team was limited in terms of time, the scope of our assessment was restricted to mills within a 30 km radius of the IIT Kamand South Campus.

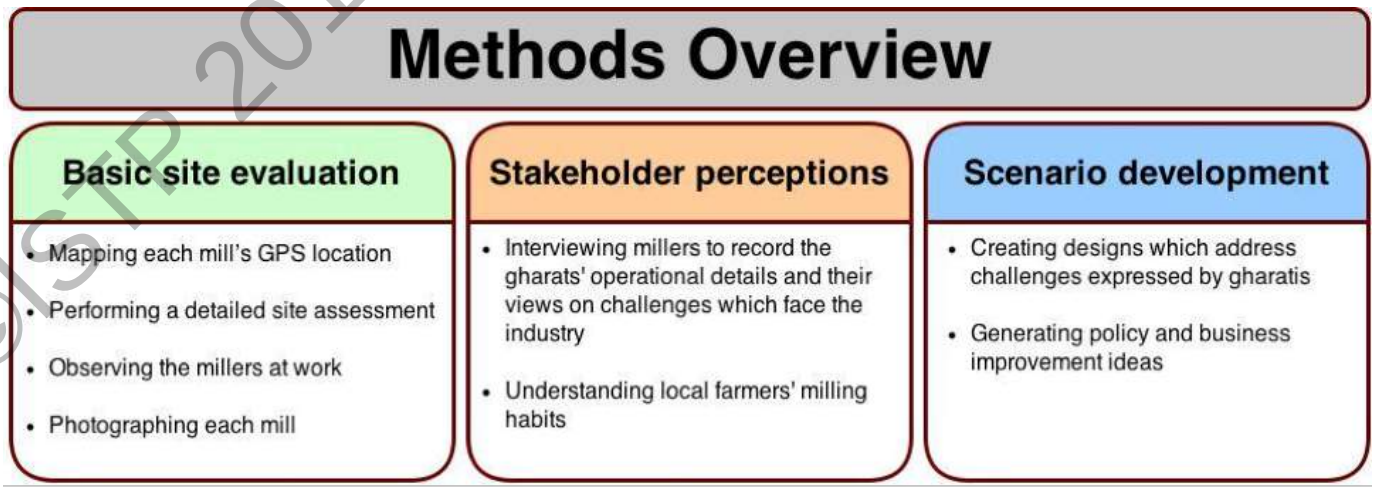

Figure 5. Project methodological approach.

Objective 2: Interviewing the Stakeholders

In order gain firsthand information into mill operations, usage, and challenges to the industry, we conducted two separate kinds of interviews: one with the local villagers and another with the gharatis. We first interviewed villagers who use the gharats to grind their grain and those who use alternative methods, utilizing snowball sampling to contact respondents (Figure 6) (Biernacki, 1981). The customers we met at the gharats were our initial sample, and with their help we identified other residents who used alternative milling methods. Villager interviews focused on the reasoning behind each stakeholder's milling practices. To encourage friendly dialogue, we recorded stakeholder responses immediately after the conclusion of the interviews.

Upon the completion of each mill's site assessment, we conducted a loosely structured, open-ended interview with each mill owner.

Figure 6. Interviewing gharati.

Open-ended interviews allowed the data to emerge naturally through discussion (Berg, 2011). We designed questions to yield specific data on general challenges to gharats, parts that frequently break down and whether attempts to upgrade or adapt the gharat had been made in the past.

Objective 3: Development of Recommendations

Our final objective was to collaborate with the gharatis to develop potential recommendation scenarios. Our team accomplished this task in two steps. First, we developed a set of mill improvement scenarios based upon our findings from site assessments and stakeholder interviews, taking care to craft these scenarios around specific issues of interest to the gharatis (Berg, 2011). Second, we identified policies and business innovations that could be favorable to the gharats. We delivered the outcomes of this work to the stakeholders for further input.

Data management

Data containing gharati and villager names was stored on a password-protected laptop. Only numbers and not actual names were used in our publications. Interviews first were obtained orally in Hindi and then translated by IIT team members. This information was relayed to WPI team members and recorded.

Results and Discussion

In this section, we present results obtained while completing our three objectives.

Objective 1: Site evaluations

We identified and assessed 21 gharats (Figure 7) by recording essential information from our checklist.

Of these 21, eleven were functional, but only three were the gharati's sole source of income. Gharats were found in clusters, usually next or close to a village. The bigger the village, the more gharats we found. Most of the gharats we found divert water from a river using stones; those located alongside larger rivers find it easier to obtain the flow rate they need. Gharats #1, #2 and #3 were each located next to a strongly flowing river, near the north campus of IIT Mandi. They are all functional, with a noticeably fast-spinning grindstone. Gharats #5 -- #10 are located in a village called Neri. Three of them are functional, but are located next to a smaller river. With the exception of gharat #8, which has a highly efficient turbine and nozzle to direct the water, these mills spin at a slower rate than #1, #2 and #3. Gharat #11 is in disrepair, and according to the gharati, it is because the turbine had broken a few years back. They could not afford to replace it, but we saw that the flow of water they were using came from a groundwater stream that was very

weak, and we wondered how it could ever be functional without a holding tank to increase potential fluid head. The last cluster we found consisted of gharats #12, #13, #14, #15, #16, #17, #18, #19, #20 and #21 near a village called Mathaneeul. Five are functional, and they all use water from a very strong groundwater stream.

The water flow that the gharats received ranged from almost none, as was the case with gharats #11 and #21 (both in disrepair), to enormous quantities of channeled water, as was the case with gharat #20. Figure 8 shows the assessed gharats' operational condition, as well as the percentage of abandoned gharats with no flow.

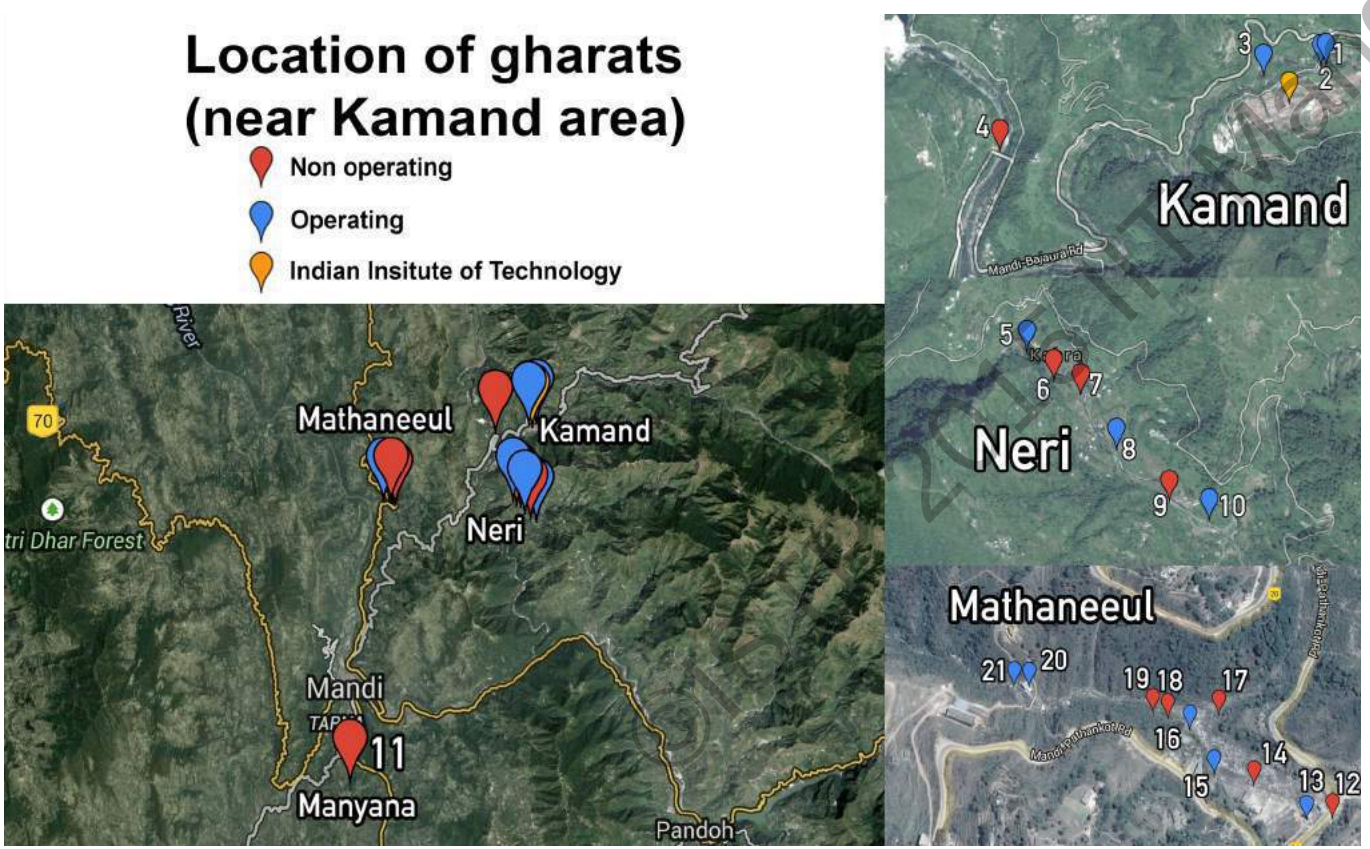

Figure 7. Gharats we assessed. (Adapted from Google Maps).

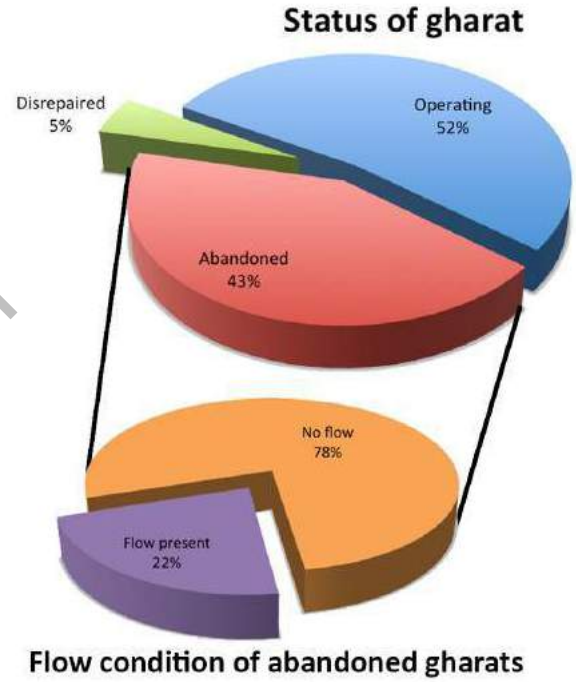

Figure 8. Status of gharats and flow conditions of abandoned gharats.

Reasons for low water flow vary. Anecdotal responses noted that road construction brings mud and silt to streams. This can make the stream "disappear into the mud" (as described by one gharati) and become harder to harvest. This was the case with gharat #11. Gharat #20, however, had diverted so much water upstream from #21 that it no longer had sufficient flow.

A gharat's flour output per hour is directly dependent upon the amount of water that it receives, the turbine's efficiency, and how well

the water is directed towards the turbine's blades. One of the most successful gharats(#20) was exceptional. It had undergone an extensive, costly renovation a few years ago, and utilized five grinders simultaneously. The gharat's owner claimed to produce 170kg of flour every hour. However, this gharat proved to be an outlier. Figure 9 shows that most gharats process between 10kg to 20kg of grain per hour.

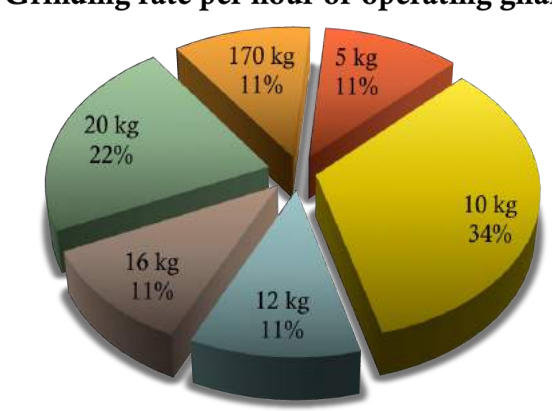

Figure 9. Reported grinding rate (kg per hour) at operating gharats.

Only two mills (both provided a single source of income) were accessible by road. Farmers who wish to mill their grain at other gharats must travel between 20 to 400 meters on foot with grain on their backs, and then the same distance back. Paths to the gharats were steep and rocky, and proved difficult for our team to use (Figure 10).

Figure 10. Reported grinding rate (kg per hour) at operating gharats.

In terms of equipment, we found at least eight different types of turbines. We were surprised to find that the majority of operational gharats had upgraded to metal turbines. Out of the 11 operational gharats, seven used metal turbines, and only four still utilized wooden ones. Reported costs of renovation varied from 5,000 to 10,000 rupees. The design of the metal turbines varied from gharat to gharat. Some were constructed by the gharati, while others were built by area welders. Figure 11 shows a renovated turbine.

Figure 11. Gharat #3's metal turbine.

Objective 2. Stakeholder perceptions

Our interviews revealed more details into lives of gharatis. Most gharatis were very committed to their occupations. Of the ten gharatis interviewed, only one was not planning for his children to inherit the gharat. Among the owners of gharats with metal turbines, maintenance was not seen as a large issue. All turbine renovations had occurred between 5 and 10 years ago, and since then no repairs had been required. Owners of gharats with wooden turbines (Figure 12) told a different story. Turbines lasted around 10 years, after which they had to be replaced at a cost of around 5,000 rupees. These turbines' wooden blades also frequently broke, and were fashioned and

replaced by the gharati himself. Regardless of turbine type, mill grindstones must be maintained and replaced at the same rate. Every month or so the gharati has to remove the stone and flip it to re-carve grooves into the surface, a process which costs around 1,000 rupees. After approximately 10 years, the stone must be completely replaced. While some gharatis cut the stones themselves and others buy them, replacement did not seem to be a hardship.

Figure 12. Gharat in disrepair in Manyana,.

Objective 3. Development of recommendations

After analyzing data obtained through our first and second objective, we developed ideas for improving mill operation and increasing their demand. When we took these recommendations back to the gharatis, we discovered that some of these suggestions were not feasible or desirable from their perspective. For example, although we thought a brochure or flier advertising gharat locations might be distributed in area, they indicated that their presence was already well known. Those recommendations they did see as feasible were developed further and appear in our Project Outcomes.

Discussion

We identified three key factors that tend to lead to mill abandonment. First is lack of water flow, which can have a devastating effect. The abandoned mills in Neri village, for example, were all located on the same side of the river. The millers told us that they were abandoned when the flow of the river changed direction slightly and left them with a very small flow rate. This problem is complex and hard to address, leaving gharatis at the mercy of the frequently occurring landslides of Himachal Pradesh. Second, we found that every operational mill was within five minutes of the nearest road. Farmers near mills that are far from roads found it inconvenient to carry their grain to and from the gharats, and chose to use electric mills instead. Third, we found that occasionally, as with gharat #11, the owner cannot afford to replace parts that have broken down.

Turbine material directly affects mill output. Gharats with wooden turbines routinely produced a lower grinding rate than metal gharats diverting water from the same stream. Gharatis who had upgraded their mills reported that the investment had paid off in around three years. This easy replacement is clearly worth the effort.

Although most villagers interviewed attested that flour ground in a gharat tastes better than flour ground in an electric mill, few were aware of the nutritional benefits of gharat flour. Over the long term, consuming only electrically milled flour has potentially devastating health effects. A German study in 1970 fed varying types of flour to groups of rats. Flour constituted 50% of the rats' diet. After four generations, only the rats that had been fed fresh, stone ground flour maintained their fertility (Bernasek, 1970).

Project Outcomes

Recommendations

Our data from site assessments and interviews led to three recommendations that can support and maintain the gharat's tradition in the future:

1. Improve gharat access and visibility.
2. Support commercial and cooperative contracts for local gharats.
3. Implement technological upgrades to gharat parts.

First, we suggest two small changes to the gharat business operation. Roadside signs can identify the easiest path to the gharat. In some cases where access is difficult, we suggested creating roadside booths at which customers might drop off grain and pick up flour. This would reduce the effort farmers need to exert carrying grain and flour over rough terrain, the biggest inconvenience of using the gharats cited in farmer interviews. Although one gharati felt this would require another worker to staff the booth, we suggest implementing a mailbox-like structure where grain can be dropped in but only the gharati can later remove it and carry it down to the gharat. To raise awareness about the advantages of using gharats, we recommend the circulation of an informational flyer distributed to local villages (Figure 13). This flyer would stress the beneficial health effects of stone ground flour and the lower milling cost of the gharats. Although we initially thought to include a map showing the locations of nearby gharats on the back side, some gharatis thought this was unnecessary as locals know their location. However, this information could be distributed to villages farther away, specifically those solely reliant upon electric milling. We plan to present these flyers to the leaders of the local villagers near the gharats we visited, so that they can distribute the fliers to their neighbors and educate them about the benefits of consuming gharat flour.

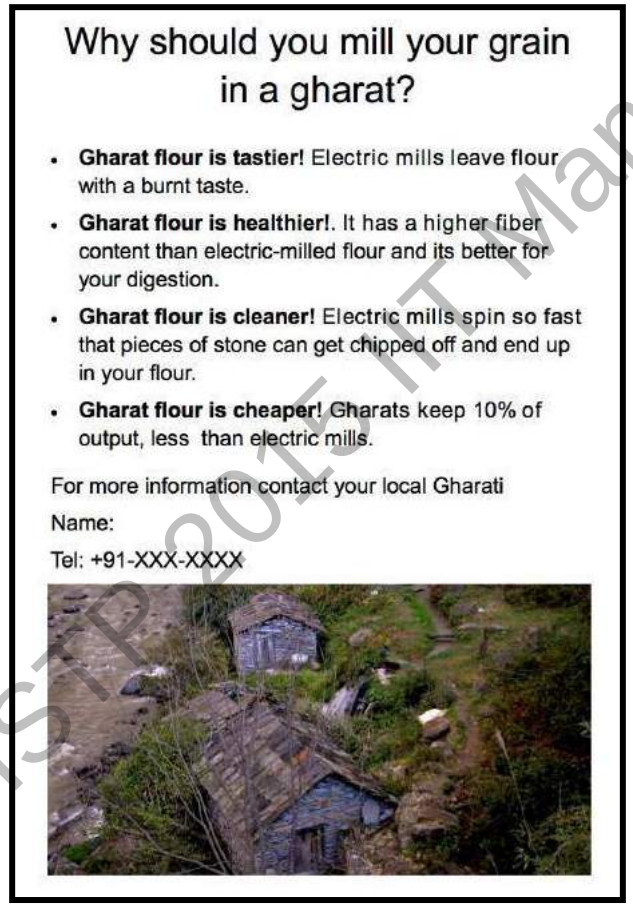

Figure 13. Front side of informational flyer (English translation).

Our second recommendation is to boost commercial and cooperative contracts for local gharatis. To take the first step, we proposed policy to the IIT recommending that they purchase grain wholesale and grind it at local gharats. Beside the health benefits, IIT Mandi would stand to financially gain from this action. Grinding grain at gharats costs around 10 rupees per kilogram less than grinding it at an electric mill. As IIT dining facilities currently purchase 450 kg of flour each day, milling at gharats could save the school as much as 1,000,000 rupees per year. Response to this recommendation was enthusiastic, both from gharatis and from the dean of Students at IIT Mandi.

Our third recommendation concerns basic technological upgrades. Expecting an increase in demand due to our previous recommendations, we recommend that mills still using wooden turbines and blades should convert to metal components due to their increased efficiency and low maintenance costs. Renovations to the gharats' water diversions were also proposed to gharatis where necessary, as some gharats' channels were leaking significant amounts of water.

Finally, we recommended to the IIT that they consider further study of gharats as either an IIT design practicum or as a future IQP/ITSP project. We believe the development of

mill-powered interior lighting could greatly benefit gharatis. While our team was able to design a prototype, we quickly realized that dedicating the time required to fully refine, test, and implement this device would prevent us from reaching our original objectives. The prototype we designed would slot into the top of the mill's grindstone, spinning along with it. A gear attached would be connected by a bike chain to a small generator in order to power a 60 watt light-bulb (Figure 14). The impact of implementing such a device would be significant, as this device has the potential to triple a gharat's potential output. However, it must be as low tech as possible so the gharati may maintain it himself (Ghosh, 2008).

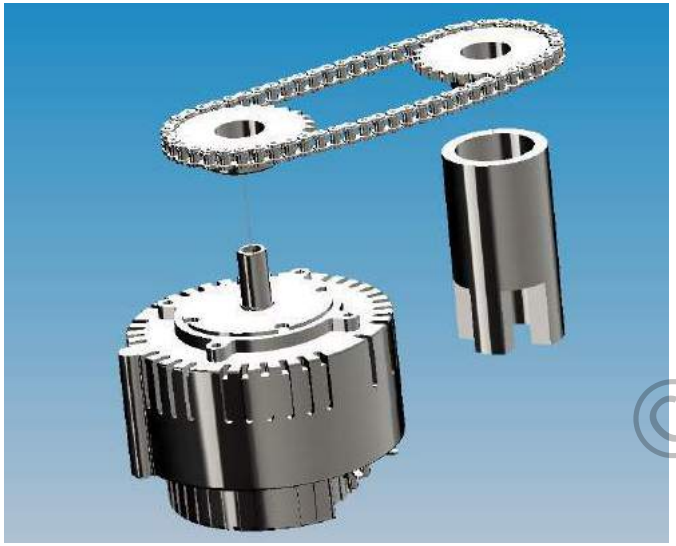

Figure 14. Electrical generator prototype.

Additionally, we recommend the establishment of a local cooperative which supplies grain to IIT dining facilities. IIT mess halls' flour consumption will continue to rise as construction of IIT Mandi's Kamand Campus progresses. If the IIT were able to cut out the middleman (their current flour supplier), the university could further cut food expenses while providing a boost to the local economy.

Pilot renovation: Manyana

In addition to our three principal recommendations, our project also facilitated the renovation of a gharat near Manyana, a small town 5km from Mandi in order to showcase possible outcomes from implementing our recommendations. After the close of our project, a new, metal turbine will be installed by IIT students, along with designs for an improved chute and water storage tank. Villagers near the gharat are currently forced to walk nearly 4 km to reach the nearest electric mill. To alert them of the renovated mill and encourage their business, the above mentioned flyer will be distributed in the area.

Conclusion

The gharat is part of the heritage and identity of Himachal Pradesh. Our study revealed a long tradition of mill culture that is integral to the lifestyle of local villagers. Gharats are a low cost, sustainable, and healthy means of grain processing in the region. With some minor upgrades and adaptations to their business model, the gharats of Himachal can be preserved, providing millers with locally important and financially viable businesses. The gharatis and their mills represent a perfect snapshot of Himachal: the old seamlessly mixing with the new to meet the unique needs of people in this region.

Acknowledgments

We would like to thank the following people for their contributions to our project:

Dr. Aditi Halder, IIT Mandi

Dr. Lorraine Higgins, WPI

Dr. Prasun Jana, IIT Mandi

Dr. Ingrid Shockey, WPI

Supplemental Materials for this project (raw data, calculations, research instruments, and additional project outcomes) can be found at

http://www.wpi.edu/E-project-db/E-project-search/search, using key words from the project title. Outcomes delivered after April 30 will appear on the IIT's ISTP page:

http://www.iitmandi.ac.in/istp/index.html

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Identifying Knowledge of Pesticides and Determining Use on Fruits and Vegetables in Himachal Pradesh, India

Abstract

This project researched stakeholder knowledge about pesticides in Himachal Pradesh, as well as pesticide use on farms in the region. We documented perceptions of farmers, government officials, and vendors, investigated relevant policies, documented application practices, and applied a method to test for chemicals in market produce. Our findings indicated the presence of pesticides on sampled fruit and vegetables, many of which have been banned in other countries. Moreover, farmers were not always aware of dangers and regulations.

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A Transition Toward Pesticides in Himachal Pradesh

Pesticide use in rural and remote locations can be difficult to measure in India, where local practices vary and are where there is limited educational outreach to inform small farmers. Himachal Pradesh faces such challenges. Located in the northwestern foothills of the Himalayan region, Himachal Pradesh is dotted with small farms (Figure 1), despite its hilly terrain. The state is largely rural and agrarian, with approximately 70% of jobs in agriculture (Himachal Pradesh, 2012).

Despite their small size, strategically placed agricultural plots supply local families and regional markets with a wide range of produce, including apples, tomatoes, carrots, radishes, cauliflower, and several different kinds of lettuce. Through preliminary discussions with our IIT mentors, we learned that farmers are turning to pesticides to raise crop production, and some rely on chemicals that have been banned in other countries. These practices limit the possibilities for export and also raise questions about the toxicity of the produce and risks to those that consume it. The shift toward pesticide use has led to internal controversy and debate as to whether or not these pesticides should be banned in India, as well (Centre in Favour of Manufacture of Endosulfan, 2014).

It has proven difficult for India to determine a policy on pesticide limits because key stakeholders—farmers, consumers, and the government—cannot agree on the numbers. It is even more challenging to gather information about how much each of these groups knows about pesticides because many may be unfamiliar with the effects they have on both the environment and humans. Preliminary discussions with our mentors at IIT suggested that local farmers are even unsure of the meaning of the term *pesticide*, which makes it difficult to gather consistent information through the use of direct questioning. Beyond this, the government has not taken a firm stance on the matter because of conflicting information on the pros and cons associated with pesticides (Pesticide Regulations, 2014).

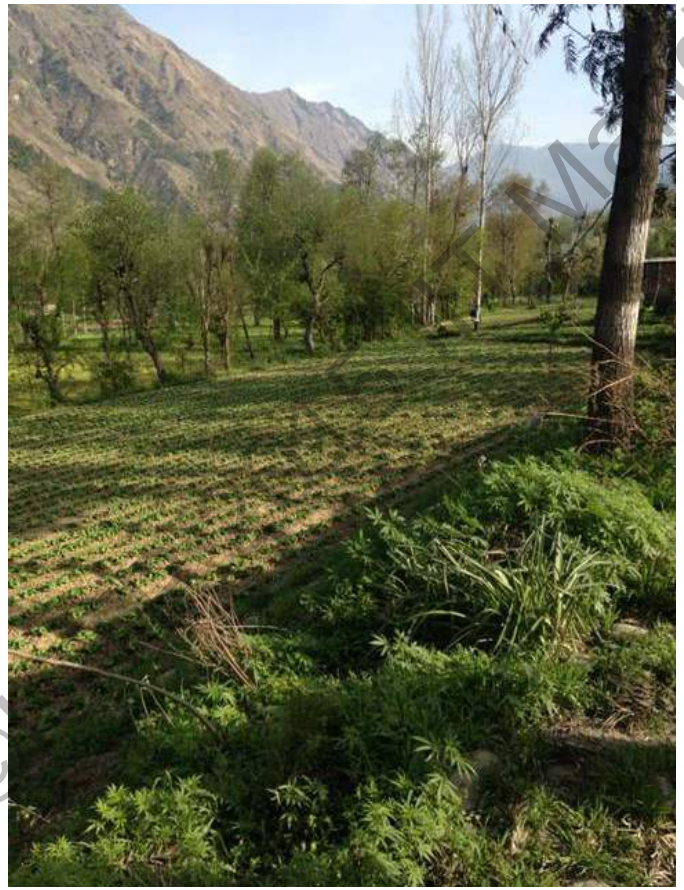

Figure 1. Small plots for lettuce cultivation.

Focused research on pesticide use will inform ongoing debates and public policies. Therefore, the goal of this project was to understand pesticide use on small fruit and vegetable farms in Himachal Pradesh and to determine the knowledge farmers, vendors, consumers, and government officials have about pesticides. In order to meet this goal, we documented perceptions that these key stakeholders had about pesticides, investigated government policies, documented pesticide application practices, and identified pesticides present in a sample of local market fruits and vegetables. Based on this data, we recommended that government offices supply information to farmers about safe practices and promote safer alternatives to pesticide-based practices.

The Dangers of Pesticide Reliance

Various fruits, vegetables, grains, and legumes are grown throughout Himachal Pradesh (Agricultural Informatics Division, n.d.). Because of the uneven terrain, crops are typically grown on small farms throughout the state. In order to maximize crop production and combat pests and blight, farmers have begun using pesticides which are sold in local markets. Local crops are sold in local markets, either through vendors who sell on behalf of the farmers (Figure 2) or by the farmers themselves. Market streets in Mandi and small surrounding villages are lined with vendor stands. Most of the produce comes from local farms, but some items out of season or not grown locally may be imported. Through preliminary discussion with our IIT mentors, we learned that local villagers rely on these markets for their produce unless they farm their own plots of land. Because of this reliance, it is especially dangerous if farmers are not conscious of the effects of pesticides.

The majority of pesticides used on crops in Himachal Pradesh fall under the category of insecticides (Abhilash, & Singh, 2009). The most commonly used chemicals have been identified as organochlorine insecticides (OCs), known for "their low cost and versatility against various pests" (ibid.). Although OCs have been banned in many countries due to their "potential for bioaccumulation and biological effects" as well as their resistance to degradation, these chemicals are still manufactured and used on a large scale across India (ibid.). While it is assumed that pesticide use is common, it is less clear which pesticides farmers are using since documentation of regional practices is scarce.

Pesticides have been incorporated into farming practices to increase profits. By using pesticides, crops are less likely to be damaged from pests or blight. Studies have shown, however, that communities, farmworkers, and consumers can suffer unintended negative consequences from pesticide exposure. Advocacy groups fear serious health and environmental effects that could emerge from chemicals not yet controlled in India (Centre in Favour of Manufacture of Endosulfan, 2014). The ability of pesticides to travel easily through various domains, such as air, water, soil, and the food chain, enables bioaccumulation in plants and animals. Numerous studies, including one from the University of Toronto, have found consistent positive associations between pesticide exposure and neurologic, reproductive, and genotoxic deficiencies in exposed subjects (Sanborn, 2007). The World Health Organization estimates one million severe unintentional poisonings each year and three million unreported poisonings (Jeyaratnam, 1990).

Figure 2. Vendor preparing produce to be sold in market.

From an environmental standpoint, pesticides tend to have long half-lives, and can remain in the ecosystem for years. Some undergo chemical reactions in the environment, often creating even more dangerous and persistent chemicals. For example, endosulfan, a pesticide used commonly in India, can transform into three different isomers, all with large half-lives. According to the Agency for Toxic Substances and

Disease Registry, the half-life of alpha-endosulfan in soil is about 37–67 days, and the half-life for beta-endosulfan in soil is 104–265 days, while the half-life of endosulfan diol in water is approximately one month (ATSDR, 2013). During this time, the chemicals interact with their surroundings and escalate the effects of the pesticide on the ecosystem. Some of the ways pesticides can be spread through a community are highlighted in Figure 3.

Clearly, there is a need to document current agricultural spraying practices: how much, how often, and what kinds of chemicals are being used. It is also important to determine how much consumers, farmers, and vendors know about these practices and their effects. Spreading information about pesticides will make farmers, vendors, and consumers make informed choices and be more aware of the dangers that these harsh chemicals pose when used excessively.

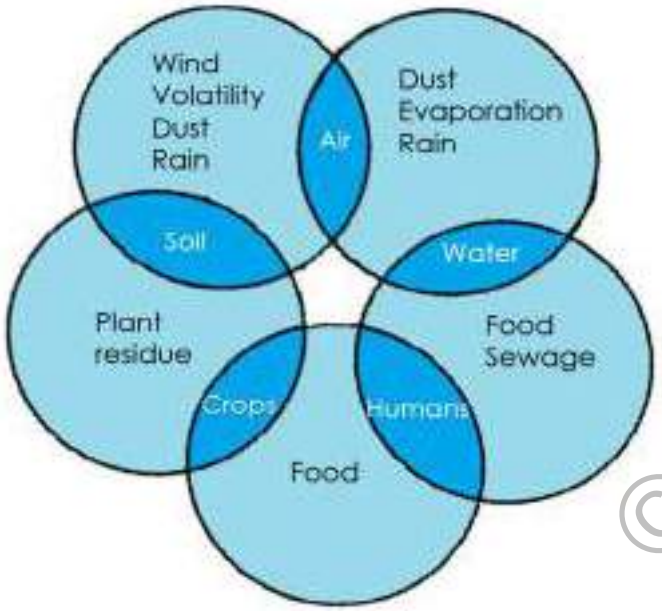

Figure 3. Pathways for transport of pesticides (adapted from Fenik, Tankiewicz, & Biziuk, 2011).

Methodology: A Hands-on Approach

The goal of this project was to understand pesticide use on small fruit and vegetable farms and determine the knowledge farmers, vendors, consumers, and government officials have about pesticides. In order to accomplish this goal, we established the following objectives and approach.

Objective 1: Collect Perceptions of Key Stakeholders about Pesticides

The first step in completing this objective was to identify the location of produce markets so that we could interview vendors. We used a site assessment strategy in Mandi town to help us gauge the flow of the market and informally map vendor locations. This also allowed us to see the options available to local consumers for purchasing produce.

Once the site assessment was completed, we planned to conduct unstandardized interviews with fruit and vegetable vendors. Unstandardized interviews allow researchers to "develop, adapt, and generate questions and follow-up probes appropriate to each given situation and the central purpose of the investigation" (Berg, 2012, p. 111). The interviews were designed to determine specific attributes vendors looked for in high quality crops and to see if any particular farms executed their standards better than others, allowing us to uncover farms that we could visit for future interviews.

We also interviewed pesticide vendors to determine the kind of information they provide farmers when selling chemicals to them. Because we were unfamiliar with the markets in Mandi, we were unsure of where we would find pesticide vendors and how many would be willing to speak with us. Since our IIT team members were more familiar with the markets, we relied on them to determine an appropriate sample size.

Throughout the interview and site visit processes, we introduced ourselves as students interested in learning about high quality farming practices and the success of small farms in Himachal Pradesh. Interviews were conducted in Hindi by IIT members of our team and translated to English. Responses were recorded on questionnaire sheets and on voice recorders. All data was stored in a password protected laptop, and any identifying materials

were destroyed upon the completion of the project.

Objective 2: Compile Government Policies

We used archival research from government websites to compile state and national policies on pesticide use with regards to farming and food quality in Himachal Pradesh so that we would know which pesticides are banned, the maximum limits of detection for pesticides when it came time to test produce, and how the government enforces these laws. We also interviewed the Department of Agriculture Officer for Mandi District to gain deeper insight on these laws. This semi-standardized interview focused on laws regarding food quality and best and safe practices in farming. We probed to find the current attitude towards public health with regards to food safety and the presence of unwanted chemicals in market produce. This also helped us to determine whether government officials were aware of actual farming practices used in the region.

Objective 3: Document Pesticide Application Practices

We traveled to ten farms to learn about pesticide practices on local crops. We asked farmers if they could give us a tour of their farms so that we could gain some insight on the types of crops being grown (Figure 4).

We also conducted unstandardized interviews with farmers to inquire about quality measures on their farms, chronic threats in terms of pests or blights that they face on a regular basis, and how they address these problems. When pesticide use was brought up in the natural flow of the conversation, we were able to ask about the application process and any safety precautions taken before spraying. Unstandardized interviews allowed a more relaxed rapport with the farmers, making it possible for our team to inquire about pesticide use without being forward.

Because we learned from the Department of Agriculture that the government and not vendors are responsible for teaching farmers proper application practices, we chose to incorporate further questions about pesticide application into our interview with the Department of Agriculture Officer. This allowed us to gather information on the resources available for farmers in regards to application training.

Objective 4: Identify Pesticides Present in Market Fruits and Vegetables

While conducting interviews with farmers and pesticide vendors, we asked what different brands of pesticides the interviewees used. We

Table 1. Objectives and methodological strategies.

Objective	Methods
1 Collect perceptions of key stakeholders about pesticides (farmers, produce	Site map of Mandi town market Unstandardized interviews: farmers, produce vendors, pesticide vendors
2 Compile government policies	Archival research on laws Semi-standardized interview with Department of Agriculture Officer
3 Document pesticide application practices	Informal site assessment of farms Unstandardized interviews: farmers Semi-standardized interviews: Department of Agriculture Officer
4 Identify pesticide levels in market fruits and vegetables	Research banned chemical compositions (U.S. and India) Acquire samples from local market Extract pesticide residues, using ethyl acetate and analysis via mass spectrometry

determined the chemical compositions of the pesticides from the labels and compiled them into a list. We checked each chemical's status in India as well as the United States. Then we determined their molecular weights by drawing the chemicals in Chem Draw Ultra 8.0 and running a chemical analysis within the program.

We originally selected five fruits and five vegetables for testing based on our mentors' recommendations for commonly sold produce: apples, oranges, bananas, grapes, mangos, carrots, spinach, cabbage, cauliflower, and tomatoes. Due to time constraints and seasonal availability, we tested apples, bananas, grapes, mangos, cucumbers, carrots, tomatoes, and eggplant instead. All samples came from stands selling produce grown locally in Himachal Pradesh (Figure 5) and were collected the day before they were tested to maintain freshness. Samples were individually placed in bags, which were labeled with the date and time of collection as well as the stand information in order to differentiate among the different stands. The produce was brought to the IIT – Mandi Chemistry Lab for testing, using ethyl acetate to extract the pesticide residues and water to extract the sugars from our samples. This mixture was then put into a separation funnel, agitated, and left so that the water and ethyl acetate could separate into two layers. Once two layers could be seen, the water layer, which was located at the bottom, was taken out and the top layer of ethyl acetate was collected and dried with sodium sulfate. This dried ethyl acetate was then put in a round bottom flask and was put into a rotary evaporator in order to remove the ethyl acetate solvent and to collect the pesticide residues. Mass spectrometry was then used in order to determine the pesticides found in the residues. A detailed laboratory procedure is located in supplemental materials for methods section. We compared the chemicals we detected with the list of banned chemicals and their exact molecular weights that we created prior to testing.

Figure 4. Team members conducting an interview with a farmer in Kullu.

Results and Discussion

Our fieldwork and lab research yielded the following results.

Objective 1: Stakeholder Perceptions

We interviewed ten farmers from the Kullu and Mandi districts, all of whom said they used pesticides. None of the farmers knew which, if any, pesticides were banned. Of these ten farmers, five were asked if they take any precautions while spraying. Two indicated they wear gloves and a mask, one said he wears gloves and washes his hands after, one said he takes a bath and washes his clothes after, and one said he has to wear a mask or cover his head else it is harmful. When directly prompted about specific protective measures, however, all five said they cover water supplies, keep animals away, store pesticides separately, and dispose of empty containers; however, they

Figure 5. Market in Mandi .

only indicated these measures after they were specifically asked, suggesting they may have been lead by our prompts. Further discussion with all ten farmers revealed that that they buy pesticides when needed instead of in bulk. One of the most important pieces of information that we gathered was that none of the farmers wash their produce before selling it because they say it will degrade the quality; they do wait an average of ten days after spraying before selling. These interviews suggest inconsistencies among farmers concerning the proper approach to safety precautions, a lack of knowledge about banned chemicals, and erroneous assumptions that harmful effects of pesticides can be washed off or can diminish after waiting a period of days.

Produce vendors were not willing to speak with us even after we offered to return after they closed for the evening.

We visited six pesticide vendors in Mandi town, but only three were willing to be interviewed. They did allow us to look around their shop and photograph their products. When speaking to the pesticide vendors in Mandi town, all three said they depend on manufacturers to provide high quality pesticides. All vendors reported that their customers come to restock once in a quarter and that they sell on average 4-5 kg per month. One of the most important things we learned was that most vendors were also unaware of which pesticides are banned in India, but they assumed the ones provided by manufacturers were legal.

Objective 2: Government Policies

Per request of our IIT mentor, we compared India's pesticide regulations to the United States' pesticide regulations. Our research on government websites revealed vast differences between the two countries. A simple internet search for a list of banned pesticides in the United States brings up the Environmental Protection Agency's website with links to lists of registered pesticides and restricted pesticides. The same search in India leads to a downloadable document listing a significantly smaller number of banned and restricted pesticides. Though the document was created by India's Central Insecticide Board & Registration Committee, it has not been updated since January 1, 2014. Only after clicking through links in the document were we able to locate the website from which the list originates. Beyond the sheer size of the lists, the registry systems are different. The EPA provides a list of registered chemicals, products, and their maximum residue level (MRL), which is the greatest amount of a chemical that can be present in a food. In addition to this, a link to query forms helps

users look up the federal status of any pesticide. The EPA also makes a point to say that if a pesticide is not registered, it cannot be used legally. Furthermore, the website states that it is illegal to use a registered pesticide on a crop for which its registration is not approved.

KEY FINDING:

The CIBRC website's list of registered products gives the names of all registered chemicals, but no maximum residue levels or crop specifications, making it difficult for farmers and those who distribute the chemicals to know the limits and proper uses for each chemical.

Pesticide regulations are not as explicit on the Central Insecticide Board & Registration Committee's website. After navigating through the links to the homepage, we were able to download more documents to gather information. The website's list of registered products gives the names of all registered chemicals, but no maximum residue levels or crop specifications, making it difficult for farmers and those who distribute the chemicals to know the limits and proper uses for each chemical.

Further research on this website revealed India's policies regarding pesticides and food quality. India's Insecticide Act of 1968 requires the government to monitor the use, manufacture, distribution, sale, and transport of insecticides (Pesticide Regulations, 2014). To build on this act, the Government created Insecticide Rules in 1971. According to these rules, anyone who desires to use pesticides with restrictions must apply to be a pest control officer. To obtain this license, the applicant "should be at least a graduate in Agriculture or in Science with Chemistry as a subject with a certificate of minimum 15 days training from [a list of authorized institutions]" (Central Government of India, 1971). We learned that there is a pesticide law in place which sets standards for food quality in every food item available in markets, and that an updated version is currently pending in parliament. After learning about this law regarding food quality standards, we continued searching for maximum residue levels for India, but we were still unable to locate them.

According to the Department of Agriculture Officer of Mandi, these laws are enforced by frequent checking done by the Department itself. Through the use of mobile testing vehicles, the Department is able to test fruits and vegetables at stands and stores in the markets throughout Himachal Pradesh. There are also informants outside the department which notify the department if any of the laws are broken. An interesting fact that we discovered was that if any of the laws regarding pesticides are broken, farmers are not held accountable. Instead, the pesticide dealers suffer the penalties according to which law was broken. In order to make sure that the policies are enforced, the Department of Agriculture organizes training camps for farmers and pesticide vendors as well as a subsidy in order to ensure that farmers are able to attend. As an extension of the training camps, government officers at block level as well as soil conservation officers make various trips to different villages to make sure policies regarding pesticides and proper application are enforced, meaning that masks and gloves are used, animals are kept away, water supplies are covered during application, pesticides are stored separately, and empty containers are disposed of after use.

Objective 3: Pesticide Application Practices

The Department of Agriculture Officer had valuable information about policies on pesticide application practices. Our fieldwork also revealed valuable insight into farming practices and use of pesticides in the Kullu and Mandi Districts. Though our IIT mentors mentioned

that many local farmers use manure or ash to protect crops, when those we interviewed were asked how high quality is ensured in their crops, every farmer admitted to using pesticides, with seven of the ten also saying they used hybrid seeds. Farmers typically get their information about pesticides from television advertisements or word of mouth from other farmers. Only one farmer had attended a training camp and received information about pesticides from the government. Farmers use various types of pesticides based on what is available in the markets. Pesticides are selected based solely on the pest, not the type of crop or size of farm, suggesting that dosages and targeted application to crop are not taken into consideration when farmers are applying pesticides. Farmers showed us the various pesticides they use and allowed us to note down the active chemicals. A list of the 24 active chemicals can be found in the supplementary materials section of our WPI report.

Objective 4: Pesticides Present in Market Fruits and Vegetables

Of the 24 active ingredients in the pesticides we found on farms and in pesticide shops, 21 have no restrictions according to the Central Insecticide Board & Registration Committee, but we did note some violations: one chemical, Methyl parathion, is banned for use in India, and two are only permitted for use when applied by a trained pest control operator. As indicated earlier, only one of the farmers we interviewed had attended a training camp where these trainings take place. Of these 24 chemicals, 17 are registered as fully restricted (banned) by the US EPA, five have some EPA restrictions on use, and two are not in the United States' registry, meaning that they too are banned in the United States (California Department of Pesticide Regulation, 2013). These statistics are represented in Figures 6 and 7.

In sum, 12% of the chemicals we found are banned or restricted in India; nearly 80% of these are banned in the US, with the remaining chemicals having restrictions on use in the United States.

The list of pesticides that we found was used throughout our testing process in the lab. We wanted to see if these same chemicals were present on actual produce we sampled from markets. The results of the mass spectrometry analysis are given in Table 2.

In sum, 19 of the 24 chemicals found on farms and in pesticide vendor shops were detected in our samples, one of which, Methyl parathion, is fully banned in India. This chemical appeared in five of our 18 samples. Another chemical, Cypermethrin, has restrictions on its use in India; this was present

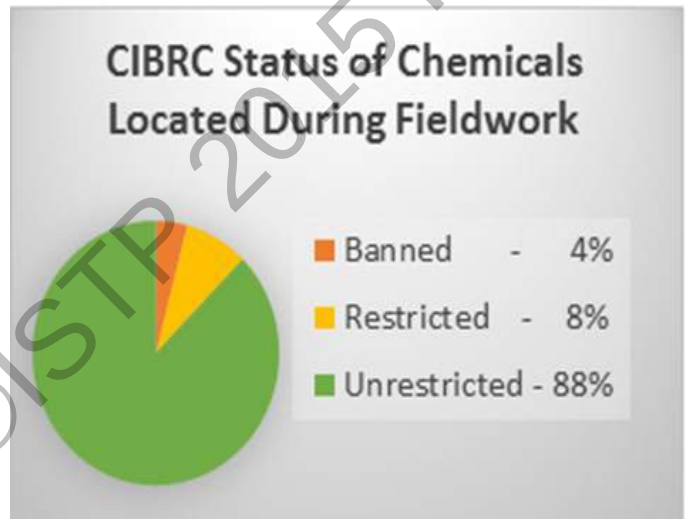

Figure 6. CIBRC status of chemicals located during fieldwork.

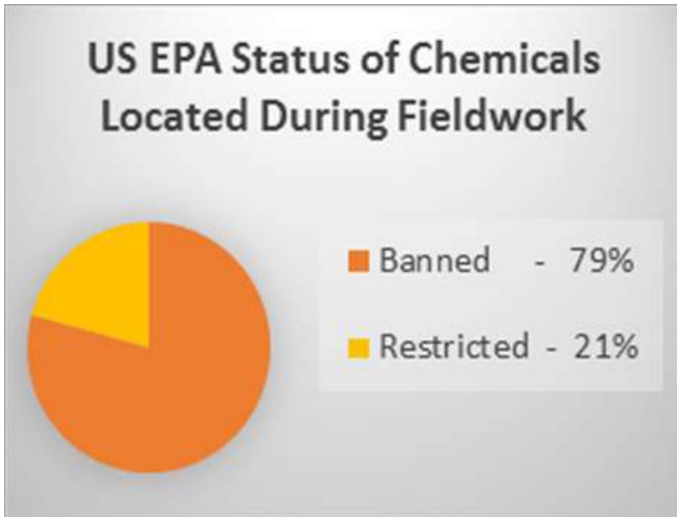

Figure 7. US EPA status of chemicals located during fieldwork.

in nine of 18 samples. The mass peaks of the chemicals were considered a match when accuracy to three significant figures was observed via comparison with the masses calculated in Chem Draw Ultra 8.0.

Table 2. Chemicals detected on sample produce via mass spectrometry.

Chemical	Number of Samples Detected in	US EPA Status of Chemical	CIBRC Status of Chemical
Pyrazosulfuronethyl	13	None (Fully Restriced) *	None
Methyl parathion	5	Fully Restricted	Banned
Glyphosate	0	Fully Restricted	None
Dichlorvos	1	Fully Restricted	None
Quizalofop-ethyl	10	Fully Restricted	None
Deltamethrin	6	Fully Restricted	None
Oxyfluorfen	4	Fully Restricted	None
Ethephon	0	Fully Restricted	None
Acetamiprid	0	Fully Restricted	None
Validamycin	8	None*	None
Paraquat dichloride	8	Restrictions on Use	None
Carbendazim	2	Fully Restricted	None
Mancozeb	6	Fully Restricted	None
Boron	0	Fully Restricted	None
Thiophanate methyl	17	Fully Restricted	None
Chlorpyriphos	11	Fully Restricted	None
Cypermethrin	9	Fully Restricted	Restrictions on Use
Thiamethoxam	6	Restrictions on Use	None
Propiconazole	15	Fully Restricted	None
Copper oxychloride	9	Fully Restricted	None
Aluminium phosphide	0	Restrictions on Use	Restrictions on Use
Lambdacyhalothrin	9	Restrictions on Use	None
Triazophos	7	Fully Restricted	None
Imidacloprid	3	Restrictions on Use	None

Chemicals with no status in the US EPA registry are considered to be fully restricted or banned by the US EPA.

Discussion

The data revealed both expected and surprising results. Our biggest challenge with data collection was presented by the language barrier. In our interviews we sometimes did not ask a general question about spraying precautions but skipped right to specific prompts about recommended practices, which may have been leading; thus, we only analyzed data from the five who were asked the general question first. None of these mentioned covering water tanks, keeping animals away, storing pesticides separately, and disposing of empty containers until they were prompted to. The responses that were given, such as simply covering one's head, waiting ten days to eat or sell the produce, or washing up afterwards, suggest the farmers may not fully understand the dangers and how to reduce risks.

We expected it to be difficult to get farmers to open up about using pesticides, but all farmers were open about their use. This made it easy to gather information on the chemicals used. Perhaps the most surprising piece of information gathered was that both farmers and pesticide vendors stated that they had no knowledge about which pesticides were banned in India. Though farmers are not held legally responsible for breaking laws regarding pesticides, the pesticide vendors are. They reported that they trust the manufacturers to produce high quality products within

governmental standards, regardless of the fact that they themselves will face serious consequences (e.g., loss of license) for violations if they sell banned or restricted pesticides to farmers.

After learning that the Department of Agriculture holds training camps for farmers and frequently visits villages to check on them, we expected farmers to be well aware of pesticide use policies. When we spoke to the farmers, we were surprised to learn that only one of ten had ever attended a government training camp. The farmers said these training camps were not advertised to them. Even without training, some of these farmers are still using restricted pesticides, which require the training noted in the Insecticide Rules of 1971. These discrepancies imply a disconnect between the availability of training resources and farmer's use of those resources, and they suggest violations of government policies.

KEY FINDING:

Even without training, farmers are still using pesticides; however, Insecticide Rules of 1971 require pesticides with restrictions to be applied only by those with extensive training.

Our laboratory testing identified the presence of many chemicals on local produce we sampled (Figure 8). Because of delayed repairs in lab equipment during our seven week research stay India, our team only tested for presence of chemicals as opposed to maximum residue levels; however, our IIT counterparts plan to continue with the research in subsequent weeks. The full results will be available on the IIT-Mandi ISTP webpage: http://www.iitmandi.ac.in/istp/.html.

Even though we only saw evidence of the banned chemical Methyl parathion in one container on one farm during our fieldwork, we detected it in five of the 18 samples we took from local markets, suggesting wider use. Cypermethrin and Aluminum phosphide have restrictions on use, but we found only Cypermethrin in our samples. Nine of the samples had this chemical present. The detection of both banned and restricted chemicals further supports farmers' statements that they are uninformed about pesticide restrictions or unaware of what they are being sold. These detections also suggest that the improvement of government testing strategies could help to control pesticide use.

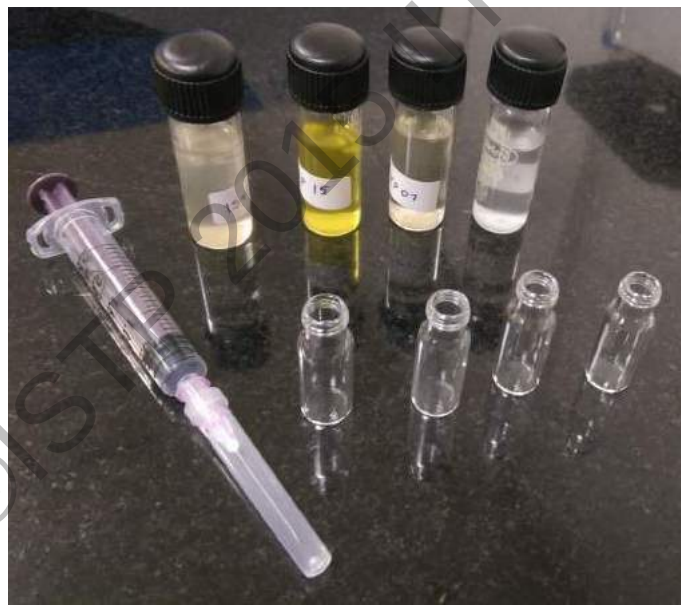

Figure 8. Samples ISTP 05, 07, 09, and 15 just before mass spectrometry.

Project Outcomes

Based our data, we made recommendations to the Central Government of India as well as to local consumers.

Recommendations

The Central Insecticides Board & Registration committee might address some of the misperceptions and misuse of pesticides that we found in Himachal Pradesh by making their official website more accessible and navigable. Farmers commonly confer with each other for help; only one participated in government training, and none discussed literature dispersed by the government, either

on websites or in hard copy form. An easily navigable website that clearly outlines registered, banned, and restricted pesticides and includes maximum residue levels for these pesticides will help. An online database of commonly used pesticides, their active ingredients and status, and an explanation of crops for which the pesticides are most effective would make it easier for farmers and vendors to verify that their products and practices are in line with government standards. This database would make it easy to confirm the information pesticide vendors receive from manufacturers.

The Central Insecticides Board & Registration Committee might also add a section to the website that outlines possible alternatives to pesticide use for farming. This section could outline traditional organic farming practices that reduce the risk of insects, mold and other diseases as well as safer alternatives that have been developed in recent years.

The Department of Agriculture might consider supplementing or replacing poorly attended training camps with informational booklets that can be updated annually with information about pesticides and their effects. These booklets would contain the same information as the online database as well as pictures of common pesticide containers to make it easier for farmers to identify potentially dangerous pesticides. Since the Department of Agriculture already holds training camps in various blocks, they would be able to determine the most appropriate language for the booklets to be written in for each block. In addition to this, Himachal Pradesh has a high literacy rate, so we assume most farmers will be able to read the booklets.

The Department of Agriculture might also benefit from altering their testing method used in their mobile testing vehicles. The procedure used was adapted from a study done in Switzerland and was very successful for detecting the presence of pesticides, easy to follow, and inexpensive. All necessary chemicals and equipment were readily available at the IIT – Mandi. A detailed procedure can be found in the supplemental materials section for project outcomes.

Finally, given the widespread presence of these chemicals on most of the common fruits and vegetables we sampled, we recommend that our IIT counterparts share their continued research with the local media to spread awareness to consumers. Since farmers do not wash fruits and vegetables before selling them, the pesticides are not being removed before arriving at the markets. If consumers do not wash their produce with soap and water before consumption, the nonpolar pesticides will not be removed because water is polar.

Conclusion

As pesticides become more prevalent in farming practices in Himachal Pradesh, farmers need to develop a deeper understanding of their proper application and effects (Figure 9). Our research, though limited, suggests that stakeholders may not be fully informed about the laws. Moreover, they may not always realize the damage that can be done to health and the environment. It is more likely that laws regarding pesticide regulations will be followed by farmers if they are provided this information on websites, in brochures, and in training workshops that are convenient for them to attend. These changes might help make fruits and vegetables safer and healthier for their own and other communities. The effects of pesticide use are not contained within the boundaries of Himachal Pradesh; drift affects surrounding states as well. When research is done locally, farmers, produce vendors, pesticide vendors, consumers, and government officials feel more connected to the issue and become more aware of the impact pesticides they use might have nationally. If pesticide presence and levels are high in the produce of Himachal Pradesh, typically considered an organic farming state, then investigating their use in other states seems equally important. The process we followed is just a possible first step in extending that research.

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Supplemental materials for this project can be found at http://www.wpi.edu/E-project-db-E-project-search/search, using key words from the project title.

Figure 9. Lettuce leaf being attacked by fungus.

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Creating an Origami Shelter Prototype for Migratory Populations of Himachal Pradesh

Abstract

Within Himachal Pradesh, India, there is a scarcity of proper temporary shelters built to withstand rough weather patterns, creating difficulty for the diverse, transitory populace. With the goal of creating a marketable, portable shelter, we investigated using origami as a tool to improve shelter quality. We have collaborated with IIT students and professors to understand the stakeholders' shelter constraints using interviews. Based on their responses, we designed and built a prototype that will address both origami and their needs.

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Indian Institute of Technology Mandi

Temporary shelters in Himachal Pradesh

In many countries throughout the world, migratory populations have a pressing need for safe and comfortable shelters. In northern India, such populations include Gaddi herders, homeless, and migratory workers. These groups have disparate needs, so designing suitable, temporary housing is a challenge. The significant environmental considerations for both rural and urban users indicates that those that lack proper housing can find life difficult. The disparate requirements of families vs. trekkers or Gaddi shepherds vs. semi-migratory construction workers means that each group generates its own checklist for suitability. In harsh environments, inadequate shelter means having to endure biting cold, scorching heat, and monsoonal rains.

The collaborators for our prototype's design were individuals who could benefit from light and portable housing. We identified parameters that could meet not only the needs of semi-nomadic herders, but also those of construction workers on a three-year stay. Migratory shepherds often travel to remote or high altitude sites and live in tarps that are not entirely suitable for the weather pattern. The Gaddi, a tribe of shepherds in Himachal Pradesh, India, migrate up and down the sub-Himalayan mountains throughout the year (Figure 1) (Chakravarty-Kaul, 1998). The geography and climate in this terrain can be taxing, including temperature ranges from -20° C to 40°C (-4°F to 104°F) and slopes up to a 70% grade (35° angle)(Kaushal, 2001).

Figure 1. Gaddi herder with his goats.

Temporary construction or agricultural workers, on the other hand, need shelters that are adaptable enough for long-term stays. Construction workers are often confined to plastic tents or tin shelters near the worksite and settle at their current job until the work is finished (Figure 2) (Kumar, 2013). These structures run the risk of damage from weather and construction debris. The workers often travel greater distances and also move from site to site over months or years (Kumar, 2013). Their average pay is low (Maiti, 2008), which forces them to routinely rely on makeshift plastic covers, rubber, or metal sheets to make their shelter with (Kumar, 2013). In addition, temporary workers often bring their families and children, exposing them to the hazardous work environment.

There is an opportunity to develop a fellowship with the transitory populations and to share ideas for creating better shelters that address their needs. The goal of this project was to create a marketable temporary shelter for diverse migratory populations. To meet the needs of the users in our stakeholder group, we

Figure 2. Tin structure destroyed by wind.

turned to origami as the basis of our design.

Origami, the art of folding paper, is an excellent method for creating different shapes while maintaining a stable structure. It offers a wide variety of properties from the different shapes that can be constructed. These qualities will be discussed in the next chapter to delve into the practicality of origami.

To meet our goal of an origami-based design, we established three objectives: 1) to assess stakeholder requirements by analyzing their shelters, environment, and needs, 2) to identify accessible, efficient, affordable and environmentally sustainable materials, and 3) to map origami principles onto stakeholder criteria to distill design requirements. Once these objectives were met we were able to recommend and test a design that our stakeholders would want to use. By providing temporary and portable origami shelters that meet the particular needs of moving populations, we can improve quality of life and overall well-being with a product that is resilient, useful, and adaptable.

Using origami as a basis for designing shelters for migratory populations

Temporary shelters must be designed to be light, compact yet expandable, and satisfactory to diverse needs in their respective environments, thus investigating the versatility of origami structures has allowed us to see its potential to address broad needs. Origami can be useful in applications of engineering the shelter in terms of deployability, strength, insulation, ventilation and wind resistance. These capabilities can be found in different folding strategies that can unleash an array of possibilities in creating a shelter.

Origami can enhance a temporary shelter because folds can be used for practical purposes such as deployability (Schenk, 2012). The most important quality of origami for shelters is that a two-dimensional foldable material is transformed into a three-dimensional structure useful for compacting and transporting, which are critical attributes for temporary shelters. Origami allows a structure to self-generate whereas tents sometimes require additional parts for assembly. Deployable structures can allow the user to erect their shelter easily. In fact, this feature allows the structure to be used by an unskilled person. Furthermore, the structure can be easier to compact, carry, and store (Schenk, 2012).

To best understand the capacity for origami shelters, we evaluated the physics of fold design, including the reverse, valley and mountain folds. The first deployable origami model we explored is shaped and behaves like an accordion, with a folding technique called the reverse fold. The reverse fold can be used repeatedly on a sheet to formulate zig-zag and trapezoidal patterns from the creases. This quality is illustrated in Figure 3. It is possible to add more folds to the structure to expand the size. Thus, with the ability to compress, the structure can be smaller or larger, allowing for versatility in size.

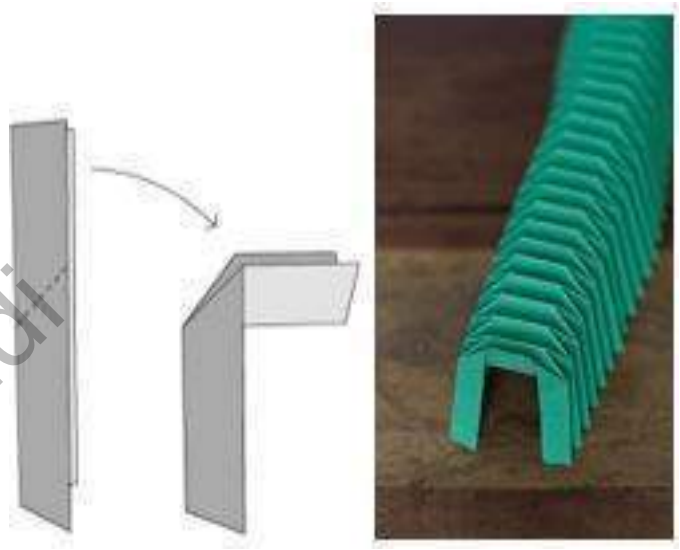

Figure 3. Reverse fold (left). Application of reverse fold in deployable structure (right).

A second folding pattern uses triangular structures. Triangles in nature have incredible strength because the sides cannot be misshapen when pushed or pulled, like other geometric shapes, and are often used in architectural design for maximum support as seen in truss bridges. Truss structures are made of triangles joined together and are often used to strength-

en cantilever bridges (Bridges-Truss, 2015). The shape of the triangle can be seen through the Diamond, Diagonal, and Herringbone folding patterns, sufficient for improving the overall strength of the structure as illustrated in Figure 4 (Buri, 2008).

These patterns can be made from modifying the reverse fold or creating mountain (outward) and valley (inward) folds. Triangular folds can be applied to the shelter to decrease the need for supporting poles, hinges, or other supporting parts for strength, as some modern tents would use.

A third dimension in fold patterns enabled us to consider pockets. In fact, origami engineering inspired Joe Gatta (Dillon, 2007), a student from University of Oxford, to develop an emergency shelter that has one origami-like plate assembly in between two layers to greatly increase strength and thermal insulation. Figure 5 shows the emergency shelter known as "Plate House." In structures, insulation can be

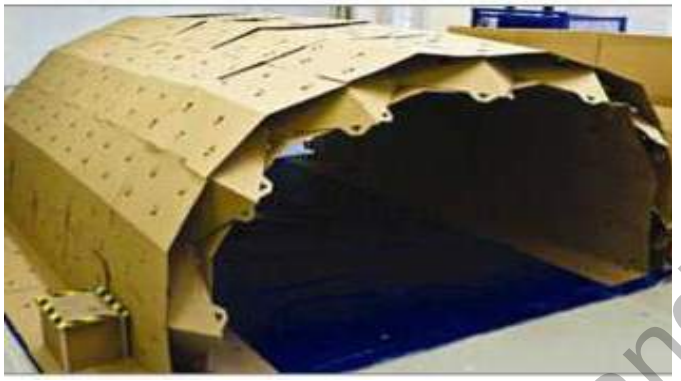

Figure 5. Multi-layered origami shelter using trapped air pockets for insulation.

done in different ways such as by layering insulating materials over air pockets to trap in heat (Dillon, 2007). In this case, the underlying fold pattern can create those air pockets. Any tessellation of diamonds, squares or zigzags can be used as air pockets to retain heat, as seen previously in Figure 4. Thus, this shows how origami can be an advantage to the design of a structure because of the variety of ways that it can trap heat based on folding patterns.

Considerations for ventilation can also be found with origami. Preliminary research revealed the capacity for pop-ups that can change airflow. This is a different form of origami, known as kirigami, or the art of cutting paper (Pop Up Card, 2015). Pop-ups are created by making a 90° fold on a sheet of paper and making two slits to create a pocket for the paper to extrude (Pop Up Card, 2015). Pop-ups can be useful for not only creating deployable structures but also for adding openings to serve as windows. This can be illustrated in Figure 6. If there is a corner, slits can be made to push

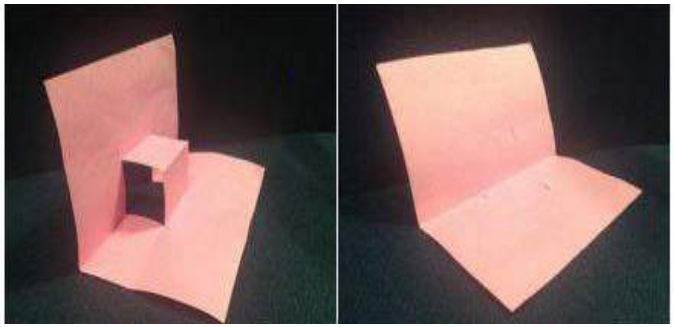

Figure 6. Pop-up origami, open (left) and closed (right).

out the material as seen in pop-up books, allowing the air to flow through. Therefore, air flow design can be dependent on origami structures as well.

Finally, the overall shape of an origami structure can affect its wind resistance. Origami has versatility in shape, where the structure can

Figure 4. Diamond, Diagonal, and Herringbone folding patterns seen from left to right.

be triangular, square or round. In this case, a round structure has been proven to be aerodynamically more windproof than a square or a rectangle (Why Round, 2015). An example of the rounder shape of origami can be seen in Figure 7. When wind gusts hit a round shelter, the airflow moves smoothly against the structure,

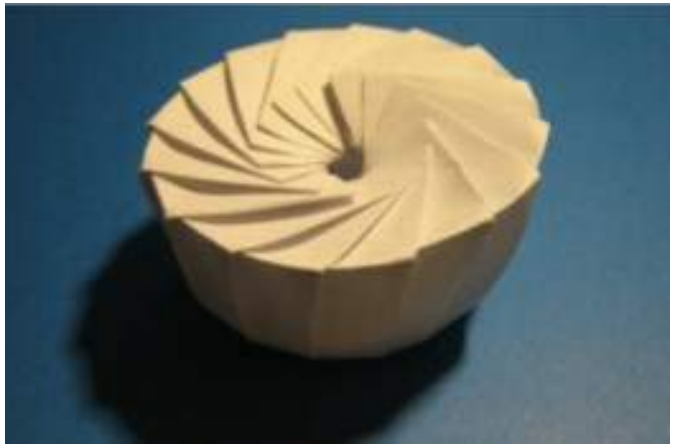

Figure 7. A rounded origami structure.

which prevents destructive gradients of air pressure that square structures would produce. Therefore, origami can be tailored to different shapes to help serve this purpose as well.

In architecture, origami has been applied to structural design for many of the reasons that have been previously mentioned. The key importance of designing an origami shelter is not only to design the structure, but also to use materials that will preserve these qualities demonstrated easily in paper. One early example of this application is Herbert Yate's shelter, the Plydome, designed for migrant farmers (A folding house for farm workers, 1967). The structure was designed with panels made of Kraft paper, polyurethane foam, and polyethylene so that it could be waterproof, lightweight, fire-resistant and self-insulated, as seen in Figure 8. While the dimensions were at a larger scale, and the structure was not portable,

Figure 8. Herbert Yate's Plydome.

the work of these architects indicates the capacity of origami as a design framework.

A modern architectural design that we reviewed was Alastair Pryor's (Estes, 2014) polypropylene emergency shelter, named the Compact Shelter because it was designed to mimic qualities of origami's deployability. This picture is shown in Figure 9. This is a reasonable model for our project because Pryor designed the shelter to be constructed in less than

Figure 9. Pryor's polypropylene emergency shelter.

two minutes, showing the ease of construction for the shelter. Also, the shelter's thickness reduces to three inches and weighs 35 pounds, making it easily portable (Estes, 2014). Therefore, this structure exemplifies portability and compressibility in a temporary shelter and serves as a helpful guide to showing these qualities in our shelter.

In sum, origami is a formidable tool for designing temporary shelters because it has potential to create a suitable temporary shelter with diverse techniques using its folding patterns. We now know that origami not only serves aesthetic purposes but also serves practical purposes. This has helped us to understand how to use these properties in incorporating a suitable prototype for the stakeholders.

Methodology

The goal for this project was to create a marketable origami structure prototype that could be customized to any migratory population. In order to meet this goal, we identified three objectives. We wanted 1) to assess current stakeholder requirements by analyzing their shelters, environment, and needs, 2) to identify accessible, efficient, affordable and environmentally sustainable materials, and 3) to map origami principles onto stakeholder criteria to distill design requirements. These objectives can be seen in Figure 10, with the required steps to meet each objective.

In order to understand the stakeholders' needs, we conducted a series of structured and semi-structured interviews and rapid vulnerability assessments. The structured interviews were conducted with construction workers in the IIT-Kamand's South and North Campuses, trekkers, and Gaddi herders, using a sample of convenience to identify potential users for temporary shelters. The questions focused on environmental conditions, travel patterns, advantages and disadvantages of shelters currently in use, and overall interest in a new shelter prototype. This was done in order to understand how to tailor the shelter design to their needs including weight, cost, and size. We also conducted semi-structured interviews with lower income stakeholders, specifically those identified as homeless and those living in slums in order to ask about affordability. Rapid vulnerability assessments can identify and prioritize vulnerabilities (Birkmann, 2007), and we used them to do so for temporary workers, the homeless, and slum residents.

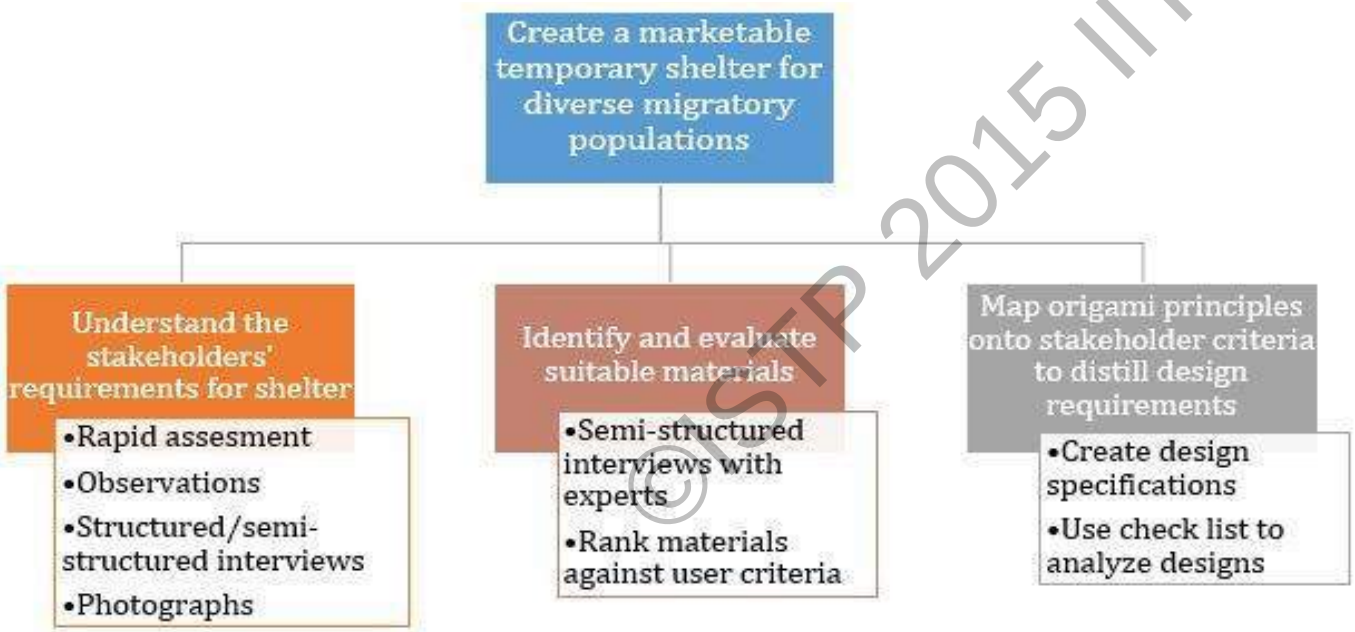

Figure 10. Methodology overview.

Our second objective identified suitable materials. Our interviews yielded criteria for what materials are essential for the stakeholders such as being waterproof and lightweight. We conducted research for materials, including ones used in existing deployable shelters, to ensure that the materials found will be sufficient based on the criteria. To obtain materials that are accessible and affordable, we conducted semi-structured interviews with both a civil engineer and an experienced trekker to gain information about the necessary materials for constructing a prototype.

Our final objective was to map origami principles onto stakeholders' criteria to distill design requirements. In order to meet this objective, we researched origami methods that are practical for designing shelters. We analyzed which qualities could be useful for the stakeholders. We produced a Venn diagram that organized overlap of all of the criteria in terms of material, origami properties, and stakeholder

needs. From there, we built a checklist of each of the attributes that could inform our preliminary designs and prototype to best fit our stakeholders' needs.

We gathered materials from local hardware stores and vendors to adapt in the Mechanical Workshop at the IIT. We used a test protocol that we constructed based on the design specifications listed previously. This way, we could evaluate the durability, foldability, and waterproof resistance, among other attributes, to ensure maximum performance for stakeholder feedback.

Results and Discussion

Here we present the results of our 3 objectives.

Objective 1: Stakeholders' needs and constraints

We interviewed 18 individuals to obtain the necessary shelter information from our stakeholders. Of these, seven were construction workers, two were shepherds, four were trekkers, two were slum residents, and two were homeless.

The first region we targeted was the North and South Campuses of IIT-Mandi to conduct interviews with construction workers. Their responses are recorded in Table 1.

By conducting a rapid vulnerability assessment, we recognized that the workers at the North campus live in tin and wooden structures. One worker allowed us to inspect his home more closely. It was constructed of tin sheets with a moldy wooden frame. There was little ventilation and light for the shelter since there was only one small window. To satisfy the need for proper lighting, the worker had a light bulb turned on even during the day. Additionally, the shelter contained shelving, a bed, and a cooking area with a space of around 60 ft^2. At the Kamand Campus, we observed that the shelters were made with either brick or tin sheets, with a few that have placed branches on their roofs to hold it down in heavy winds. The construction workers' children were present, some at the side of their parents working in an environment filled with dust and high potential for injury from bricks, rebar, and other construction materials.

Table 1. Construction workers' interview responses.

Construction worker responses
• Willing to pay to ₹1,200- 20,000
• Willing to carry up to 30kg
• Move every 1-3 years
• Required Area for shelter: 60ft^2 to 100ft^2
• Five live in mountainous terrain; two live in cities

We visited Mandi town to interview two residents of the slum and three homeless individuals that were staying in the Tibetan market across the street from the IIT-Mandi campus. Table 2 shows the responses of the slum population. The two residents in the slum neighborhood reported that they move about once a month depending on their work. We did not ask how much they would be willing to pay. From our rapid vulnerability assessment we observed that there was a lot of trash with glass and excrement around the area. The tents were made of tarps and scrap plastic with wooden frames.

Table 2. Slum residents' interview responses.

Mandi slum residents constraints
• Move once a month
• Willing to carry 15kg
• Require shelter larger than 60ft^2
• Live in groups of five

Responses from the three homeless individuals can be seen in Table 3.

Table 3. Homeless people's interview responses.

Tibetan Market homeless constraints
• Value a shelter with roofing and insulation
• Move everyday

The homeless reported that they move every day because the market where they sleep opens for business during the day. They live in groups of four people in each market kiosk, but for the purpose of data analysis to determine our origami shelter size, we marked them down as living individually. The assessment concluded that these kiosks give them no protection or

privacy. Just as before, we did not ask about how much they could afford and they all made no comment on how much they would be willing to carry.

We organized the responses in charts and explained our observations from our interviews for each group. To broaden our stakeholders to include migrant shepherds, we interviewed two Gaddi herders, one at the IIT Kamand campus and the other on a mountain between the North and Kamand campuses. Their responses can be seen in Table 4. They both travel with animals on mountainous terrain. An assessment was not conducted on the herders' shelters, because their shelters were not set up when we were with them.

Table 4. Gaddi herders' interview responses.

Kamand valley Gaddi herder constraints
• Move every 2-3 days • Live in shelters of 3-4 people • One willing to pay ₹1,000; the other between ₹3,000-4,000 • Shelter must be waterproof • One herder would carry 5-10kg but the other does not care about weight because they have a horse • Ventilation is a concern for one of them while the other is concerned about deployability.

Finally, we interviewed four trekkers. Their responses can be seen in Table 5. From the interviews we learned that they typically move daily while trekking in mountainous terrain. Just as with the Gaddi herders, an assessment was not done on their shelter, because at the time of the interview, they did not have their tent set up.

Table 5. Trekkers' interview responses.

Trekker constraints
• Move daily • Shelter must be waterproof • Three out of four mentioned that the shelter must be anchored and floored • One said shelter must be 4ft tall and 18ft^2 in area • One required good ventilation • One is willing to pay ₹3,000-5,000

The data from all of the stakeholders can be seen in Table 6 and Figure 11. Table 6 is an overview of the interview responses from our stakeholders while Figure 11 shows the properties that found as key to a good shelter. The table clarifies that the shelter must be able to satisfy these parameters based on the responses that we have collected from the stakeholders. In sum, the responses have helped us to determine specifications of the shelter in terms of size, cost, weight, and durability. The graph shows the key properties. The top three responses are insulation, ventilation, and size.

Table 6.. Overall data ranges for interview responses.

Characteristic	Response Range Value
Time in one location	1 day-3 years
Number of people in one shelter	1-6 people
Weight willing to carry	5-30kg
Amount willing to pay	₹500-20,000

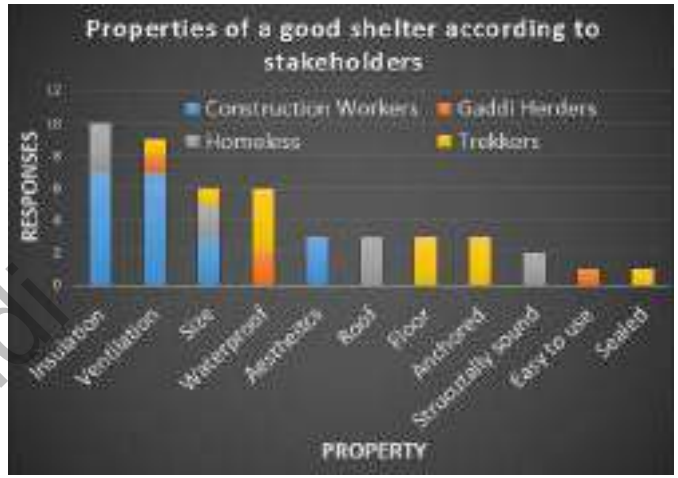

Figure 11. Properties required in a good shelter.

Objective 2: Identifying suitable materials

We observed that the stakeholders had a wide variety of materials to construct their shelters. The construction workers used tin sheets, wood, and bricks to have longer lasting dwellings, and likely also due to the proximity of building supplies to their site. The Gaddi herders reported that their shelters are made of their own clothing, plastic sheets and wood. The trekkers use plastic sheets and wood, and lastly, the slum populations use plastic sheets, wood

and scrap materials, such as old tin sheets.

After assessing the materials commonly used, we also evaluated readily available materials. We found that cardboard can be found or repurposed from industrial waste and is a good insulator (Swanson, 2015). We also identified plastic tarpaulin, Velcro, and mesh in local vendors in Mandi that can achieve weather resistance in a shelter.

Plastic tarpaulin will serve as a waterproof covering and flooring of the shelter. Also, it is normally used in temporary shelters, is lightweight, durable, flexible, rot and weatherproof (The Toughest Tarpaulin, 2012). Velcro was used to seal the door and windows, while mesh was used for the windows to help seal out insects and animals. Thus, these materials were suitable for constructing the origami shelter based on their functionality.

Objective 3: Map origami principles onto stakeholders' criteria to distill design requirements

We combined origami properties with the needs of the stakeholders and materials to see overlap. From the interviews, we created a list of criteria that satisfy the design needs for a shelter. Each of these considerations is expressed in Figure 12.

Table 7 shows the final design specification in detail for the shelter as a whole. We used

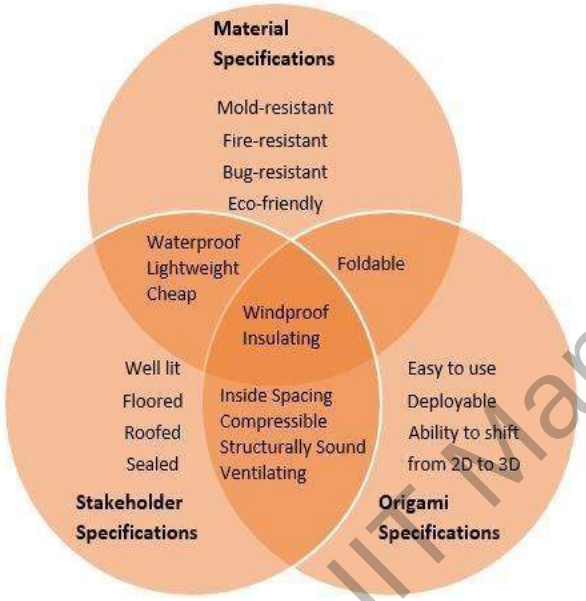

Figure 12. Design specifications Venn diagram.

these measurable criteria to further determine our prototype. We created a checklist. The checklist has some of the design specifications that are dependent on structural design that would correlate to origami and stakeholder specifications. The (x) indicates that the structure is satisfactory in this area, while the (-) indicates it is not. Table 8 presents the results of this synthesis. From this checklist it was determined that we would build full-scale prototypes of the dome and accordion house pavilion since they scored the highest.

Table 7. Shelter design specifications.

Property	Definition
Waterproof	Sustain 1270mm of rain
Insulation	Hold 19°C
Wind Resistance	Withstand 9.6km/hr
Mold Resistance	Must be waterproof
Eco-Friendly	Must be recyclable
Bug Resistance	Completely sealed
Lightweight	Less than 5kg
Affordable	Less than ₹1,000
Ventilation	Air flow through structure
Well Lit	Brightness must be 100 Lux
Compressible	No dimension can exceed 120cm when collapsed
Ease of use	Less than 5 min. to set up

Table 8. Design checklist.

Property	Dome	Accordion House Pavilion	U-Pavilion	Diamond Fold
Waterproof	x	x	x	x
Insulating	x	x	x	x
Wind resistant	x	-	-	-
Bug resistant	x	-	-	-
Lightweight	x	x	x	x
Affordable	x	x	x	x
Ventilation	-	x	x	x
Compressible	x	x	x	-
Easy to use	x	x	x	-
Sheds water	x	x	-	-
Total points (out of 10)	**9**	**8**	**7**	**5**

Discussion

Our data revealed some surprises while confirming some of our predictions about stakeholder needs. We identified new trends in terms of migration patterns. We also found a wide range of responses when asking about affordability, migratory patterns and vulnerabilities that we had not predicted before our interviews. For example, construction workers could afford up to ₹20,000 on a shelter. Though we expected they could pay some amount, we did not expect that the price would be so high. At the same time, the homeless and slum residents need a shelter that is low cost or subsidized for them to make the shelter affordable. In order to provide these subsidies, we considered reaching out for NGO support, but we were informed that funds would not be available to support the shelter. This forced us to consider the difficulty in setting a reasonable price range for all stakeholders. The range must balance amenities and quality with affordability. We made the decision to prototype a version that will have some unit cost, in order to test a range of materials and sizes.

We also found that migration patterns factored into the lifestyle requirements of the shelters. Construction workers' shelters were ultimately outliers in that they are semi-permanent, which greatly affected the trends in our data. For example, these workers cook in their homes, need storage options inside the structure, and bring in full-sized beds. Their shelters are closer to second homes to the occupants, than they are temporary shelters. Contrary to construction workers, the other stakeholders in our study were more transient. They cooked outside and did not carry furniture, meaning that the shelters are used mostly as a sleeping and sitting area. Most of these more transient stakeholders require a shelter that can be transported daily or monthly, so the temporary quality of the shelters has more importance.

Overall, the qualities that stakeholders value most are insulation, ventilation, and a suitable shelter size. This fact is not surprising because the weather in the area tends to have cool winters and hot and rainy summers, making weather protection highly important in a shelter. In fact, the structures that the stakeholders currently use have this issue because there were vulnerabilities in both material selection and structural design. Thus, durability and weatherproof materials are important.

From the constraints given by the stakeholders and our research, we realized that finding materials would be challenging, especially when considering origami within the design. One obstacle that we faced in our search was accessibility of suitable and affordable materials. The materials that we would find online were either not available in India or would take too long to ship from other states. Moreover, we realized that the materials that we obtained could be found easily in Mandi to replace or repair the structure. Another obstacle we faced was finding a foldable material. At first, we wanted to fold the material to create the entire structure, as we have seen in previous inventions. However, we could not find an available material to solve this issue. Instead, we found a different strategy to mimic the creases in the shelter that we have created. Hence, as a solution, we decided to construct the shelter out of corrugated cardboard panels and plastic tarpaulin to satisfy these qualities.

Project Outcomes

Origami shelter prototype: Dome origami structure

The prototype that we built can be seen in Figure 13. The dimensions are 104cm for the height and 194cm for the diameter. We chose

Figure 13. Full scale dome prototype.

this design based on the results from the checklist mentioned earlier. The prototype is made from cardboard and plastic tarpaulin, with Velcro attachments. The prototype is circular because it will help with wind resistance. Also, there is an attached floor to help the inside stay clean and add protection from insects and rain for the user. When folded the structure looks as it is in Figure 14. There are backpack straps attached for easy transportation. When compressed the structure is 23cm thick and 158cm long. The entire structure weighs 15kg. Figure 15 displays how the structure gets to its collapsed form.

Figure 14. Full scale dome prototype in compressed form.

Recommendations for future projects

Figure 15. Shelter transforming from popped up to compressed

There is room for improvement in the design of the shelter. The materials that we obtained were out of convenience because of time constraints and the difficulty in delivering from long distances. If ordered sooner, corrugated plastic sheets can replace cardboard to significantly reduce weight. Furthermore, the need for tarpaulin would not be necessary since plastic sheets are waterproof. Overall, for future projects, advanced research should be considered to find materials to improve the quality of the shelter design.

Conclusion

There are diverse migratory populations that are in need of temporary shelter. After investigating the range of requirements of these stakeholders, we have been able to find many design innovations that can be implemented into a shelter that could satisfy their needs. Moving forward, these shelters could have merit with other stakeholder groups as well. Further research could evaluate their effectiveness as relief or refugee housing, for example, given the ease of transport of these shelters to affected areas.

Moreover, we have discovered that origami can contribute greatly to engineering applications and has far more capabilities than what we imagined in the beginning. Thus, we can conclude that the art of folding can transform the way structural problems are solved. We hope that this application of origami will not only positively contribute to any group that requires a temporary portable shelter, but to the engineering communities as well.

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Supplemental Materials for this project (raw data, calculations, research instruments, and additional project outcomes) can be found at http://www.wpi.edu/E-project-db/E-project-search/search, using key words from the project title. Outcomes delivered after April 30 will appear on the IIT's ISTP page: http://www.iitmandi.ac.in/istp/index.html

Feasibility of Community-Based Businesses in Kamand Valley

Abstract

Community-based businesses (CBBs) are important in developing rural areas. This project evaluated the feasibility of CBB's in Northern India's Kamand Valley. Through interviews with fifty-seven respondents, we obtained information on resources, interest in participating in a CBB, and products purchased in the market. Our findings indicated potential for the development of a CBB in the Kamand Valley, and an assortment of products. We made recommendations for two prospective CBB's: producing soap made from soapnuts, and creating hand woven products.

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Potential for Community-Based Businesses in Villages of the Kamand Valley

Community-based businesses (CBBs) have added significantly to the quality of life for families in rural India ("NRLM SKILLS : Success Stories," 2015). They typically involve a small group of local residents who use their own knowledge, equipment, and skills to develop and sell a product (Figure 1), which makes them easily adaptable to rural settings. All production is done within the community, and business operations are generally local. CBBs fall under the general category of Micro Small Medium Enterprises (MSMEs), a term in India used to classify businesses based on size. In recent years, India has seen consistent success and documented growth in the number of these enterprises, as seen in Figure 2.

Figure 1. CBB owner selling woolen clothing in Mandi Market.

MSMEs account for a large percentage of exports and are growing faster than the industrial sector of the Indian economy (Deshpande, 2013). Minimal requirements in business experience and low input costs make CBBs an efficient model for entrepreneurs, particularly in rural areas.

This project investigates the potential for CBBs in Himachal Pradesh, a northern Indian state that includes part of the western Himalayas. In the heart of the state, the rural Kamand Valley is a hilly region composed of approximately twenty villages outside the town of Mandi. This area has an abundance of natural resources, agricultural products, and dense forests. The introduction of a CBB could provide the opportunity for villagers of this region to develop locally derived products that can generate a reliable source of income.

The goal of this project was to investigate the feasibility of developing a community-based business in villages of the Kamand Valley. In order to accomplish this goal, we identified five objectives. First, we explored the available resources of the Mandi district, including raw materials, skill sets, and government programs that could offer support. Next, we assessed villagers' interest in participating in a business of their own. We then applied criteria to raw materials and products to determine the most promising material and product to be sold in the Kamand Valley. Afterwards, we identified a village with the highest interest and potential, and re-visited to introduce the possibility of a CBB and solicit feedback from its residents. This helped us determine the feasibility of starting community-based businesses in the selected village.

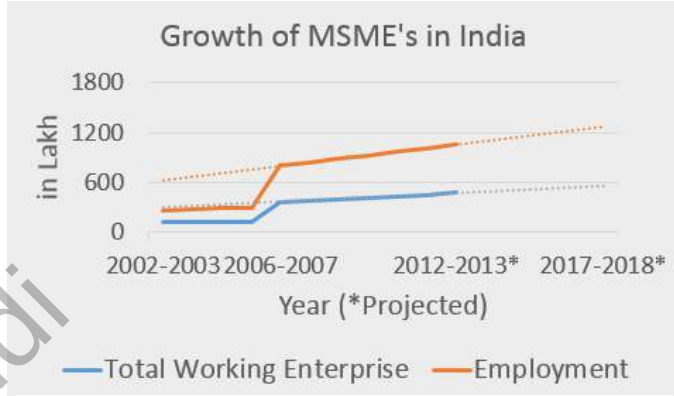

Figure 2. Overall and projected growth of MSME's in India, 2001-2018 (India, 2014).

Understanding Community-Based Businesses

Micro Small Medium Enterprises (MSMEs) account for 45% of India's manufacturing output and 40% of its total exports (Deshpande, 2013). In the past ten years, both the number of these businesses and

people employed increased approximately four-fold (India, 2014). The community-based business (CBB) model, a subset of MSMEs, has the potential to benefit communities by providing supplemental income, the opportunity for better education and nutrition, and the ability to contribute to the local economy (Azid, Aslam, & Chaudhary, 2002).

Community-based businesses are operated locally, giving residents the opportunity to manage a business alongside daily responsibilities, whether it be household duties or any other employment. Materials are gathered and processed in the area, minimizing material costs, then sold in neighboring villages and markets. Typically, fewer than thirty people are employed, each of whom has some training, skills, or knowledge contributing to the success of the business. CBBs encompass the business models of cottage industries, cooperatives and collectives. Each has the goal to improve their participants' quality of life; however, they accomplish them through different business structures.

Cottage industries operate within the home, where each worker has a role in the hierarchy of the business, whether it be managing the organization or producing the product. Cooperatives bring together participants from a community with a common business purpose, which tends to be values-based and supportive of local empowerment. These organizations are owned equally by all employees, resulting in a shared decision-making process (Datta & Gailey, 2012; "Lijjat Homepage," 2015). Finally, collectives are groups of businesses--which could include cottage industries and cooperatives--that share a common interest and utilize each other's resources to target larger markets. Each of these models is illustrated in Figure 3.

Resource Base for Community-Based Businesses

A strong foundation for a CBB depends on its available resources. Basic resources, shown in Figure 4, include raw materials used in production, skills required for production and sale, and government programs that provide training and funding.

Communities can identify appropriate raw materials and products by following specific criteria: availability, collection, and production ("About - Tbag Shop," 2015; "Lijjat Homepage," 2015; Lysen et al., 2013; Peterson, 2014). Availability means that enough raw materials can be locally sourced. Collection means that raw materials can be gathered quickly and easily. Production means the raw materials can be developed into a product with little time, effort, new equipment, and capital. Our preliminary research on Mandi District, which encompasses the Kamand Valley, showed that 43% of the area is covered in forest,

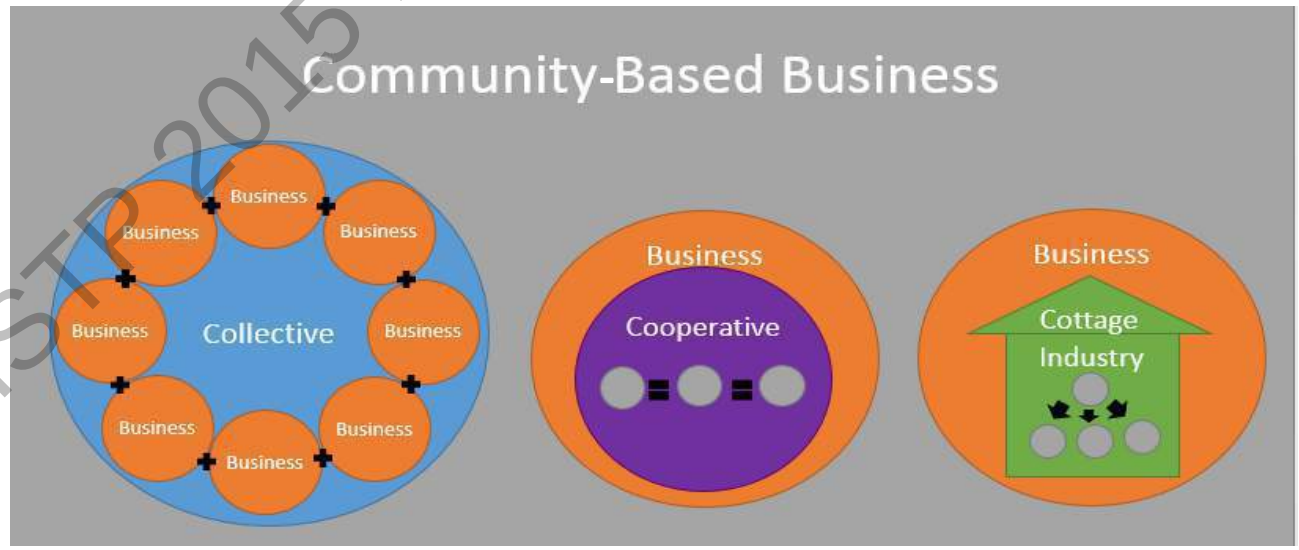

Figure 3. Differences in structures of collectives, cooperatives and cottage industries.

Figure 4. Elements of basic resources.

providing many natural raw materials. Over ninety plant species can be found in this region, with properties ranging from edible to medicinal to hygienic (*Himachal Forest Statistics 2013*, 6457). The abundance of these resources offers many possibilities for locally derived products.

Beyond raw materials, skill sets should be considered. Useful skills include general business knowledge about management, sales, and organization, as well as production and crafting skills ("About - Tbag Shop," 2015; "Lijjat Homepage," 2015; Lysen et al., 2013; Peterson, 2014). Women in the Kamand Valley traditionally possess food processing, handicraft, and crop cultivation skills due to their roles in the home and their agrarian lifestyle (Deshpande, 2013; Garg, et al., 2013). More specific skills were identified in our on-site research.

Finally, government organizations that aim to assist the growth of rural areas can support the development of CBBs. One such Indian organization is called the National Rural Livelihoods Mission (NRLM). It strives "to reach out to all poor families, mobilize them into [community-based businesses], link them to sustainable livelihoods opportunities and nurture them till they come out of poverty and enjoy a decent quality of life" ("Brief About NRLM"). The organization's objectives are carried out on the district level, by the District Rural Development Agency (DRDA), and on a smaller level, through the Block Development Organization (BDO) (*NRLM Annual Action Plan 2014-2015 Himachal Pradesh*, 6458). The NRLM guides impoverished villagers through every step required to start a CBB. This includes training on product development and business skills, and financial assistance through low interest loans. The NRLM can be a valuable resource to people in impoverished communities looking to establish a CBB.

Market Potential for Community-Based Businesses

The market potential of a CBB can be identified primarily through the number of prospective buyers (Mundy & Bullen, n.d.). The Kamand Valley is located twenty-one kilometers away from the town of Mandi, a major marketplace in the Mandi district, which is shown in Figure 5.

Mandi is home to over 26,000 people, according to the 2011 Census, providing a large customer base ("Mandi [Mandi, Himachal Pradesh, India] - Population Statistics and Location in Maps and Charts"). Additionally, the introduction of the Indian Institute of Technology -Mandi in Kamand will bring a large population of students, faculty, and staff. The growing population will "add to the development of consumerism and in turn [create] new markets and [increase] job creation opportunities" (Garg et al., 2013). The positive market potential and available resources of the region show promise for introducing a CBB in the Kamand Valley.

Preliminary research provided a baseline of potential resources which could prove useful for the introduction of a CBB. The next section discusses our methods for further investigation, which were completed on site.

Methodology: Collecting Data and Identifying Potential

The goal of this project was to investigate the feasibility of developing a community-based business in villages of the

Kamand Valley. In order to meet our goal, we identified the following objectives and data collection strategies, as seen in Table 1. Scholarly research was primarily done before we arrived onsite. We investigated the raw materials in the Kamand Valley and skills of the residents. On-site we researched available government programs related to CBBs, and we delved deeper into scholarly research on the collection and production of a range of raw materials.

To determine village interest and understand their skills and raw materials, we conducted semi-structured interviews, targeting five villagers in nine villages, chosen by a sample of convenience: Neri, Navlay, Chahal, Doohuki, Kathindi, Kataula, Sirum, Kara, and Nishu.

Each interview was conducted in Hindi and took 45 minutes to one hour. Each took place in the interviewee's home or business, with IIT students acting as translators. Questions addressed what raw materials are available in the area (crops, animals, and so forth), what they do on a daily basis, what skills are required, how often they go to the market in Mandi, what they purchase, whether they sell anything in the market, and finally, if they would like to participate in a CBB; the full interview can be seen in our online Supplemental Materials: Methodology section. Semi-structured interviews were ideal for two reasons: we maintained control over the subject matter, and most importantly, we were able to ensure completeness, that all desired

Figure 5. Several CBBS selling products in the Mandi Market.

Table 1. Objectives and corresponding data collection strategies.

Objective	Data Collection Strategies
Explore Resources of the Mandi District	Scholarly Research: Raw Materials Skills Government Programs Semi-Structured Interviews: Village Community Kamand Forest Department
Assess Local Interest	Semi-Structured Interviews: Village Community
Apply Criteria to Raw Materials and Products	Scholarly Research: Collection of Raw Materials Production of Raw Materials Cost of Production Profitability Semi-Structured Interviews: Village Community Small Business Owner
Identify a Village with Potential Success	Semi-Structured Interviews: Village Community Observation: Population Supporting Infrastructure
Solicit Feedback from Identified Village	Focus Group: Village Community

information was gathered (Fitt & Cohen, 2014). When choosing individuals to interview, we used a sample of convenience, targeting adults who were outside their homes and closest to the road (Figure 6).

Based on our initial research on raw materials and products, we chose one raw material and product that seemed feasible. To do this, we conducted scholarly research on the collection processes of the raw materials identified to us by villagers. We then detailed the production processes for products that can be made from these materials by noting time, effort and any material and associated costs. We also determined potential profits through research on costs required to process the material into the product, and through observation of local costs of similar products. Market potential was determined through our interviews, when we asked the villagers what they went to the market in Mandi to buy. Lastly, we spoke to a small business owner who produces and sells our chosen product to confirm our research and obtain information on the success of this product in a CBB in the Kamand Valley. These criteria allowed us to narrow our products down to one which could result in the most successful CBB in the Kamand Valley.

Figure 6. Interview at Mandi Market.

Once we determined a feasible product, we focused on a particular village based on interest, infrastructure and population. Interest was identified through interviews, transportation was noted through observation and interviews, and population size was found using the 2011 Census. Our idea was to return to the village to conduct focus groups in order to gather supplemental feedback on our product ideas, connect interested parties, and facilitate early business planning with the community.

Results and Discussion

Our objectives were to explore available resources of the Mandi District, assess local interest and baseline capacity of villages, identify the most promising material, product and village for a CBB, and assess whether it will be feasible to introduce a CBB in that village. Here we outline our key findings by objective.

Objective 1. Resource Base

To assess local resources and capacity for CBBs, we asked our fifty-seven interviewees from nine villages to think about the materials that are available locally. By "resources", we solicited both raw materials that could be gathered and processed, as well as skills that could be utilized. We also considered government programs that provide financial and training resources for local entrepreneurs.

Available Raw Materials

Our interviews revealed a range of raw materials that are available in the Kamand Valley, shown in Figure 7. These included resources from which potential agricultural, animal, and plant products could be derived. All are commonly found or easily grown in the region.

Villagers frequently identified the crops they grew, along with animals they raised as a raw material available to them. Wheat, maize, rice, and cows were some of the most identified materials by respondents—all of which are used by villagers to feed themselves and their families. Agricultural products were mainly used in the home, with surplus maize and milk sold to the markets in Mandi. Naturally found materials such as soapnuts, gooseberries and

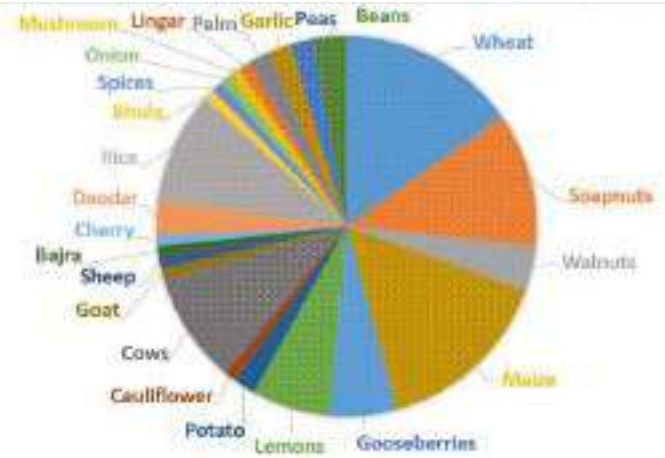

Figure 7. Resources identified through interviews.

walnuts were also identified by villagers, but were not often used for any purpose outside of the home.

Soapnuts were the highest identified non-agricultural material, but were not commonly used by villagers. There were three instances of soapnuts being gathered and sold raw to the Mandi market in Neri and Navlay, and two instances of soapnuts being used by villagers as a soap product, limited to Doohuki and Navlay. Although a couple villagers knew how to use soapnuts to produce a soap product, seventeen who identified soapnuts as an available raw material indicated that they were unaware of the process by which to produce them into soap. Gooseberries were commonly used by villagers in the production of pickles and chutney, with families making gooseberry jam in the home. In the Kamand Valley, these products were used in the home only, although we found a women's cooperative in Mandi, formed through the DRDA, selling these products at profitable rates. Lemons were identified by seven respondents, but no villager shared their use in the home or suggested any potential products derived from them. Walnuts were never processed into a product, but we did find two occasions of walnuts being collected by villagers in Navlay and sold raw to the Mandi market.

Available Skills

Local skills identified by respondents include farming, weaving, sewing, and knitting. These skills were prominent across the Kamand Valley, regardless of village, and were primarily used in the home.

Twenty-one of the thirty-one adult female respondents identified weaving, sewing, and knitting as skills. They explained that these skills were used to make clothes, blankets and mats for their families and children. One respondent from Navlay occasionally sells hand woven blankets to local villagers. Another respondent, in Neri, told us that every girl in the area knows how to weave, and while adult women are content using these skills in the home, younger girls are looking for employment.

Beyond these primary skills found across the region, we found fewer mentions of English speaking skills, basic business skills, teaching skills, and rope making skills. English speaking and teaching were identified twice, business six times, and rope making eight times. Respondents with these skills were more educated; for example, one woman in Neri is currently getting her masters in English at a local university. Along with other educated individuals, she was highly enthusiastic about the possibility of introducing a CBB in the area, expressing that work needed to be brought to her village.

Available Governmental Support

Interviews with officials from the Block Development Office (BDO) of Kamand, and the district livelihood officer of the District Rural Development Agency (DRDA) for Mandi district, revealed how assistance is provided to rural entrepreneurs. When a group of villagers identify a product they would like to sell in a business setting, they can submit a proposal to the NRLM. Once the proposal is approved at the state level, it is brought to the village's DRDA and BDO to oversee implementation of the business. To date, this program has assisted the growth of over 9,000 CBBs in the Mandi district. If the proposal is accepted, then training is provided by the DRDA. Training programs include business skills such as financial

responsibility, and technical training, based on the product selected. Financial support is provided by connecting the group with a bank for loaning services. Interest rates on loans in Himachal Pradesh are 7%; however, through this program, loans are offered at an interest rate of 3%. If the CBB complies with the policies set by the BDO and pays back their loans on time, they have the opportunity to increase their credit annually.

BDO Policies:

1) weekly worker meetings
2) regular contributions to group savings
3) regular loaning from group savings
4) regular repayment of loans
5) regular recording of meetings

The first loan offered is for a maximum of 50,000 rupees with the possibility of borrowing up to 100,000 rupees.

Objective 2. Identified Interest

To assess local interest, we introduced respondents to the structure of a CBB and inquired whether they would like to participate in one and the motives behind their decision. Of our fifty-seven completed interviews, forty-one respondents were interested in participating. Interested villagers specified increased income as a reason to participate in a CBB, but mentioned that training in the production of a product would be necessary under most circumstances. They did not express preference, but said they would do any type of work to increase their quality of life. On average, villagers claimed they would have two to three hours available per day that they could commit to the business, but mentioned that it would vary according to season and child responsibilities. Those who were not interested either said that they were content with their income or that they did not have enough available time. Interest on a village by village basis is shown in Figure 8.

In Neri, the only respondent who was not interested in participating in a CBB was a woman who said she was too old to get involved, but many of her relatives would most likely be interested. We found that many villagers in Kataula were already part of successful businesses and therefore were not interested in a CBB. One respondent identified people who work in CBBs and make natural products as being 'backwards;' meaning that it is senseless not to purchase goods made from factories at lower costs. All of the seven Navlay villagers we interviewed expressed interest, and they indicated that many of their neighbors might also be interested in participating. In Doohuki a number of villagers, mostly women, did not want to be interviewed or interact with us, which left our group feeling the assessment was incomplete. In Kara, five out of six respondents expressed interest, with one specifically mentioning community development and livelihood improvement. Chahal respondents did not demonstrate much interest

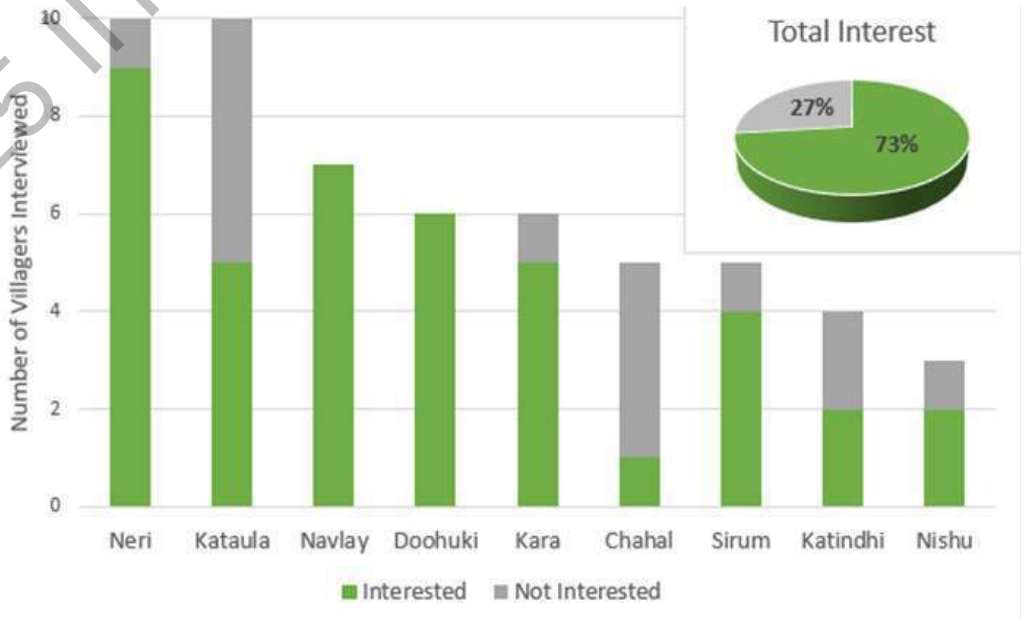

Figure 8. Interest in participating in a CBB by village in the Kamand Valley.

in a CBB. The only woman who was interested mentioned that she had a small child and would not be able to give much time to the business until her child was older. Residents of Sirum were interested in the development of a CBB for employment opportunities. One respondent, an adult male who had received no formal education, said he would be interested, and that it would be a great opportunity for a better life for his children. Similar to Kataula, residents of Katindhi were involved in successful businesses, and only two out of five expressed interest in a CBB. Although not many individuals were interviewed in Nishu, twenty-six adults and children were present during the interviews. Often times the other villagers nodded or verbally agreed with what was said by the respondent, and occasionally, someone other than the interviewee would respond, giving our group a feeling of a complete assessment.

Another question posed to villagers was whether they were interested in purchasing locally made products. One respondent explicitly answered no, and another said it would depend on the quality of the products. Though the majority wanted to support the local community through the purchase of locally made products, and reasoned that it would be more convenient to purchase products that were locally sold rather than traveling to Mandi.

Objective 3. Identifying Potential

We initially identified five raw materials from our interviews that were locally available and easy to collect: soapnuts, walnuts, gooseberries, maize, and dairy. We chose these materials because they require minimal ingredients and equipment, and have a simple production process. These raw materials, their associated processing, and the resulting products are condensed in Figure 9.

We further narrowed this list to the potential products soap, walnuts, and gooseberry jam, by determining profitability. For the profitability assessment, we identified startup costs, one-time expenditures such as equipment, and unit costs, which account for ingredients, packaging, and processing costs, which can be found in Supplemental Materials: Project Outcomes. From there, we identified the market value for each product and a competitive price to maximize profit. Profit was calculated by subtracting unit cost from selling price. Although startup cost was not included in profit calculations, we determined the number of units that needed to be sold in order to pay off the initial investment. A summarized profitability assessment is shown in Figure 10; the full profitability assessment can be found in our Supplemental Materials: Results section.

Finally, to assess market potential in the Kamand Valley, we asked villagers what they bought from the markets in Mandi on a regular basis. The most frequently mentioned item was soap and bathing products, next was cloth and clothing. Nobody mentioned buying gooseberry jam or walnut products, both of which were identified products based on the selected resources.

This indicated to us that soap, as shown in Figure 11, had the highest market potential out of the three choices in the Kamand Valley. We interviewed the owner of a small handmade soap store in Mandi, who makes and sells approximately three tons of bar soap per month. In this interview, he confirmed our research on the production of soap and detailed associated costs. Although he did not make bar soap from soapnuts, he told us that his business was successful and that a business selling locally made soapnut bar soap would have potential as locals are drawn toward naturally derived products. A profit analysis of bar soap can be seen in Table 2, while a profit analysis of the other raw materials can be found in Supplemental Materials: Project Outcomes.

Objective 4. Identify Village with the Highest Interest and Potential

The village which showed the highest potential for the introduction of a CBB was Navlay, considering all seven respondents expressed interest in participating. There is a proper road running through Navlay with bus service available to other villages, the IIT-

Figure 9. Resources suitable to a CBB.

Mandi, and the city of Mandi—all of which are potential markets that could be accessed. In relation to the other eight villages, Navlay had a medium size population with two hundred thirty-one people, which is suitable for a CBB because it allows for an ample amount of potential workers and customers.

Objective 5. Solicit Feedback from its Residents

With a raw material, product, and village selected, our original approach specified a return to a selected village to introduce the possibility of a CBB and solicit feedback in a focus group format from the community. After engaging with the stakeholders, however, we scaled back our approach to identify just one villager that expressed interest in participating in a CBB. This allowed for a deeper conversation to

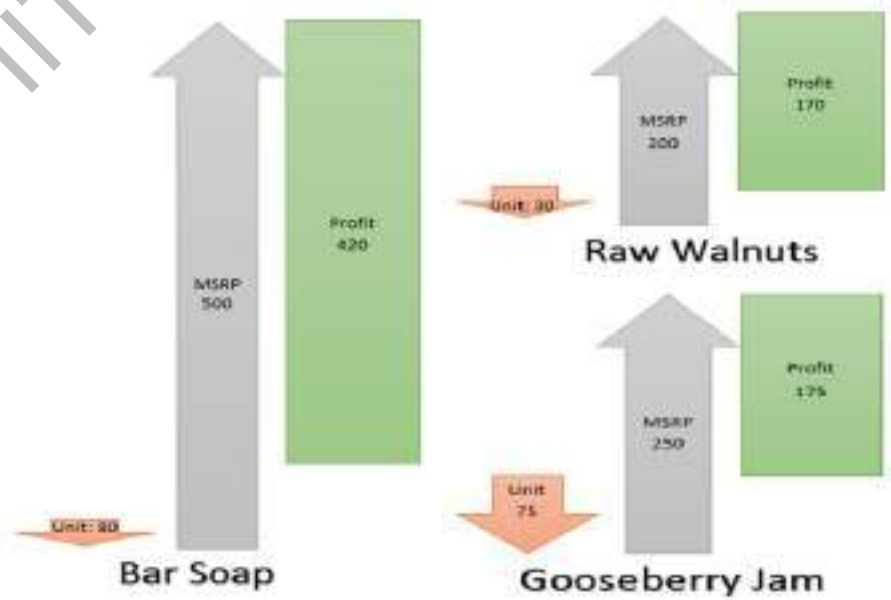

Figure 10. Profit assessment of suitable products (in rupees).

Figure 11. Soapnut bar soap: criteria assessment.

get an honest opinion on the potential, and the challenges that a CBB would face in this village. Additionally, we believed that the introduction of the CBB would be better received by the community if presented by one of their neighbors.

We identified Raj Kumar, a 32 year old male from Navlay, as a potential leader in implementing a soapnut-based CBB. We presented our research on the potential of soapnuts as a business and asked him what his thoughts were on the business idea, what his concerns were in starting this business, and whether he was interested in organizing such a business. Raj's responses were very positive; he believes this business has a very high potential in the Kamand Valley. His concerns were funds for the business, the time and labor involved in production, and marketing the product. In his home, Raj produces and uses a powdered form of soapnuts for washing clothes and blankets. To create powdered soap, he collects soapnuts, grinds them against a stone one at a time by hand, and collects the powder for use—an arduous process. In order to create larger quantities of soap to form a business, an innovation in this process would be beneficial. After collaboration with Raj, we identified this innovation to be a large-scale grinder, allowing multiple soapnuts to be ground into powder at once with minimal labor, which would greatly expedite the process of grinding soapnuts.

When asked to clarify his concern of marketing, Raj said it could prove difficult to collect the material, produce the product, advertise and sell. To alleviate his concern, we discussed potential organizational structures for the business. We identified the best position for him based on his strengths and discussed possible employee roles. He said he would be happy to gather a group of interested people for this business, and that he would prefer to be involved in all aspects during its infancy before shifting his focus to marketing. He felt that with his vast connections both in the Kamand Valley and in Mandi, he would be better suited for growing the business.

Table 2. Bar soap profit analysis.

Startup Costs (₹)		Unit Cost	(₹)	Labor Time	(Hrs)	MSRP (₹)	Profit (₹)	Number of Units Sold to Break Even
Pot	5000	Bag	10	Collection	1	500	410	13
		Lye	10	Production	3			
		Oil	70					
Total	5000	Total	90	Total	4			

Discussion

Throughout our project, we struggled with optimizing the scale and the breadth of our approach to best meet the needs of rural Kamand Valley villages . The sample size used

in our baseline capacity assessment of resources and interest was relatively small, compared to the total population of the Kamand Valley, giving us only a snapshot of interest in the entire Kamand Valley.

An interesting trend found in our data was the classification of livelihoods for villagers across the Kamand Valley: small business-oriented and agriculturally-oriented. The small business-oriented villages are Katindhi and Kataula, while the other seven are agriculturally -oriented. While access to the village was not the only factor in a village being agriculturally-oriented, it was a major part. Other factors depended on the geography of the village and wealth of its residents.

The small business-oriented villages had several shops and markets that were sufficient for the villager's shopping needs, as a result they rarely had to go into Mandi. Since they tended to be better off due to successful businesses of their own, there was low interest in a CBB, and therefore we focused our efforts on agriculturally-oriented villages.

The agriculturally-oriented villages had residents who possessed the same skills, grew the same major crops, and purchased the same products from the markets in Mandi, which they could not produce on their own. A skill identified by nearly every respondent was farming, with women identifying skills in weaving, knitting, and sewing. Villagers with these skills grew most of their own food and made their own clothes, only traveling to Mandi periodically to buy soap and fabric. This self-sufficient lifestyle needed to be considered in the selection of a product, considering it is inconvenient for villagers to get to Mandi. By producing these necessities in the Kamand Valley, it reduces the need to travel to Mandi as frequently. These trends were explicit in our data; however, we believe that it extends to the entirety of the Kamand Valley due to lifestyle similarities.

As previously established, the DRDA and BDO offer many services under the NRLM scheme to aid in starting a CBB. We concluded that this program would be essential in the development of a CBB in the Kamand Valley. Through our interviews, we discovered that many villagers were unable to identify any local CBBs. This indicates that this program is not widely advertised and villagers are unable to benefit from its support. This unawareness could be a potential problem in empowering villagers to start their own CBB.

After assessment of current markets, we identified that bar soap had the highest potential of success in the Kamand Valley. Interestingly enough, the only respondents who seemed aware of the market potential associated with the IIT-Mandi were established businessmen. Currently, the IIT-Mandi is home to six hundred students; the school is in the processes of finishing construction of its North Campus, which would allow it to grow to approximately 6,000 students in just a matter of years. This rapid growth will establish a new sustainable market building on students, faculty, and tourists. Although the incoming market could not be assessed at this time, an initial presumption would be to join similar skillsets of the region to create a product and develop a business selling to people not native to the region. Initial results from our baseline capacity assessment identify weaving, sewing, and knitting as skills many women of the region possess, pointing towards a high potential for handicraft CBB's across villages of the Kamand Valley. This future market will certainly provide villagers of the Kamand Valley with new opportunities to open CBBs based on a variety of products.

Project Outcomes

Recommendations

We have two short and two long-term recommendations that can promote the development of CBBs in the Kamand Valley.

Develop a business plan with one resident to pilot and model a CBB startup

In our meeting with Raj, we recommended future steps to develop a CBB based on the production of soap made from

Short Term:
1. Develop a customized business plan with one resident to pilot and model a CBB startup.
2. Create a Valley-based CBB guide that will outline identified products, startup costs, production costs, and estimated profits; as well as other materials to jumpstart CBB planning.

soapnuts. These steps are outlined by year for the next two years.

Fall 2015: Begin gathering soapnuts, purchasing required materials, and producing small quantities of bar soap to find the perfect recipe. With a complete understanding of the production process, Raj (Figure 12) can gather a group of villagers to assist with the daily operations of the business, and write a detailed project report to the NRLM to receive funding for the operations of the business.

Fall 2016: With funding, Raj can begin producing soapnut bar soap in greater quantities and selling to local villages and Mandi town. He should connect with villagers who own small shops in each village and have them begin selling his product. Raj is friends with a shop owner in Mandi, to whom he can reach out in order to sell his product or to connect him with other shop owners.

In addition to a timeline of business development, we recommend the introduction of a grinding technology to simplify the production process used to make bar soap from soapnuts. This technological innovation will be designed by students from the IIT, Mandi after the completion of the seven-week fieldwork.

Create a Valley-based CBB guide

As a result of research, we have put together a guide for residents of the Kamand Valley, identifying potential products and providing key information on the steps required to start a CBB. The first portion outlines key steps in the planning of a CBB, including completing a cost analysis of the product the reader wishes to sell, identifying the market potential of that product, and piloting the CBB on a small-scale. The next portion provides the reader with a template on how to write a report to the NRLM to receive proper training and funding for the business. The last portion of this guide includes products which can be easily produced using raw materials found in the region, each with their corresponding cost analysis and estimated profits.

Enhance government-village cooperation around schemes covered by the NRLM

In order for villagers to be more aware of the NRLM scheme, we recommend that village leaders are educated on the available assistance that the government could provide. With information on the scheme's background, its benefits, and how to apply for assistance, village leaders could then relay this information to villagers and assist with the community's development. In order to accomplish this, a workshop could be hosted by the DRDA for village leaders once a year.

Long Term:
3. Enhance government-village cooperation around schemes covered by the NRLM.
4. Re-analyze the potential for a weaving based CBB based on the changing markets associated with the growth of the Indian Institute of Technology, Mandi.

Re-analyze potential for a weaving-based

Figure 12. Students interviewing Raj Kumar.

CBB

Although not the focus of this project, we recommend that a large-scale CBB is started in the Kamand Valley around handmade weaving products in the next three to four years as a result of the changing market associated with IIT-Mandi Kamand Campus. Weaving is a prominent regional skill, and these products could be geared towards this incoming market to maximize profit.

Conclusion

Community-based businesses have the potential to significantly increase the quality of life for families in rural regions of India. This project aimed to evaluate the feasibility of community-based businesses in the Kamand Valley, a cluster of villages located in Northern India. The project initially targeted the entire Kamand Valley in order to learn about available resources, potential products, and interest levels, but was then narrowed as the strongest possibilities emerged in our data. By narrowing the scope of the project to one product, and talking in depth with one villager, we were able to get much more detailed information about what would be necessary to make this product viable in a CBB and what potential problems the selected villager perceived. We used this insight to determine feasibility. Having completed that step, we met with Raj to suggest the next steps he needs to take to establish a CBB, provided him with plan to grow this business, and educated him on the governmental resources provided by the NRLM.

Implementation of the CBB was beyond the scope of fieldwork we could complete in seven weeks, but we were able to see through the planning required to develop a CBB and are optimistic about the results after our meeting with Raj. With the tools provided in this report, we hope to create new opportunities for residents of the Kamand Valley to increase their income through the CBB model. With these tools, villagers can write a detailed proposal to the NRLM of Himachal Pradesh to receive assistance for their community-based businesses.

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Supplemental Materials for this project
(raw data, calculations, research instruments, and additional project outcomes)
can be found at
http://www.wpi.edu/E-project-db/-E-project-search/search, using key words from the project title.

Developing a Collaborative Process for the Application of Appropriate Technology on Farms in Mandi District

Abstract

Agriculture is the primary occupation in Himachal Pradesh, yet farming implements have not modernized alongside national trends. Indian Institute of Technology Mandi (IIT Mandi) students have been developing prototypes that can alleviate regional cultivation challenges. Our project documented existing agricultural practices, challenges, and perspectives on technology in order to develop a collaborative process for students to design devices that suit local needs. We tested our appropriate technology rubric to develop a seed planter and irrigation system for terraced farms.

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WPI

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Collaborating with Local Farmers to Improve Agricultural Practices

The last five decades have seen tremendous growth in farming capacity in India, providing the country agricultural independence (Department of Agriculture and Cooperation, 2012). The farmers of Mandi District, Himachal Pradesh, rely heavily on local agriculture, despite the hilly terrain. They produce crops for both commercial and subsistence purposes, commonly cultivating wheat, maize, potatoes, and rice, as well as other staple fruits and vegetables (Heitzman, 1995). Recognizing a regional need for innovation in suitable agricultural technology, the Indian Institute of Technology Mandi (IIT Mandi) is developing prototypes that can alleviate challenges in cultivation and harvesting processes in the region. Such technologies could increase productivity and profitability for local farms.

Modernization in agriculture, however, has often led to standardized, general-purpose technologies. Standard equipment and machinery useful for some farms, does not match the diverse needs of local farms in unique sites. Himachal Pradesh is a prime example (Figure 1). Government-endorsed farming technologies such as large tractors and mechanical farm equipment, are often designed for large-scale, flat farmlands. The terraced or small-scale farms of Himachal Pradesh are excluded from the design process, resulting in environmentally incompatible machinery. Furthermore, experts recommending or designing these devices sometimes fail to address that farmers may lack experience with the use, maintenance, and the long-term costs that come with complex innovations (Stone, 2014). Farmers should be included in the design of agricultural technologies that suit their local needs. Such collaboration could mitigate the alienation of the grower from the designer, resulting in more relevant, feasible innovations.

This team collaborated with farmers in a region surrounding Mandi Town to identify appropriate design innovations that might improve local agricultural practices. To accomplish this, we addressed four primary objectives. First, the team documented current practices and technologies used by local farmers. Second, we evaluated farmer perceptions of new agricultural innovations, with regard to their existing challenges. Third, the group developed a rubric to guide the design process for appropriate agricultural technologies. Fourth, we developed appropriate innovations to address the farmers' greatest challenges. The team also provided suggestions for additional opportunities for development. Special attention was given to a technology assessment of recent IIT prototypes in small village settings.

Figure 1. Farming in Mandi District requires unique technology, independent of the large scale faring machinery that operates on large, flat farms.

The Need in Mandi District for Appropriate Agricultural Technology

To design the most relevant tool for local farmers, our team adopted criteria for *appropriate technology*, an approach to engineering that establishes design criteria to "enhance human fulfillment through satisfaction of human needs" (Hazeltine, 2003). Theorists of appropriate technology insist innovations should be appropriate to the economic and cultural setting of the user. This movement originated in response to U.S. President Harry S. Truman's Four Point Plan in 1949, a technology-heavy aid program for developing nations (Pursell,

1993). Engineers implementing Truman's Plan followed a heavily western bias toward industrialization. The result was the construction of complex infrastructure that often fell into disuse. Theorists generally agree on a set of core principles for appropriate technology, which we have synthesized in Figure 2, with farming in mind. In 1973, economist E. F. Schumacher published *Small is Beautiful: Economics as If People Mattered*. He advocated for the development of "intermediate technology". The tools provided should be cheap and relatively simple to use and maintain by local users; only these technologies would be considered "appropriate" (Pursell, 1993).

The application of appropriate technology to the region around Mandi requires understanding the local context of agriculture. In the 1960's, the Indian government committed to feeding its expanding population without extensive reliance on imports, consequently pushing to improve the efficiency of Indian farmers. This "Green Revolution" emphasized improvement of agricultural technology to increase the output and transportation of goods. Since then, India has dramatically increased output through improved cropping methods, seed distribution, and agricultural machinery. This has allowed the country to expand its gross output of agricultural products without greatly increasing the total amount of

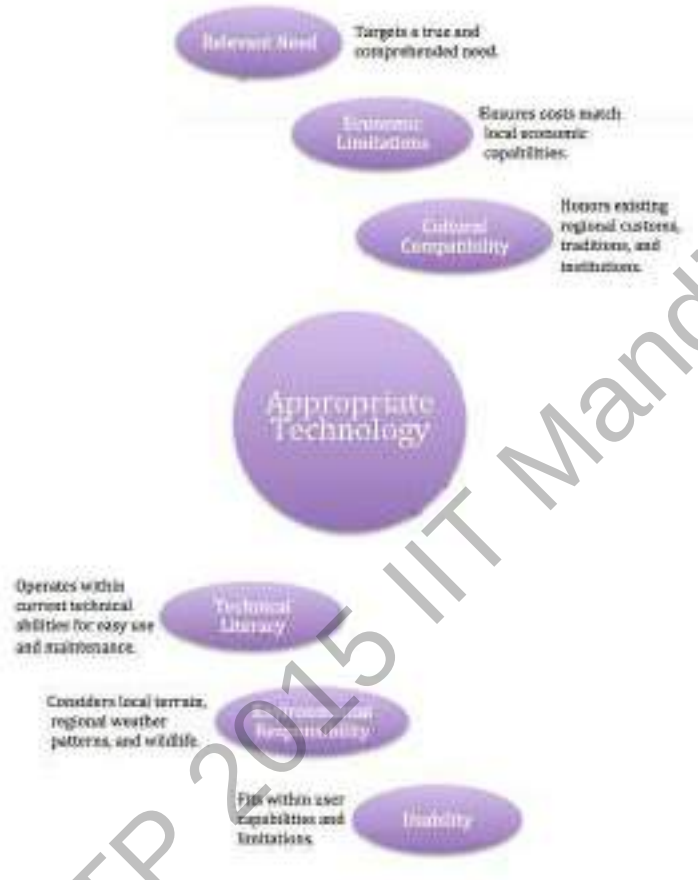

Figure 2. The six dimensions of appropriate technology. Adapted from Pursell, 1993; Hazeltine, 2003.

cultivated land (Department of Agriculture and Cooperation, 2012).

Many farmers in the southern and central regions have followed government suggestions and adopted modern farming machinery, including tractors, automated seed planters, and combine harvesters (Department of Agriculture and Cooperation, 2012). This strategy has yielded mixed results, though. While the methods dramatically increase farming output in central India, this type of machinery is not as suitable for small farms in the topographically-challenging landscapes of Himachal Pradesh (Department of Agriculture and Cooperation, 2012).

The majority of farmers in Mandi District operate terraced farms, cultivating step-like outcrops carved from the sloped hills dominating local landscape. The locations of these terraces can range from steep, formidable hillsides to more hospitable valley floors. There is no standard shape, height, or width for an average terrace as each depends on the terrain, tools, and the specific farmer who originally created the terraces. Terraced land is traditionally passed down through a family, with the same land available for use across several generations. Farming on such terraces involves primarily manual labor with a variety of traditional tools.

Small farms in Himachal Pradesh, specifically in Mandi District, can be put at an increased risk if an inappropriate technology is adopted. Many of the innovations developed for the rest of India are inefficient in this region. For instance, less than 10% of the land is

suitable for agriculture, yet the majority of the population is employed in this sector (Heitzman, 1995). As of the 2011 census, Mandi District's population was 94% rural. The majority of these citizens subsist on the cultivation of less than one hectare of mountainous land (Figure 3)(Mandi District: Census 2011 Data, 2011; Vaidya, 2006).

In 2013, university researchers H.R Sharma and S.K. Chauhan conducted a study on habits of technology adoptation and challenges in Himachal Pradesh to identify overall farmer readiness to implement new technology. They found that the three primary reasons farmers delayed adopting new technology were uncertainty about future markets, fear of crop failure,

Figure 3. Terraced, mountainous terrain dominates much of the region surrounding Mandi Town..

and threat to their own food security. Keeping these factors in mind, it is important to consider past successes and failures in the development of site-specific farming machinery. Any new farming implements should limit the financial risks farmers feel when considering such investments.

Methodology: Approaches to Collaboration for Agricultural Improvement

Table 1 summarizes our research objectives and describes the research tools and methods we used to achieve each.

Our first objective was to document the current practices and technologies used on local farms. In order to assess whether village proximity to a substantial urban center would affect their practices, we chose to focus on sites within a 20-kilometer radius of Mandi Town in Himachal Pradesh. This radius allowed us to evaluate the direct impact of Mandi Town.

To ensure that we sampled an approximately equal distribution of farms, we divided the area surrounding Mandi Town into four geographic sectors. Quadrant I is found northeast of Mandi Town, Quadrant II is northwest, Quadrant III is southwest, and Quadrant IV is southeast. We visited four to five sites per sector, choosing at least one village near Mandi Town and at least one approximately 20 km from Mandi Town. For the remaining sites in each sector we selected villages that would provide the best distribution or provide data for a large portion of land not yet accounted for in a survey. We recorded each location on a map. The team conducted 36 farmer interviews in 18 local villages to identify irrigation, sowing, and harvesting techniques. When approaching farmers in each village we used a sample of convenience. As we gathered data from these four sectors, we categorized similarities in farming methods in an attempt to generalize typical farming practices across the region.

The surveys were typically conducted in Hindi, with team members asking prepared questions and recording the answers on a note sheet in English or Hindi. Our interviews were semi-structured, so as not to risk missing important concepts that could be explained through dialogue (Newton, 2010). At the conclusion of the interview, the team filled out a document recording farmer responses, the nuances of the conversation, and any other important information. These answers were later uploaded into an Excel datasheet to identify trends and create the appropriate visuals for representing our data. We also used direct observation and photography to record information on topography, field/terrace size and shape, and general layout of the farm. Photography was also vital in documenting available tools, with the team capturing an

Table 1. Methodology Work Table

Objectives:	**Research Tools:**
1. Document current practices and technologies used on local farms	Identification: Stakeholders, setting Mapping: Map of farms Observation: Tools, planting, irrigation, land, residents Documentation: Photography, recording Interviews: Semi-structured farmer interviews Interviews: Semi-structured government interviews
2. Evaluated farmer perceptions of new agricultural innovations, with regard to their existing challenges	Observations: Tools, planting, irrigation, methods Documentation: Photography, recording Interviews: Semi-structured farmer interviews Interviews: Semi-structured government interviews
3. Developed a rubric to guide the design process of appropriate agricultural technologies	Synthesized local farmers' needs and criteria with appropriate technology tenants Farmer interviews; scholarly research
4. Developed an appropriate innovation to address the farmers' greatest challenge	Applied design rubric and generated sample product and process Community meetings: Held design input meeting with local farmers; incorporated feedback

image of various farming implements as permitted by the landowner.

Our second objective evaluated farmer perceptions of new agricultural innovations, with regard to their existing challenges. The framework to capture this data was already established by our first objective, and the responses for these questions were captured simultaneously with objective one. These questions differed however because they focused on understanding the perceptions attached to changing or adopting a new technology. This also provided respondents with an opportunity to present their own perspectives on the challenges they faced, and catalyzed them to ask for solutions. To expand on this objective, we asked farmers if or how they would like to improve their current tools or processes. These answers were recorded in a similar fashion to objective one, eventually being uploaded into an Excel data sheet. We again used photography as a method of documenting the nuances of farming challenges.

To accomplish objective three, we created a rubric to guide the design process for appropriate agricultural technologies. This rubric was a natural extension of the six sides of appropriate technology previously researched and presented in the background section. We synthesized this with regional data and the reported challenges faced by farmers. Our criteria were reached through the careful understanding of the interview responses. By using our regional data, we ensured that our rubric could address the specific social and technical aspects of users in this area.

Our fourth objective was to develop an appropriate innovation to address the respondents' greatest challenge. Testing our new design procedure, we developed a process and product that satisfied our requirements for ap-

propriate technology and that solicited user feedback in the design phase itself.

Results and Discussion

We gathered data to identify appropriate innovations that might improve local farming practices. Results and discussion appear below.

Objective 1. Practices and Technologies

The current age of our participants ranged from 22 to 70 years, the average age being 42. These individuals worked almost exclusively on terraced farms with their families. Household size ranged from 3 to 17, with the average number being 6 co-habitants. In terms of division of labor, men tend to take responsibility for plowing and tilling (manual or mechanized), sowing, pesticide spraying, and fertilizer spreading. Children often participate in weed removal, fertilizer spreading, and harvesting. Women are most often responsible for weed removal and harvesting. The education level of respondents (the majority of whom were head of household) ranged from no formal education to graduate studies. In total, 22 out of 36 had passed the 10th grade, and all had been farming since childhood. Most of the farmers had secondary sources of income, ranging from shopkeeping to government jobs. Proximity and secondary employment increased the frequency of their visits to Mandi Town.

The size of the targeted farms ranged from 1 bigha to 40 bigha, a local unit of measurement ranging from ⅓ to 1 acre. In Himachal Pradesh, 12.5 bighas are equal to one hectare. All farms grew corn and wheat, corn exclusively for sale, and wheat typically for personal consumption. Farmers also grew a variety of household vegetables at their own discretion, either for sale or consumption. Corn and wheat are the most prolific crops.

Before the planting phase, fields are tilled for rocks and residual root systems. The proportion of respondents that used the oxen-plough method was 30/36, a majority that transcended elevation differences. We found 13/36 interviewees have used a motorized tractor on their lands as a rental or a personal purchase. The farms at higher elevations were less likely to have used a tractor on their field, (Figure 4). Crops were grown over spring, summer, fall, winter, and kharif (a season which extends from April to September). Grains were cultivated from seed, yet vegetables were grown from seedlings. All seeds and seedlings were purchased at markets. Sowing and harvest deadlines are traditional for each crop, but there must be a rainfall before sowing. Farms with irrigation facilities, however, do not need to strictly abide this rule. Furthermore, farmers can delay planting up to 10 to 12 days in ad-

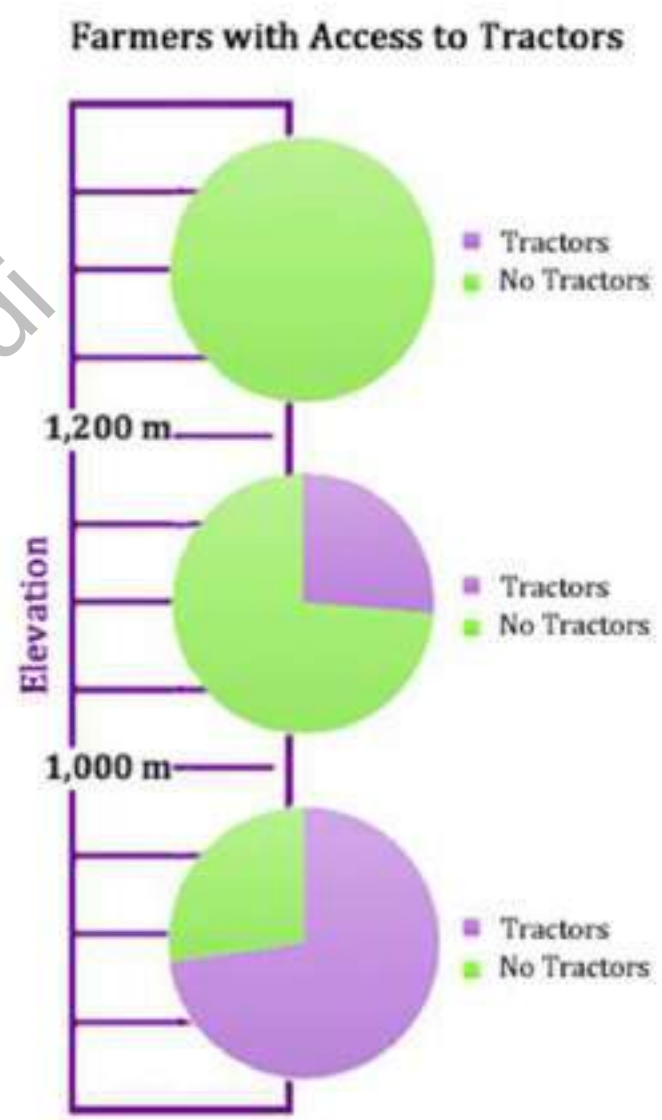

Figure 4. Farmers at different elevations reporting access to tractors.

on rainwater. Current irrigation systems rely on pumps to pull water from the river to deposit on the fields, or collected rainwater from roofs and patios. Available subsidies cover Rs. 15,000 of irrigation implementation and the 600m of pipe. Additional coverage is provided for power tillers and greenhouses. Purchase of tractors and threshers are not subsidized.

The most commonly used local tools included the plough, ax, darati, fawara and faruda. A detailed presentation of these tools can be seen in the Tool Catalogue in the Project Outcomes section. A typical plough is adapted from a single blade mounted to a frame at approximately 45 degrees. This frame is dragged behind two oxen across a field to either disrupt or make grooves in the soil (Figure 5). The ax follows classical design, and the darati resembles a scythe. This tool is available in two different girths--thinner blades are used to harvest wheat and cut grasses for livestock, while the thicker blades are used to harvest corn and remove thicker brambles. The fawara and faruda displace and dig soil.

Objective 2. Farmer Perceptions on Agricultural Technology and Challenges

In response to our interview questions measuring receptivity to innovation, the farmers expressed interest in implementing technological solutions and making better/modern devices more available. Most were cognizant of new technologies such as seed planters, tractors, and power tillers, and frequently reported having had experience operating them. There was no direct correlation between distance from Mandi town and degree of technological receptivity, although Mandi Town was the primary location for the purchase of traditional and modern farming tools. Only respondents from Rewalsar, Pandoh, and near Ner Chowk purchased their tools at these respective towns. Respondents were interested in owning equipment that might ease the burden of certain tasks reported below.

Cost/benefit was the greatest concern for any potential device introduced to their farms. We observed instances in which agricultural machines were available as rentals. We also observed communal threshers during our walks to farms. We only encountered 13/36 respondents who had purchased a small tilling machine, pesticide sprayer, or small tractor. Half of these individuals were stationed below 1,000 m. The cost to own these devices is considerably greater than the simpler, petroleum-independent, manual options available. A breakdown of comparable costs are in Figure 7.

Figure 5. An example of traditional farming technology in Bindravani, Mandi District.

In addition to cost, respondents were also concerned about the ability of new technologies to remain functional on a terraced landscape. We observed that the paths between farms in the villages are steep, up to 50 degrees, and the height between terraces ranged from 1 to 4 meters. Secondly, the terraces themselves can be narrow, we observed several being less than a meter wide. Size and maneuverability in this uneven landscape appeared paramount.

A third most frequently reported concern about device functionality was the complexity of operation. Farmers expressed interest in owning "semi-tech" devices, or non-electronical, automated machines. Each village we visited had at least one blacksmith or mechanical workshop that could facilitate repair of simple equipment. Farming tools were taken to these garages for repair and modification using rudimentary equipment such as a drill press, hammer, or anvil.

Existing Farming Challenges

The most severe impediments to a successful harvest were reported as unpredictable weather patterns (particularly rainfall frequency), animal attacks on crops (monkeys and wild pigs), and decreasing field fertility, in this order of gravity. Furthermore, according to government statistics, only 20% of the cultivated land in Mandi is irrigated by sponsored systems or from diverted streams and groundwater. We observed only two instances of sponsored irrigation systems and no farmer mentioned using the diversion or well-based watering techniques, given the scarcity of mountain streams.

The majority of respondents would grow more vegetables for personal use, and eventually sell, if they had access to a system for irrigation. Inconsistent rainfall makes it difficult to successfully grow water-intensive vegetables such as onions, black-eyed-peas, ginger, garlic, and rice. On the other hand, farms with government-sponsored irrigation are able to increase yields so as to supply vegetables to the Mandi markets. These systems operate by pumping water from local rivers. Therefore, there is a distinct preference towards river-bordering farms for the implementation of irrigation technology. The Department of Agriculture is planning to implement micro-irrigation sprinkler systems soon, but to unspecified candidates. Irrigation of crops is entirely farmer driven at this point, limited by access to water sources and funds to build watering systems that incorporate pumps, channel diversions, or collection systems.

Farm upkeep could be made more efficient. Certain processes were reported to be especially labor intensive: corn planting, shucking, and non-mechanical wheat threshing. Mechanical threshing is an option, but is reported to be uncomfortably expensive for rent and operation. The by-hand alternatives demand large amounts of time. Farmers expressed interest in automating these procedures, but the most pressing of these requests were, in order of ascending frequency, a device for field tilling, irrigation, and seed planting.

A final, and concerning common problem was decreasing field fertility and expensive seed price. Every year, their fields are producing less while seeds and vegetable seedlings are reported to be expensive. Farmers were keen to see government assistance in rectifying these trends. Mandi District manages farmer education by holding training camps. They are held at a larger local village once a month, in each of Mandi District's ten blocks. Farmers can report what aid they need in order to be successful, and soil testing is provided for free. The government identifies seed availability, seed planting, animal attacks, and water availability to be the greatest problems faced by farmers. These findings mirrored our interview responses, but we were surprised to hear monkey attacks are becoming worse. Animal attacks on farms are managed by Department of Forestry—this problem falls under their jurisdiction. Farmers we interviewed were not aware of these camps or how to apply for subsidies. At the same time, low attendance has baffled the Department of Agriculture. As it stands, there are subsidies up to 40% of the cost for agricultural devices for the average farmer and 50% of the costs for farmers who are women and members of scheduled castes (SC), scheduled tribes (ST), and the impoverished. The subsidies will cover any agricultural device which has been investigated by the KVK (Krishi Vigyan Kendra) and been granted approval by the University of Agriculture.

Objective 3. Appropriate Considerations to Local Farming

We designed a rubric regionally-tailored to primary farmer needs, affordability of possible tools, environmental demands, acceptable device complexity, cultural practices, and basic criteria for usability. Our interview with a representative from the Department of Agriculture shed light on some conflicts of perception. Farmers reported their most profitable crops to be vegetables and corn. The Department of Agriculture specified peas and tomatoes to be the most profitable vegetables, but claimed wheat to be a for-profit crop. While the department agreed that corn and vegetables

were the most problematic and time consuming to grow, he informed us that 25% of the population used mechanical threshers for wheat and no one uses oxen for agricultural labor, in spite of our findings to the contrary.

While farmers are eager for government aid, they are ignorant of existing subsidy programs that facilitate the purchase of modern implements. The typical handheld tool costs from Rs. 100-400 rupees, while the slightly more advanced options, such as pesticide sprayers, cost in the order of thousands of rupees. A subsidized, semi-tech device could be found at a price ranging Rs.1,000 to 10,000 (Figure 6). Subsidy benefits for women and lower castes have even greater benefits, but are often not realized, as they must be claimed in person upon the purchase of a device. Women are typically at home to maintain the house, while the impoverished perceive the cost of transportation and purchase of the devices as unaffordable. These challenges need to be addressed, but the government hopes that someday subsidies can be provided for all modern devices and farmers will be actively involved in ongoing education.

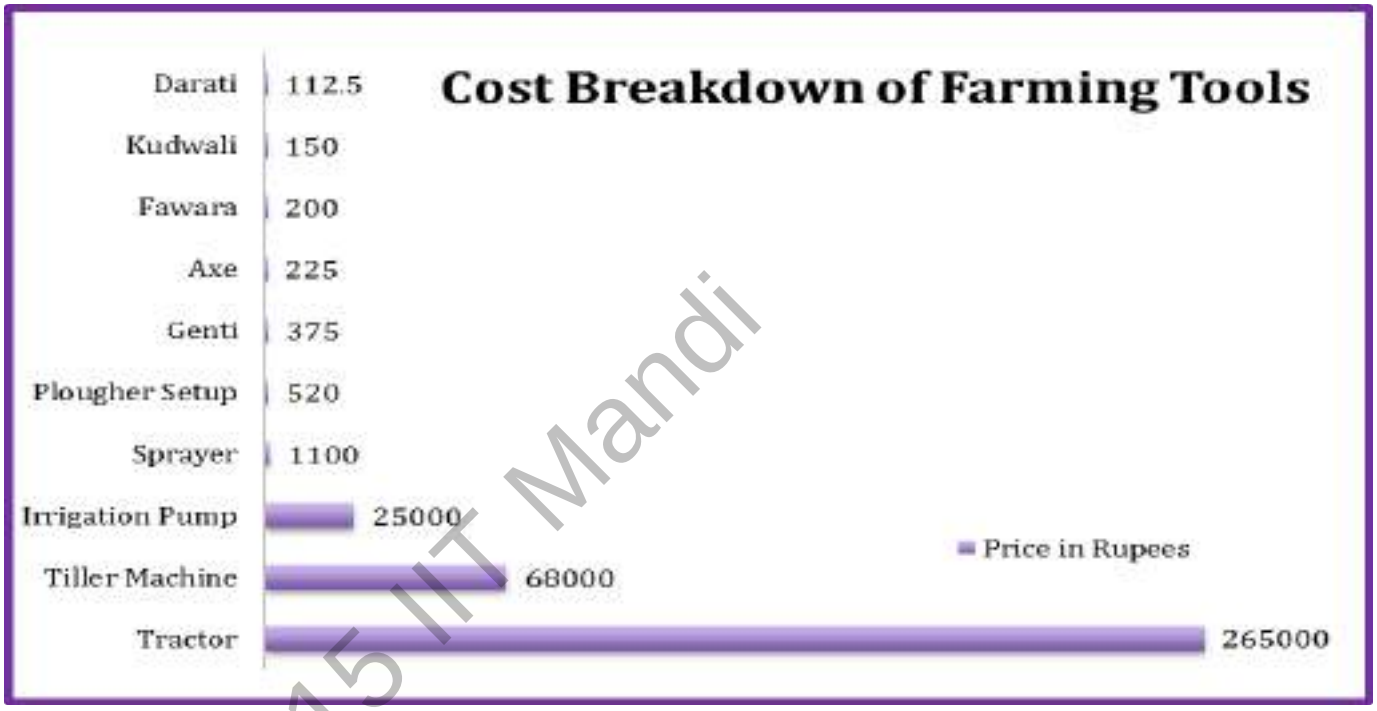

Figure 6. Farmers pay approximately 100-500 rupees for traditional tool while the mechanized counterparts sell in the order of thousands.

Any device designed for this area would need to operate on terraced farms. Their shape is typically long, narrow, and gently curved, and therefore need be compact to be able to perform tight maneuvers. The device must be lightweight, durable, and ergonomic to carry up the terraces from field to field, at inclines ranging from mild to dramatic. To preserve weight, it should not rely on expensive fuel.

Increasing the precision of existing practices will translate into greater time efficiency. We observed that it was difficult for a single operator to simultaneously control the speed of the oxen and the angle of the plow. It is clear that greater control over these chaotic practices can pave the avenue for higher efficiency. Non-automated wheat threshing, oxen tilling methods, harvest of randomly planted crop, and the entire production of corn were cited as the most time expensive. Devices that accelerate these processes could dually serve to make the processes easier and less expensive. Given the for-profit nature of the corn harvests, the economic factor of this advancement can have far reaching effects.

The visual summary of engineering criteria matched to local socio-economic features can be found in the Project Outcomes section. Future teams should assess their problem statements according to the six sides of appropriate technology before beginning their design project. Our rubric can serve as a guide to the primary design points so a student's innovation or a farmer's improvisation can be integrated into the existing societal infrastructure and agricultural industry.

Objective 4. Design an Appropriate Innovation

Our results indicated an automated corn seed-planter would be a highly beneficial product for local farmers. To meet farmer demands, we designed a corresponding device that would appropriately address this issue.

Consulting the rubric previously created in Objective 3, our team developed a corn seed planter that would remain functional on the challenging terraced terrain. Design parameters for this device include the ability to perform tight turns with minimal disruption to the soil, and maximum ease of use for the operator. Further criteria developed through the examination of the rubric were that the design was durable, safe, and lightweight. The minimalist design ensures lower overhead production cost, in hopes that this technology will be marketable to all local farmers in the future. After the ideal design was completed, we gathered materials and assembled an initial prototype by means and manners analogous to ones found in Mandi market. Additional detailed computer aided design (CAD) renderings and photographs appear in the outcomes section (Figure 7).

Our data also indicated that irrigation systems, especially for villages at high elevations, are in significant demand. We developed the plans for an irrigation system that can address the needs of an average hilltop farm. This system could be further refined if tested at a village-technology center, or a campus farm.

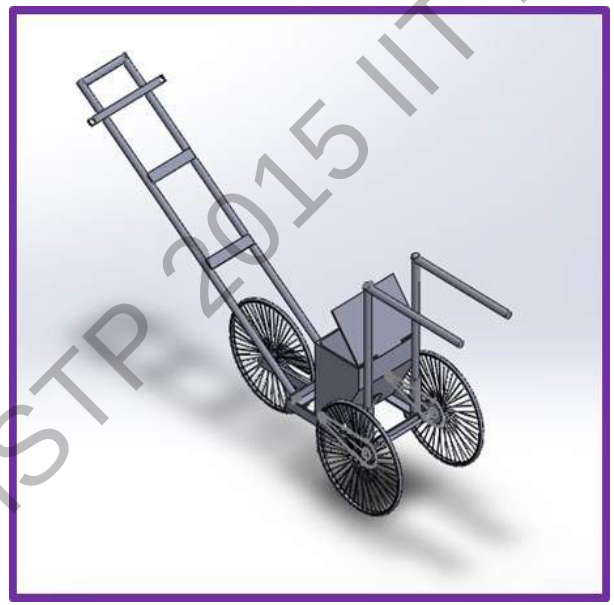

Figure 7. CAD model of a mechanical corn seed planter.

Important data on approximately how much water can be collected from each rainfall, the exact quantity to properly irrigate an average field, and so forth could be extracted from an appropriate trial field. On-site trials are necessary to determine the total efficacy of our designs.

Discussion

The data revealed 3 key challenges faced by the farmers:

1. Laborious nature of corn planting and harvesting
2. The lack of irrigation facilities
3. The consequences of damage from animals

The typical farmer lacked irrigation on steep terraced farms and was most concerned about automating or facilitating manual tasks, and protecting fragile crops. However, our interviews gave us insight to more nuanced elements to the farming lifestyle. We expected the most pressing need to be related to the planting process. Our preliminary research indicated Himachal Pradesh was prosperous and independent from subsistence agriculture. Indeed, many requested assistance to ease the sowing process. However, we were surprised at the profound concern expressed over irrigation, despite the state's "water surplus". Farms with irrigation were more productive and far wealthier. In turn, this meant that they had the means to access more advanced technology and

to experiment with more profitable crops. These opportunities were denied to the farmers on more isolated or elevated locations.

One farm in Lagdhar reported hundreds of monkeys raiding his fields along with the local wild pig and bear populations. We had considered that animal raids might be a frequent nuisance, but he proved to us the devastating severity it posed when left unchecked. A failed crop is a net loss of food for the family as a whole, and this is especially concerning when compounded with field infertility. Minimizing crop failure is a priority, but making the farming process less taxing could enable the farmer to spend more time investing in secondary employment or crop security measures, which could provide a more dependable safety net in times of crisis.

Farmers are unaware of government schemes aimed to help them. We observed that while camps are held in relatively local venues, advertising and outreach are not reaching their targets. The camps can potentially be useful as venues for transfer of training and petitions. Attendance might be increased through more relevant advertising and deliberate outreach mechanisms. Additionally, Mandi Town should be a hub of agriculturally innovative and affordable devices. It is the primary location for tool purchases, both subsidized and retail.
We found 7/36 respondents explicitly cited collaborating with neighbors if they needed additional help during planting or harvesting. This cooperative disposition is extended to the shared ownership and renting of modern agricultural devices, a practice more pronounced in villages near Mandi Town. If intelligently engineered devices are beyond the users' economic allowance, perhaps marketing new devices to communities could be an option. Most of our respondents also requested low/semi tech devices. These must be intuitive for the user and the mechanic of the village garages. Complex electrical repairs may be beyond the expertise and resources of farmers in Mandi District.

Our findings allowed us to reflect on the designs and prototypes made by previous IIT teams. In retrospect, they proved to be highly complex and reliant on electronic components. These design proposals included a battery powered seed planter, an electronic drip-irrigation system, and a quad-copter pesticide delivery system. Innovation should be collaborative in order to produce intuitive and functional devices for local farmers.

Project Outcomes

Our research resulted in two key project outcomes:

1. A set of curricular recommendations that can enable students to work with an appropriate technology rubric for innovation in small villages, and
2. A case study of two agricultural prototypes that we used to test our own program.

We begin with our recommendation for technology design students.

1. Curricular recommendations.

To enable students to work with users in small villages, we developed a set of curricular strategies. The first is the use of an Appropriate Technology Rubric for the Design and Innovation courses (Figure 8), the second is a resource guide that contains an archive of existing tools used in the region, the third is a rubric for innovation courses, and the fourth item is the suggestion for the foundation of an experimental farm on campus. To facilitate collaboration with local farmers during the design process, our team suggests the following strategies: Utilize an appropriate technology rubric from pre-project conceptualization through completion, in order to ensure maximum compatibility of any technology within the region's existing infrastructure as a whole, and develop an on-campus farm plot where sample technologies can be tested in a realistic environment without interfering with day-to-day activities in working communities. The campus plot might be

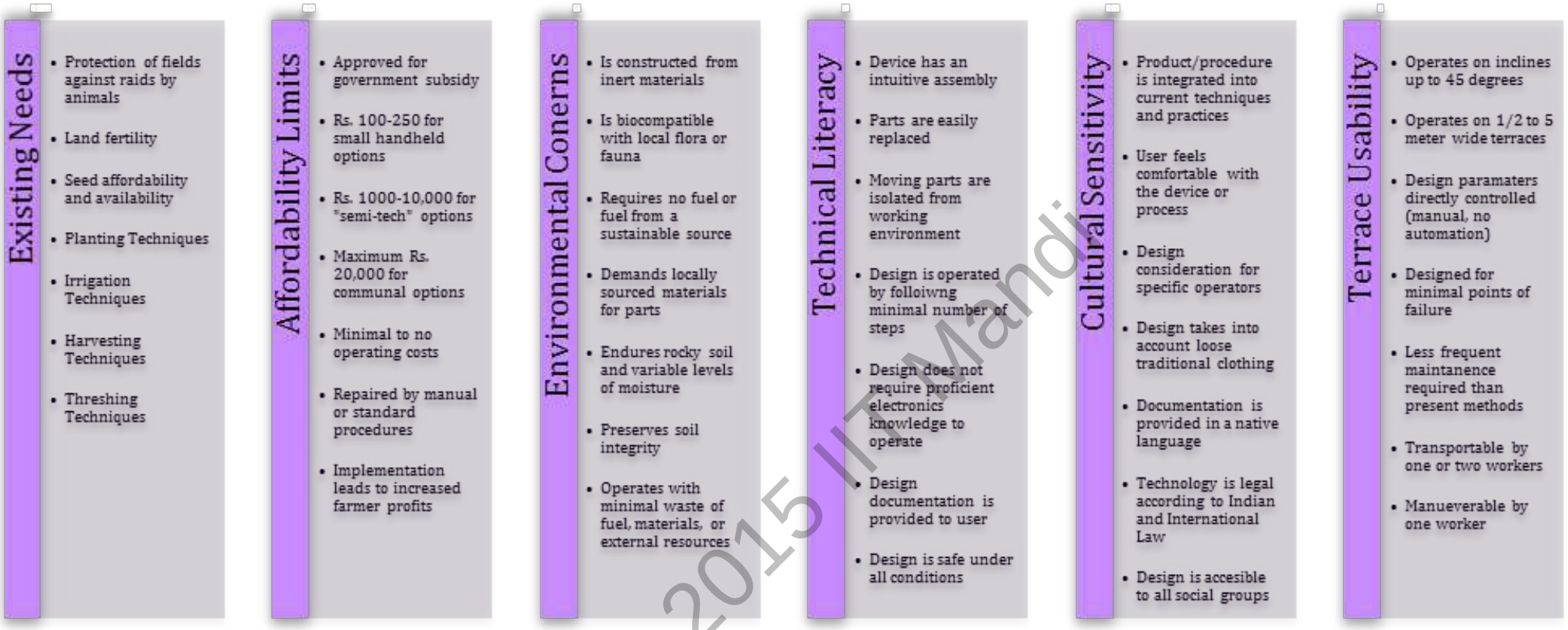

Figure 8. Appropriate Technology Rubric customized for the needs of farmers surrounding Mandi Town.

managed by ISTP/Design Practicum students and faculty, and equipped with a variety of local tools and IIT-developed implements. Local villagers can visit this plot to directly observe the benefits and/or provide input on technologies currently being developed.

By using an appropriate technology rubric at the very start of a project and by collaborating early with users, design students can optimize their time. Complexity and usability will be addressed early in a prototype's life. After completing a prototype, it could be checked against the rubric and through user testing.

The farm plot could replicate terraced farming, simulating the dimensions and soil conditions. Student designers will be able to directly engage the targeted environment, and will be able to maintain long-term demonstrations of their innovations. Local farmers could be invited to see the viability of newly developed ideas and provide feedback on field performance. This test farm could provide a control environment for future students testing any outdoor or agriculture related technology. In

the future, IQP and ISTP projects will have the opportunity to focus on energy availability, technological education or government involvement, and providing appropriate technologies that can be immediately placed into use on regional farmland. Innovators can approve their technologies for government subsidy by submitting designs for evaluation by the KVK and University of Agriculture. This follow-through will only enhance successful implementation.

The previous figure is the Appropriate Technology Rubric, customized to the needs of farmers surrounding Mandi Town.

This rubric is accompanied by documentation of the traditional tools that are commonly used in the area. A full version of this summary can be found in the supplemental materials.

2. Prototype test for Corn Seed Planter and Roof-top Irrigation System

These designs represent the first devices produced while following the guidelines of the Appropriate Technology Rubric. Both the corn seed-planter and the irrigation system have been graded for regional applicability. We recommend that follow-on researchers take our finished prototypes to local farms and record their input, making necessary adjustments to the design.

The CAD design scored 27/33 for applicability. However, the prototype can still be refined. Primarily, future designers will have to optimize the mechanism for depositing individual seeds. At present, a bicycle chain drives an auger, and has proven difficult and costly to build. A future student team should look into developing an affordable, simpler option. This team should also dedicate close attention to the ergonomics and overall functionality of the device. Our team was limited in design time and may have overlooked options that could increase functionality. With these project outcomes, future projects may address relevant problems from a social and technological standpoint.

Conclusions

In collaboration with village farmers in the Mandi District, we were able to profile local farming practices, needs, and the use and perceptions about local agricultural technologies. This profile can enable future tech designers at the IIT to produce appropriate technological solutions that ease the burden of everyday farm work and increase productivity. In the future, student teams can use our rubric and catalogue to learn about local needs and practices. They can also work in conjunction with government schemes for agriculture to enhance the linkages from policies to local farms. These schemes have the potential to provide monetary support and training for tech advancement, but as we have shown, they often do not reach those who need it. Finally, developing an on-campus village technological innovation center could improve the collaboration that the IIT has with its agricultural neighbors and allow future IIT students to move from prototype to user testing. This plot could be a demonstration site that highlights accomplishments and models as well as the positive impact of community university collaboration. We hope our project outcomes form a precedent for future social impact.

Acknowledgements

We would like to acknowledge the extensive help and guidance of our WPI and IIT mentors, Dr. Ingrid Shockey, Dr. Venkata Krishnan, Dr. Lorraine Higgins, and Professor Rajeev Kumar. Thanks are due to the US Department of State

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Supplemental materials for this project can be found at http://www.wpi.edu/E-project-db/E-project-search/search, using project keywords.

Outcomes delivered after April 30 will appear on the IIT's ISTP page: http://www.iitmandi.ac.in/istp/index.html

Assessing Public Healthcare Infrastructure in the Kamand Region

Abstract

In the Kamand region of Himachal Pradesh, the healthcare challenges of rural communities are unique due to difficult terrain, distance between health-centres, and disease patterns. This project assessed the public healthcare infrastructure's ability, in terms of quantity and quality, to cope with these challenges. Our assessment revealed three bottlenecks in service delivery: inadequate supplies, lack of specialists, and inaccessibility of facilities. Based on our analysis, we recommended changes to the system that might improve public access to quality medical care.

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Challenges to Public Healthcare in the Kamand Region

Access to quality public healthcare remains a pressing need amongst rural and remote populations of India. While the government has introduced successful initiatives (e.g., for malaria and tuberculosis) at the state and district levels (Ministry of Health & Family Welfare Government of India, 2005), lack of resources and other constraints limit healthcare efforts from reaching remote areas. The healthcare needs of urban populations and those of rural areas differ significantly, in part due to distance between health centres and villages, poor infrastructure and water quality, and site-specific disease patterns

Health is an intrinsic human right as well as a central input to poverty reduction and socio-economic development . (WHO, 2015).

Our research focused on Mandi in Himachal Pradesh. In this mountainous region difficult terrain and ongoing road construction impair transportation and lead to infrequent deliveries of medicine. Another challenge includes insufficient treatment capacity, including a paucity of trained professionals in rural areas and operating hours in clinics.

The goal of this project was to assess the public healthcare infrastructure in the Kamand region, specifically, the Zonal Hospital Mandi (Figure 1) and the health centres and sub-centres in the medical block of Kataula. We identified bottlenecks so resources might be allocated to improve health system functionality. In order to achieve our goal, we developed a "Rural Healthcare Assessment Model" to assess
the infrastructure across the dimensions of location, facilities, services, and stakeholder perceptions of quality. Our objectives for performing this assessment were to document geographical locations, the facilities' physical resources and operation, and medical services. We also evaluated provider and user perceptions of service quality. These data allowed us to locate high-pressure areas in service delivery, bottlenecks in the system. Our research led to recommendations that we delivered to the Chief Medical Officer of Mandi.

Figure 1. Zonal Hospital Mandi.

Healthcare Facilities, Personnel, and Health Risks in the Kamand Region

In preparation for our fieldwork, we researched the existing healthcare system in Mandi, prevalent disease patterns, and criteria for assessing healthcare systems.

Regional Medical Capacity

Mandi City, located in the center of Himachal Pradesh, is home to the district's zonal hospital, which serves nine medical "blocks," each comprising sub-centres, primary health centres, and community health centres, as defined in Table 1.

In order to manage the large population of Himachal Pradesh, public services are augmented by several medical practitioners who receive only minimal training. They serve local villages and often rely on plant –based and traditional healing. They and their roles are described in Table 2.

Environmental Factors and Disease

The Kataula Medical Block, which services Kamand, is accessible by a network of narrow

Table 1. Definition of CHC, PHC, and SC in India (adapted from SRM University, n.d.).

Facility	Population	Intangibles
Sub-Centre (SC)	3,000-5,000	• Data Collection • Health Programs • Triage
Primary Health Centres (PHC)	20,000-50,000	• Health and Nutrition Education • Personal hygiene and safe water education • ANC and PNC • Immunizations • Triage • Training • Disease and injury treatment
Community Health Centre (CHC)	80,000-100,000	• All of the above • Surgery • Pharmacy • Gynecology • Pediatrics • X-ray

Table 2. Local practitioners at the village level (adapted from SRM University, n.d).

Occupation	Description	Training
Village Guide	The first person a patient see. Their jobs include fist aid, material and child care, family planning, satiation and health education.	Minimal 3 months training at a PHC.
Anganwadi Workers	Preform check ups and immunizations. They also teach nutrition and general health. They also provide referral services.	4 months training in many areas of health.
Local Dias	Work as mid-wife to help deliver babies in home.	30 days training at PHC/SC with minimal 2 days at PHC and 4 days with a practitioner.
Lay Practitioner	Traditional healer the use medicinal herbs.	No formal training.

dirt roads. Emergency evacuations and basic transportation to health centres may be challenged by road conditions, weather events, flooding, landslides, and earthquakes. Kamand's susceptibility to natural disasters exacerbates these problems.

Seasonal weather also can influence the patterns of regional disease. According to a doctor at the Ratti CHC, during monsoon season, cases of gastroenteritis, diarrhea, and typhoid rise; in winter, cases of respiratory ailments such as influenza and tuberculosis increase.

The weather and fertile soil of Himachal Pradesh is conducive to the growth of medicinal plants that have been used to treat ulcers, acidity, sores, inflammation, dyspnea, fever, stomach ache, head ache, arthritis, wounds, and allergies, among other symptoms associated with local seasonal and communicable diseases (Kuar, 2011).

Table 3 displays the statistics for these diseases in 2014. In rural areas specifically, the severity of respiratory ailments and gastrointestinal disease is exacerbated due to poor sanitation, anemia, and malnourishment (Health, n.d.; Vora, 2005).

Other common ailments include diabetes and cardiovascular disease (Himachal Pradesh, n.d). The Indian Department of Medicine predicts that by 2025, 70 million Indians will be diagnosed with diabetes, which also accounts for many cases of reported blindness (Raina, 2012). As of 2011, cardiovascular diseases were contributing to roughly 40 million deaths annually in India (Yudkin et al., 2012). In rural areas, cases of hypertension have increased exponentially due to poor diet and increased physical and mental stress from agricultural and labor-intensive work (Yudkin et al., 2012).

In addition to the risks detailed above, residents in remote and rural areas have higher risk of trauma injuries. Since there are no governmental regulations in India that establish standards for trauma-care, only elementary systems exist and are located in urban areas (Joshipura, Shah, Patel, & Divatia, 2004). Thus, road-side or work-related injuries, lacerations, fractures, and other accidents common in Himachal Pradesh put its rural population at a greater risk for trauma-related death, especially where response is delayed (Joshipura et al., 2004).

A trauma-related death occurs in India every 1.9 minutes (Joshipura et al., 2004).

Rural Healthcare Delivery

In rural areas with difficult terrain and long distances between villages and health centres, more residents will get healthcare if it is easily accessible. This was shown when mobile medicine options such as The Lifeline Express train in another rural Indian setting reached patients in remote areas and when government sponsored hospital trucks in Zambia reached huge numbers of patients (Singh, 2010 & Williams, 2011). In addition to providing better access, rural areas can improve healthcare delivery through better communication between doctors and healthcare professionals. For example, in a case study in rural Peru, where a few small clinics had to serve a very large population, unimpeded communication between healthcare workers was instrumental in ensuring that each patient got the correct care for their ailment (Martinez et al. 2004). Having a network in place in which doctors can consult with one another and make referrals can ensure that the correct treatment is administered and resources are conserved.

Healthcare Standards and Assessment

Standards exist in healthcare to ensure that the "highest possible percentage of the best medical knowledge and skill available in a community reaches the patients in the [healthcare facilities] of that community" (Timmermans & Berg, 2010). The World Health Organization recommends that primary healthcare facilities should include preventative, curative, and rehabilitative

Table 3. 2014 disease statistics of the Ratti and Kataula CHCs.

Institution	Dysentery / Diarrhea	Typhoid	Anemia	Worm Festation	TB	Eye Diseases	Otitis Media	Injury	Pneumonia	Respiratory Diseases	Other Ailments	Total Patients
ZH Mandi	2332	133	1465	1649	158	20369	10392	8368	944	22652	337838	406327
CHC Ratti	1204	19	3650	3247	60	615	129	432	4	5398	52951	67709
CHC Kataula	348	10	140	197	11	219	109	480	27	2148	16504	20193

services. However, factors such as poor accessibility, limited resources, and hindered communication may prevent the medical knowledge and skill from reaching all the facilities in rural or remote areas. A commonly used service quality assessment tool is known as SERVQUAL/RATER. The tool measures reliability, assurance, tangibles, empathy, and responsiveness in the context of any service industry. This rubric can reveal inadequacies or gaps in management and communication, as well as whether or not there is a mismatch between consumer expectations and the actual service received (Shahin, 2006). For the purposes of our project, we combined criteria from SERVQUAL/RATER with the World Health Organization's requirements for healthcare infrastructure to create a comprehensive assessment framework we called the Rural Healthcare Assessment Model (RHAM), depicted in Figure 2.

> ***Primary healthcare…will include at least: promotion of proper nutrition and an adequate supply of safe water, basic sanitation; maternal and child care, including family planning; immunization against the major infectious diseases; education concerning basic health problems and the methods of preventing and controlling them; and appropriate treatment of common diseases and injuries (WHO, as cited in Walshe, 2011, p. 169).***

> ***Healthcare quality can be defined in relationship to the technical aspects of care, the interpersonal relationship between practitioner and patient, and the amenities of care (Andaleeb, 2001).***

We created RHAM to describe and assess whether the rural healthcare infrastructure has adequate facilities, is accessible, has adequate services, and is perceived as satisfactory by patients and professionals. Accessibility is assessed through the facility's geographical location and the distance between it and other facilities as well as villages, surrounding road conditions, means of entry, visibility, and ambulance routes. The facilities are assessed by looking at hours of operation, number and type of employees, diagnostic and treatment equipment, supply of emergency medicines, telecommunication

Figure 2. Rural Healthcare Assessment Model.

equipment, level of sanitation, and safe water supply. Services are assessed by examining whether the health personnel have adequate training and professional certifications, whether preventative and rehabilitative services including educational and outreach programs exist, whether cost of services is feasible, and whether emergency and routine medical services available are sufficient. Finally, stakeholder perceptions refer to provider, patient, and user experiences. These are assessed by examining their experiences and the challenges they note, satisfaction with the infrastructure, as well as gathering their feedback about the system and how they think it can be improved. This rubric enables analysis across a broad range of health services and capacity. We used RHAM to document and assess elements of healthcare infrastructure in Kamand as it allowed us to both quantify and measure quality of services when integrated into our data collection strategies.

Methodology: Documenting and Assessing Regional Public Healthcare

To assess the quantity and quality of public healthcare infrastructure in a rural community, we followed the dimensions of RHAM, including location, facilities, services, and stakeholder perceptions. We established three objectives, which are outlined in Table 4.

Our first objective documented locations, facilities, and services offered by the Zonal Hospital Mandi, the Kataula CHC, and the seven SCs that serve the Kamand region. We designed a documentation sheet to record the location, facilities and services dimensions of the RHAM. To record the location of these health centres, we traveled to each facility using the IIT as a reference point to mark their positions by measuring distance using an odometer. We took note of road conditions, construction areas, and other obstacles that would impede access to the facilities. We also noted ambulance routes to identify the ease of getting to the medical facilities from various villages. We compiled this information on a map.

We documented the facilities through direct observation and photographs to record the hours of operation, the staff at the centre, equipment and supplies, sanitation, and the telecommunication technology. This helped us

Table 4. Objectives and associated strategies.

Objectives	Methods
Document the location, facilities, and services of the healthcare infrastructure in Kamand	• **Documentation Sheet** • **Archival Research from Zonal Hospital Mandi** • **Semi-standardized interviews with healthcare professionals** • **Observations** • **Photographs**
Obtain provider and user perceptions of regional healthcare service quality, including personal experiences, challenges, satisfaction, and suggestions	• **Semi-standardized interviews with healthcare professionals** • **Unstandardized interviews with IIT workers and local villagers** • **Survey IIT students and faculty**
Identify the bottlenecks and high pressure areas in service delivery based on information gathered from our previous objectives	• **Compare infrastructure observations with stakeholder responses to identify common themes in healthcare delivery**

understand the facilities' capacity for treatment. We also obtained information about the non-tangibles of service, including medical services, costs, governmental programs, and educational programs. We verified our findings against archival research from Zonal Hospital Mandi and the Ratti CHC.

Our second objective obtained stakeholder perceptions of the quality of the public healthcare system. We gathered data from sources in Hindi and translated their responses into English. We only disclosed the dates and locations of the interviews to protect respondents' identities. We held semi-standardized interviews (Figure 3) with healthcare professionals to identify the system's successes and shortcomings. To garner input from typical users, we interviewed 20 IIT Mandi construction workers and 20 residents of local villages. We held unstandardized interviews with these groups to encourage respondents to share personal stories with the healthcare system. Finally, we sent a survey to 600 faculty and students of the IIT to collect information about experiences with the campus health facility and the local referral process. Using the information collected from these three sources, we identified the respondents' frustrations, commendations, and suggestions. Finally, we compared stakeholder responses with our own observations to identify bottlenecks and common high-pressure areas in service delivery.

Figure 3. Interview at an Ayurvedic centre in Neri.

Healthcare Assessment Results

In this section we present results of the RHAM assessment according to our objectives.

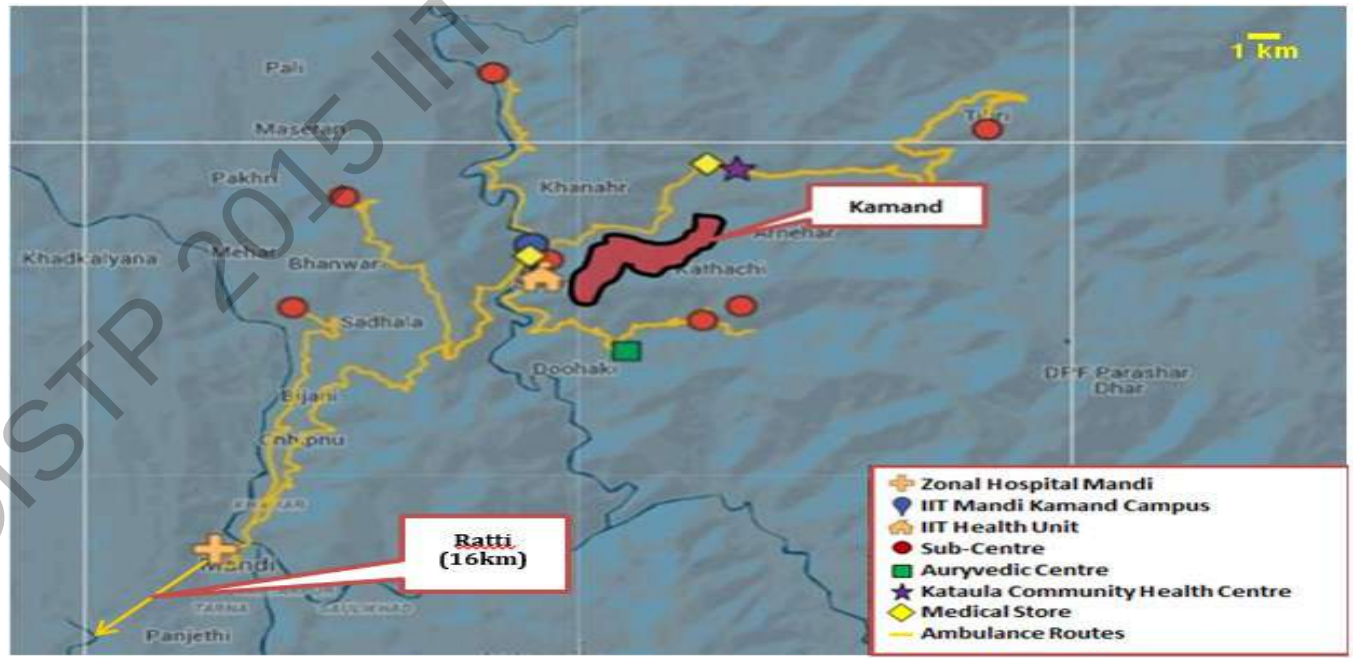

Figure 4. Healthcare infrastructure in the villages surrounding Kamand.

Location and Distance

After traveling to each facility, we created a map, indicating the number of regional public health facilities, shown in Figure 4. On April 1st, 2015, the Ratti Medical Block was split in two. This arrangement upgraded the Kataula Health Centre from a PHC to a CHC, creating the Kataula Medical Block that serves the Kamand region. We limited our map to show the regional facilities of the Kataula Medical Block.

Measuring distances between facilities and the Zonal Hospital Mandi, we found the range to be from 10 to 33 kilometers, which without obstruction, was between .5 and 1.5 hours of travel time. We took note of road conditions, construction areas, and other obstacles that would impede access to facilities. For example, the road to reach Neri/Navlay was under repair, creating an obstacle for vehicular travel. Two streams flowed over roads to the

Table 5. Regional facility characteristics.

Type or Name	Hours of Operation	Number of Employees	Positions	Number of Beds	Equipment	Medical Supplies	Telecommunications	Sanitation	Water Filter
Sub-Centre (SC)	9:30am-4:00pm (lunch 1:30-2:00pm)	2	Health workers, Asha workers	0	N/A	First Aid, seasonal and common ailments	Mobile phone	N/A	No
Kataula Community Health Centre (CHC)	9:00am-4:00pm (lunch 1:30-2:00pm)	24	Medical Officer, nurses, pharmacists, ophthalmologist, dentist, radiologist, maternal and family health worker, support staff	6	X-ray, laboratory, minor operations, injections	Emergency, first aid, seasonal and common aliments	Landlines, mobile phones, fax machine	Yes	No
Zonal Hospital Mandi	24 Hours a day	300	Same as above, Chief Medical Officer, Medical Officer of Health, physicians, surgeons, and many kinds of specialists	300	Same as above, CT, pathology, Major surgical equipment, ECG, Ultrasound	Treatment for major aliments, anesthesia, emergency, first aid, seasonal and common aliments	Landlines, mobile phones, internet, and fax machine	Yes	Yes

Riyagari and Tandu Sub-Centres. These are likely exacerbated during monsoon season, hindering transportation. The Balmand Sub-Centre and the village Dhukki are completely inaccessible by ambulance. Finally, all seven sub-centres were obscured behind trees, fences, and other buildings, reachable only by climbing dirt ramps and steep staircases.

Facilities and Treatment Capacity

We collected and classified facility information according to RHAM (Table 5). While Mandi Zonal Hospital has a wide array of medicines at its disposal, the supplies of the Kataula CHC and sub-centres is variable and currently dictated by the Block Medical Officer at Ratti. The supplies are delivered to the centres bi-annually and include 50 basic medications including bandages, vaccines, prescriptions for seasonal ailments, and first aid necessities. With these supplies, doctors at the Kataula CHC were able to treat 60 patients per day, while sub-centres treated only around 10. However, Zonal Hospital Mandi saw patient numbers as high as 730 per day.

The JSY and JSSK programs have been successful, particularly in Tandu where only 7 of 54 childbirths this year were performed in the home. Polio cases have dropped to zero and due to their widespread effectiveness; leprosy programs have not been necessary in years.

Cost and Services

The Zonal Hospital Mandi contains the region's only specialists. Specialists have MD degrees earned after receiving their MMBS degree. Doctors at Kataula had MBBSs, obtained after six years of study and an internship period. Sub-centres were operated by staff with 18 months of medical training. Overall, those with more medical education are concentrated at the Zonal Hospital, not in rural areas.

Table 6. Government programs in Himachal Pradesh

Program	Description
JSSK (Janani Sishu Surkasha karyakarm) translates to Infant protection Program	Medicine is free for all children under 1 year of age
JSY (Janani Surakaha Yojna) translates to Mother Protection Plan	Women below poverty line are given free medicine throughout and up to 42 days after birth
RBSK (Rashtriya Bal Swathsya Karyakarm) translates to National School Health Program	Students (K-12) are given free checkups at school
Malaria Program	Free testing and assistants at CHC
Leprosy Program	Free testing and assistants at CHC
Polio Program	Free testing
Immunization	Sub-centres offer vaccines every third Wednesday of each month
Smartcard	Card given to families that cover five people with free food in medicine if in-patient care and cover surgeries up to 1.75 lakhs

Regional staff work in conjunction with government programs (Table 6) that enhance healthcare delivery and target vulnerable groups.

Figure 4. Himachal Pradesh maternal and child care ambulance.

Although diabetes is a widespread concern in India, the regional infrastructure did not offer any programs for diabetes prevention. This may be because the disease is less prevalent in Himachal Pradesh than in other Indian states, with only 568 cases reported in the entire Ratti Medical Block (population 175, 517) in 2014. The Himachal Pradesh government sponsors programs for safe sex practices and family planning. There are also services for prenatal and postnatal care unique to the state. All prenatal care and ambulatory transportation for childbirth (Figure 4) are free of charge. If the ambulance is unavailable, the cost of travel to the Zonal Hospital is subsidized by the government. For postnatal care, doctors visit homes to monitor a newborn's health and administer free immunizations until the child is 1.5 years old.

Typical charges for services are standardized wherever they are offered. Overall, costs for common procedures are largely subsidized and fall within the range of ₹15 to ₹2200 Complex surgeries such as heart and neuro surgeries can cost upwards of ₹175,000. The cost of emergency services varies, depending on the patient's financial status. Zonal Hospital Mandi is the only facility in the region with emergency services. To prepare patients for travel to the Zonal Hospital, the Kataula CHC performs triage and can administer stitches, pain relief injections, and oxygen cylinders for patients reporting difficulty breathing. Sub-centres bandage patients before referring them to the Kataula CHC, and if necessary, the Zonal Hospital but do not provide routine medical services.

Workers at the Tihri and Tandu sub-centres stated that IFA tablets, a prenatal care supplement, had been unavailable for a year, while Vitamin A supplements had only recently become available for children.

Stakeholder Perception

Our interviews with healthcare professionals revealed that personnel at all seven sub-centres in the Kataula Medical Block (Kamand, Tihri, Taryambli, Neri/Navlay, Balmand, Tandu, and Riyagari) noted an inadequate supply of medicines. The supply of medicines at the sub-centres is not standardized. Workers make lists of and retrieve their needed supplies from Kataula. This unreliable supply is also exacerbated by a lack of medical stores in the region. Other obstacles mentioned were a lack of staff and specialists, lay practitioners administering ineffective treatments, and unreliable public transportation. Despite these problems, personnel cited government health programs as successful.

Users typically cited transportation and cost as major obstacles to care. To avoid travel costs, they stated that they would seek traditional healers and herbal medicine or travel upwards of three hours on foot to the Katuala CHC. Our survey of IIT students and faculty, patients with greater than average income, were not referred to the public healthcare facilities in Kamand, but rather to private hospitals such as Mandav Hospital Mandi and K.S. Hospital Mandi. Respondents expressed concern for public healthcare facilities' ability to treat major illnesses and for their lack of ICU wards.

Discussion

Our assessment identified a number of troubling trends, summarized below.

Access to Supplies

Medications for common ailments are available in each CHC and PHC, but these facilities are typically resupplied only twice per year. Doctors stated that they would prefer being resupplied quarterly. They are required to have only basic medications, but Balmand, Tandu, and Tihri sub-centres noted that certain medications have not been delivered to them in over a year.

Operators of all seven sub-centres expressed a need for more frequent resupply of medications. There are several possible reasons for this problem. The roads near most sub-centres are in fairly poor condition. This in combination with the centres themselves being fairly inaccessible can make getting supplies there difficult. Often, sub-centre operators use private transportation to pick up supplies at a CHC, which is expensive and time consuming. Having supplies delivered directly to the sub-centres also incurs a great cost. Distributing and coordinating resources across the region costs more due to distances between health facilities.

Access to Specialists

According to yearly statistics collected by the Zonal Hospital, each doctor at the Kataula CHC sees approximately 19 patients each day. The Kataula CHC currently has two working medical officers on staff, increasing patient volume per doctor to about 30 per day. The shortage of medical doctors we observed could be attributed to the fact that many doctors are not inclined to work in rural areas (Kumar, 2012). Doctors typically begin their careers in rural clinics but later move on to work in hospitals. Kumar's respondents noted that the circumstances of working in rural clinics are difficult, mentioning academic and social isolation (Kumar, 2012). Postings in underserved rural communities offer less in the realm of money and glamour than a position in an urban, private practice (Kumar, 2012). As skilled practitioners leave rural clinics, patients lose access to quality care. Finding replacements can be difficult, leaving facilities short staffed for long periods of time. Our data indicated that patients needing specialists must travel some distance to the Zonal Hospital Mandi, or do without, and even that hospital could benefit from additional specialists, including cardiologists, neurologists, and gastroenterologists .

We spoke to a man in Dhukki that said that a private vehicle to get him to the Kataula CHC could cost ₹500; a vehicle to Mandi could cost ₹1000. This does not include the cost of additional medical services or medication upon arrival.

Access to Facilities

One of the points brought up in village interviews was the challenge of facility accessibility. In emergency situations, an ambulance is contacted to transport the patient, ambulance routes are limited. In the instance of the Balmand Sub-Centre, residents reported tying patients to a chair in order to carry them down to an ambulance access point. Interviews in Dhukki revealed a similar practice, using a mattress instead. This method is slow and risky. Transportation to Zonal Hospital Mandi from Kataula CHC (21 km away), or from the sub-centres in Tihri, Taryambli, Neri/Navlay, Balmand, and Riyagari could take over an hour. This estimate assumes good road conditions without obstacles; however, roads are prone to landslides, washouts, and construction, thereby adding travel time. Villagers and IIT laborers typically take more affordable public busses as an alternative, a cheaper but unreliable option since bus schedules can conflict with facility operating hours. Due to the cost of travel, the Kataula CHC and Zonal Hospital Mandi are inaccessible to rural, remote populations and healthcare quality for these communities is compromised.

Project Outcomes and Deliverables

Three healthcare delivery bottlenecks emerged in our findings: access to supplies, specialists, and facilities. To address these, we formulated three recommendations, using a SWOT analysis to gauge feasibility.

1. Increase access to the medical resource network in the region by adding a Mobile Unit that can deliver both supplies and care to doctors and patients in remote villages and facilities.
2. Expand care available to patients in and around Kamand by increasing the number of specialists, especially cardiologists, gastroenterologists, neurologists, and psychologists.
3. Introduce affordable and simple equipment, such as lightweight stretchers discussed below, into villages with limited or no accessibility to main roads or ambulances.

Maintain regular evaluation with RHAM to track progress in the quality of the healthcare system.

1. Access to Mobile Unit

To increase access to healthcare in the Kataula block, we propose adding a Mobile Unit that would periodically visit towns and villages with poor access to sub-centres. The unit could also deliver medications on a more regular basis. There are two ways to implement a mobile unit. The first is to add a branch of the National Rural Health Mission (NRHM) Mobile Medical Units to the Mandi District. MMUs have been implemented in Himachal Pradesh, but we found no evidence of this service in Mandi. The MMUs consist of one to three vehicles that contain trained medical personnel and medications. In instances where there are multiple vehicles, one might carry basic laboratory facilities and one might carry more advanced diagnostic equipment (MMUs, 2012). Thus, as an expensive (roughly 18-23 lakhs) district-wide investment, a fully equipped unit would not be able to focus exclusively on the Kataula Medical Block, meaning that it would be unable to make regular stops at sub-centres to deliver supplies. Regular maintenance also costs up to 23.71 lakhs per year. Another option is to create, a single vehicle with fewer capabilities, having a staff of only three, an MO, a nurse, and a driver. This unit could be based at the CHC Kataula and travel to each of the sub-centres in the block on a rotating four week cycle, with two days spent at two different sub-centres and one day spent on call each week. The centre would be outfitted with an examination bed, supply closets, and medicine lockers (Figure 5). The Mobile Unit would be stocked with first aid equipment, including the 50 basic medications required by each sub-centre and any other supplies deemed necessary by the operator. Having a doctor visit sub-centres regularly will increase the quality of care and will allow medicinal supplies to be delivered more often.

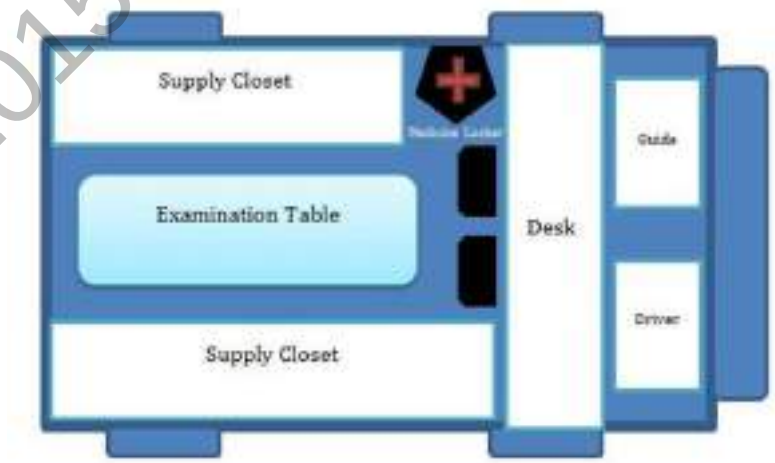

Figure 5. Scaled-down Mobile Unit

2. Care: Rural Doctor Scholarship Program

To replenish the current system, we recommend that professionals and specialists, including gynecologists, pediatricians, and MBBS graduates, are distributed throughout the region to rural health facilities. This will relieve some of the pressure that doctors currently face, providing more staff to treat patients. However, there are current issues in training specialists and getting them to work in rural areas. We recommend a

partnership with the new ESIC medical school in Ner Chowk in Mandi. This partnership will have medical students interning at local PHCs, CHCs, and sub-centres. As part of the MBBS education, students are required to perform a one year rotation internship. In addition, the government might, through a Rural Doctor Scholarship Program, offer scholarships or subsidize the students' education if they commit to work at regional facilities after graduating. Funding could be drawn, in part, from existing funds for currently unfilled but sanctioned positions at rural clinics. Furthermore, this program could be expanded to subsidize MBBS doctors' educations for a specialty degree in gynecology or pediatrics (sanctioned positions in CHCs and PHCs for those who agree to work at the clinic for some subsequent period). Ultimately, this could alleviate the regional staffing problem, encourage students to pursue more training, and bring specialized treatment to rural populations.

3. Technology: Safe Stretcher Transportation

Our final recommendation is to provide stretchers to all villages and sub-centres in the Kataula block. Several facilities we visited had poor accessibility to roads and ambulance routes. Stretchers could ensure safer transport of patients in these situations. The stretcher design should be durable, inexpensive, lightweight, and have immobilization capabilities. The design should maintain a patient's position even during transport on the region's steep inclines. Supplying every village and sub-centre with this equipment will increase patient safety while they are moved to ambulance access points or the nearest care facility.

4. Evaluation: RHAM for Repeat Assessment Follow Up

One result of our project was the creation of the Rural Healthcare Assessment Model. This model allowed us to assess healthcare infrastructure in the Kamand region, revealing bottlenecks in service delivery. The RHAM could be used periodically to identify system improvements. RHAM, with its four categories of location, facilities, services, and stakeholder perceptions, could also be used to assess the healthcare infrastructure in any rural community, but the sub-criteria in each quadrant could be changed according to community needs or constraints. Our goal was to identify bottlenecks in service delivery; however, at a later date a team could use RHAM to search for mismanagement or standardized practices, among other possibilities.

Additional Observations

Although our stakeholders did not note this, there is no management information system in place in the Kataula block. Without a database to record patient information, epidemiological statistics, inventories, shipments, and deliveries, it is not surprising that there are often shortages in needed supplies, and that disease statistics are often misreported. To increase the existing system's efficiency, to improve information sharing and referrals across facilities, and to give professionals access to expert resources on diagnostics and treatment plans, a management information system could be implemented. To implement such a database, however, computers and internet connections would need to be provided to all sub-centres in the medical block.

Conclusion

The results of our collaboration with regional stakeholders revealed three existing bottlenecks in the healthcare system: inadequate access to supplies, specialists, and facilties. More importantly, we learned that the assessment of rural healthcare requires emphasis on factors that go beyond the sheer number of facilities. Site-specific obstacles including road conditions, cost of public transportation, and access to specialists greatly undermine the capacity of local facilities to provide needed services. The RHAM determined healthcare vulnerabilities in rural communities,

and we subsequently identified short and long-term recommendations to overcome these obstacles.

While our project focused on infrastructure of the public healthcare system, future research could further investigate the management of these facilities and could expand to private sector healthcare as well. Moreover, future efforts will be needed to develop, test, and implement a Mobile Unit or a Rural Doctor Scholarship Program as suggested. While the existing public healthcare infrastructure has many strengths, including extensive government programming and treatment subsidies, improvements can be made through informed technological, social, and administrative solutions.

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Supplemental materials for this project can be found at http://www.wpi.edu/E-project-db/E-project-search/search, using key words from the project title.

Problems and Prospects of Tourism in Himachal Pradesh

Abstract

This project investigated transportation problems faced by tourists in Himachal Pradesh. The goal was to assess the feasibility of developing a technological innovation that could improve the experience of tourists and tourism operators in Himachal Pradesh. We identified the needs of all the stakeholders, including tourists, taxi drivers, travel agents, and hotel operators. On evaluation of the data, we determined that an app could likely to enhance tourism potential in Himachal Pradesh.

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Introduction

Tourism has witnessed a dramatic transformation into a multifaceted economic and social activity. Travel and tourism have been confined to a privileged few, namely the rich, at the time of independence of India. Tourism is now an industry with many facets and varied activities. It calls for a perfect co-ordination among diverse segments that go to structure this industry. Tourism has now grown to such dimensions and importance that it has become the largest industry in the world. The tourism industry is the third highest foreign exchange earner in India.

Himachal has a wide variety of flora and fauna that attracts tourists from all across the globe. The state is endowed with variety of landscape and vivid topographic features (Himachal Pradesh, Wikipedia). Apart from its scenic beauty, the state is also known for its adventurous activities like paragliding, rafting, and skating. To improve tourism activities in the state, various facilities have been provided viz. hotels, transportation, adventurous sports, hiking & trekking guides, websites. Also, a large part of population is dependent on the transportation and tourism department for employment. As of 2011, the number of tourists visiting Himachal Pradesh is known to be 151 Lakhs (Department of Tourism, Himachal Pradesh). Thus, it is very important to understand the problems of tourists and taxi operators. Major tourist and religious destinations include Dalhousie, Dharmshala, Shimla, Manali, Palampur, and Kasauli (Himachal Pradesh, Wikipedia).

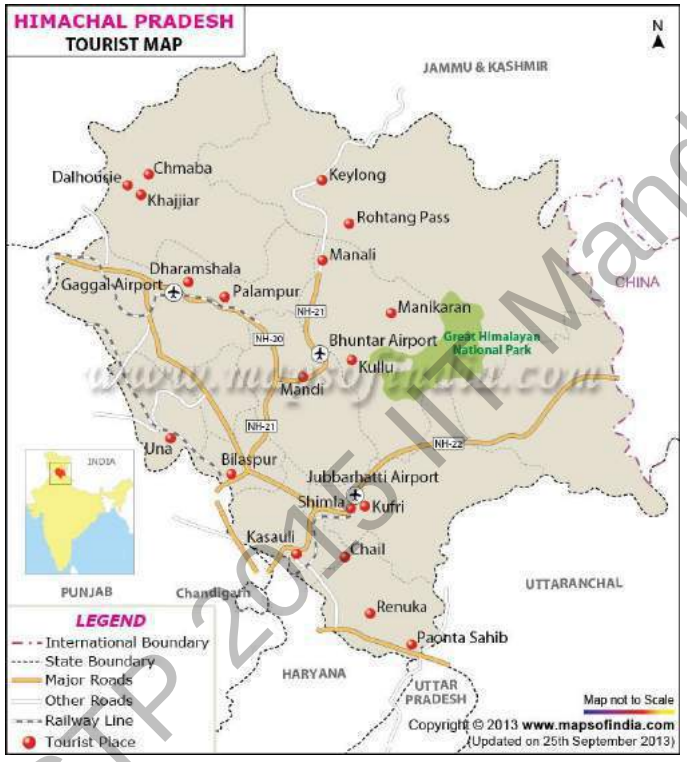

Figure 1. Key tourism areas in Himachal Pradesh.

It is therefore a fact that Himachal Pradesh has immense tourism potential, a potential that it must leverage and sustain. Tourism has its benefits which Himachal Pradesh must cash on without getting affected by its shortcomings. To leverage on this tourism potential, it is necessary for Himachal not only to sell itself but also analyze the needs, the perceptions, the preferences, and the satisfaction of the customers that it can provide. Also, tourism provides foreign exchange.

Hence the study aims to analyze these very tourist responses with the help of a questionnaire. Although Himachal has unique natural offerings it is not able to cash upon them due to lack of various facilities. Most of the tourists' expectations are met with but they depend on the presence of good necessities like amenities, food and water and proper infrastructural facilities like accommodation, transport, and accessibility, which were found lacking in certain cases.

Past studies on the tourism industry in India have focused mainly on how to sell the tourism product. But it is more important to view it from the tourist's point of view. This study will help to understand their perceptions and needs and thus aims to

- Exploit the full potential of Himachal tourism
- Increase tourist arrivals by provides better amenities
- Combat the competition by newly developing tourist destinations
- Decrease the cost of transportation in Himachal.

The goal of this project, therefore, is to assess the feasibility of developing a technological innovation that could improve the experience of tourists and tourism operators in Himachal Pradesh.

Previously, people used to tour mainly on pilgrimage. But now, the culture has changed. In our country also, many people plan for their tour as a regular affair maybe once in a year. In this growing field, it is important to study the major issues faced by tourists and to take necessary steps to reduce such problems. Currently we don't have any efficient transportation system in the state. The tourists face many problems during their visit due to either non-availability of transport or surplus amount being charged by the travel agents. On the other hand, the taxi drivers also face shortage of customers due to lack of interaction with customers. To achieve the aim of the study, the objectives for the proposed research, would be as follows:

Objective 1. Establish a baseline of the problems faced by stakeholders (tourists, taxi drivers, hotel operators, and travel agents)

Objective 2. Understand the needs of the stakeholders

Objective 3. Design and test a booklet and an app interface (technical solution) that can improve the experience of tourists, drivers, and operators

Background

Himachal Pradesh Tourism Development Corporation (HPTDC) is an organization which provides information about hotels, transport, visiting places to tourists. They have done many improvements in the past years. Generally, tourists prefer online booking of hotels and transport. The main websites for online booking of hotels include *Goibibo.com*, *Himachalhotels.in, tripadvisor.in*, and *cleartrip.com*. Himachal Tourism HPTDC is the government run bus service in north India. Connecting to cities like; Manali, Shimla, Khajjiar, Kullu and other top hill stations.

Himachal Tourism HPTDC offers the reliable and value worthy bus service for passengers. To keep a good relationship with passengers, the HPTDC offers tour packages and other service facilities (travelyaari.com). The hptdc website provides a good information about the top tourist destinations, hotel booking, online reservation of buses, travel tips, and offers. Most of the foreign tourists use tripadvisor app for booking hotels etc. Some of the Indian tourists are in favor of offline booking. The taxi drivers are contacted through travel agents and operators (sometimes online also). The pie-chart (Figure 2) shows the share of foreign and Indians tourists in 2013.

According to Times of India, the percentage of foreign tourists visiting Himachal in 2013

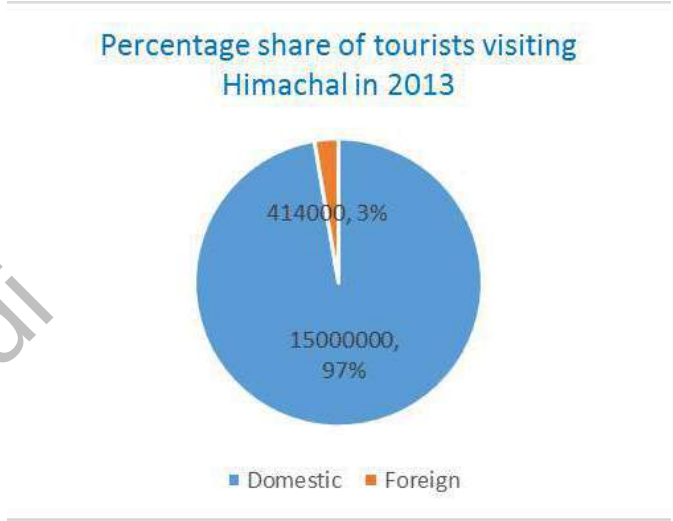

Figure 2. Percentage share of tourists visiting Himachal in 2013.

is 2.76% and rest are Indian tourists. This clearly shows that the main visitors here are Indians. This could be due to lack of advertisement, connectivity to the rest world and mainly due to development concerns. Transportation is one of the main concern here as taxi services charge too much as compared to buses and the frequency of buses is low. Moreover, shops are also not frequent. The tourists who usually visit come along with their families and friends. Age group comprises of all ages but mainly there are youngsters. They usually interact with travel agents and operators. But in some cases they book offline. The common adventurous activities are hiking and trekking, rafting, paragliding,

ice skating etc. Generally they book these activities offline. Figure 3 shows the common problems which tourists face.

Most visitors come here to witness the natural beauty of the snow-capped mountains while others come for adventurous sports. Places like Shimla, Dharmashala, Mcleodganj, Dalhousie, Manali are famous for their scenic beauty. In Shimla, there is an ice skating club. The club has its own website where one can get information about the location etc. Kullu is famous for white water rafting. In Kullu Valley, white water rafting can be enjoyed in the river Beas throughout the year except during rains and winters. Paragliding facilities are available at Solang Nallah and Marhi. Paragliding is organized in Kullu valley throughout the year at Solang Valley, located 14 kms from Manali and other locations like Marhi, Fatru, Bijli Mahadev etc.

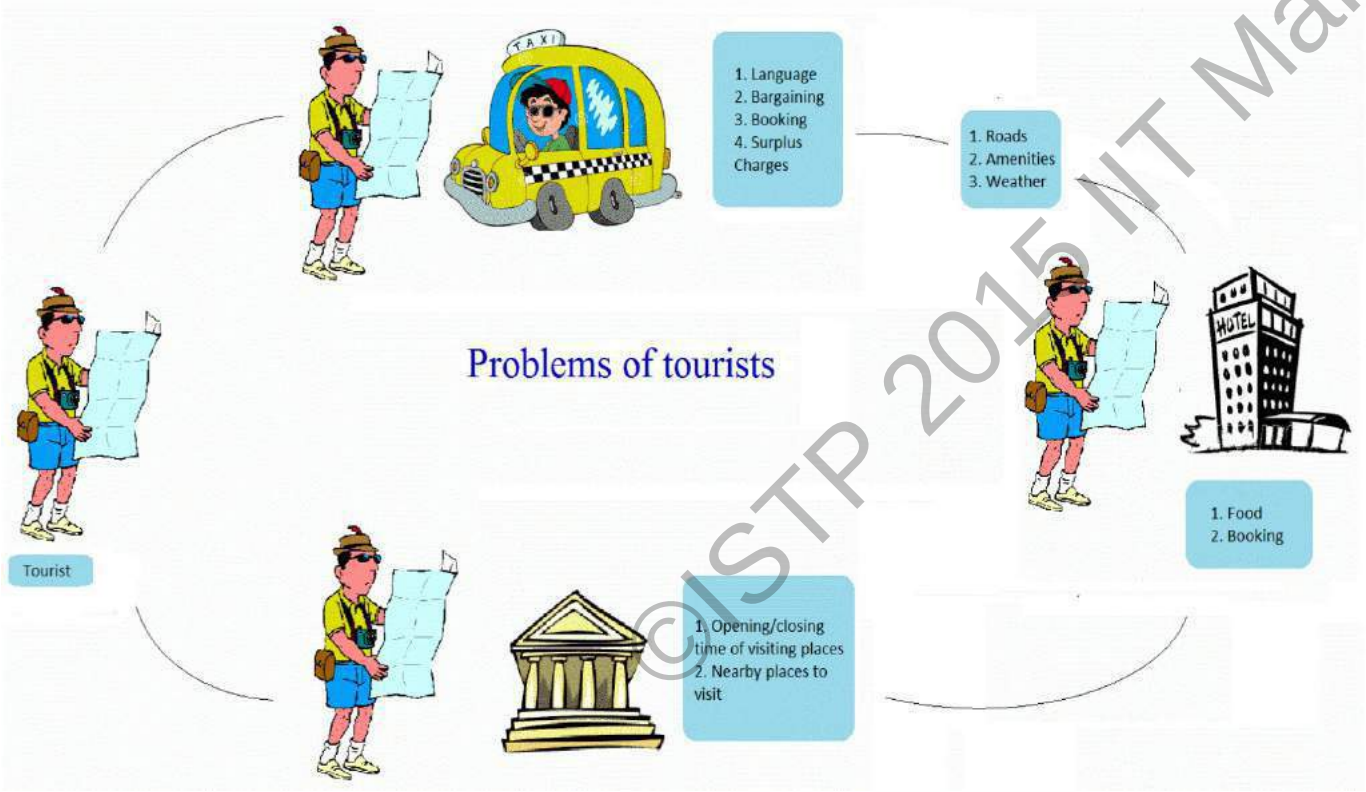

Figure 3. Common problems faced by the tourists during their visit.

Methodology

A questionnaire was prepared to collect the primary data from the public. Content validity has been ensured by the consultation with subject experts. The questionnaire was pre-tested and few corrections have been made based on the suggestions given by the respondents. Suitable analysis has been carried out to study the stated objectives. The study area has been fixed to cities like Shimla, Kullu, Manali and Mandi because city respondents have more experience on tour and they have the practice of touring periodically. The respondents are those who have gone on tour in the last six months. The sample size was 100 as it was convenient sampling. This is the most suited sampling technique because the respondents have been those who volunteered to provide data. This will definitely reduce the bias in their responses.

In order to meet objective 1 (Establish a baseline of the problems facing stakeholders), we have performed site assessment (In this case Himachal area). We have prepared a basic map showing all the key tourist destinations. Then we interviewed some individuals to get more insight of the problems. We also interviewed some officials who are related to Himachal Pradesh Tourist Development Corporation. We mainly focused on tourist groups as they are more likely to volunteer to participate in the study. Families and groups of tourists were in-

terviewed. Tourists from all around the world come to visit this place. The respondents were mainly Indians. A significant part of the respondents were visiting for their second time.

In order to meet objective 2 (Understand the needs of the stakeholders), we categorized the stakeholders as tourists, drivers, travel agents and hotel operators and managers. We had to facilitate all the stakeholders. Until and unless the auto drivers and travel agents are not satisfied, the goal cannot be met. Problems of tourists range from infrastructural to linguistic. Infrastructural problems consist of the condition of roads (Bad roads or no roads), lack of amenities, transportation. Whereas, they face other problems like language, guidance etc. Security is a major challenge to the tourism and travel industry.

Tourists who visit Himachal don't have proper knowledge of the key visiting places. For foreign tourists, travel agents emerge as the major source, followed by family members or friends. Therefore, they don't have any control over the surplus amount which is being fetched by the agents. We surveyed and interviewed various tourists and as a result we found that they don't have proper information. We are planning to prepare a booklet which will provide all the available information to the tourists. This will include the description of the visiting places, a map showing them, bus reservation, contacts of taxi operators, hotel booking information, opening and closing time of visiting places etc. Also, we were thinking of coming up with an app which can reduce the travelling cost of individuals.

In order to meet objective 3 (Design and test a booklet and an app interface), we installed the necessary software required for the app. Also, we have designed a booklet. The booklet consists of all the necessary information required by the tourists during their journey. The app will consist of several features like chat, comment, boarding and destination, date and time of travel, preferred routes etc. The app will be beneficial for both the tourists and taxi operators. The fare can be shared by the tourists who are travelling to the same destination on the same day. After making the booklet, we have again visited for feedback and reviews.

Tourist destinations surveyed

We surveyed in Mandi, Sundarnagar, Kullu, Manali and Shimla. The table below shows some of the places we visited. The number of respondents was around 100. Major number of respondents were interviewed in Shimla and Manali.

Limitations

This study was conducted in selected areas like Mandi, Shimla, Manali, and Kullu. and hence the result cannot be generalized without reconfirming the result in another areas. The sample size is limited to about 100 respondents. Furthermore, the limitation of applying questionnaire as a tool for data collection is applicable here too. However, the bias is minimized because the respondents are those who have willingly participated in the study. Some of the tourists were not willing to participate in the study either due to lack of time they had or due to personal reasons.

Table 1. Sites and respondents.

S No.	District	Towns	Destination	Respondents
1.	Mandi	Mandi	Indira Market	9
			ISBT Mandi	5
			Hotel Riverbank, Hotel Paras, Hotel Rajmahal, Hotel Regent Palms	8
		Sundarnagar	Hotel Valley View, Hotel Midway Resorts	7
2.	Shimla	Shimla	Jakhoo Temple	9
		Old Shimla	Old Bus Stand	10
			Auckland	6
			Mall Road	9
			Himachal State Museum	4
3.	Kullu	Kullu	ISBT Kullu	6
			Hotel The Nest, Hotel Shobla International	5
		Manali	Van Vihar	17
			Hidimba Temple	11
			Mall Road	7

Findings

The tourists may experience problems relating to various factors such as unexpected ex-

penses, safety and security, service, guidance, accommodation, language, health care, transport facilities, seasonal effect, public washrooms, food, and infrastructure. In this study the problems we found are grouped according to their intensity. According to the respondents, high intensity is given to roads, infrastructure, accommodation, and seasonal effect. Moderate intensity is given to guidance, language, transport facilities and unwanted expenses.

S. No.	Factors	Intensity
1.	Service	Low
2.	Safety and security	Low
3.	Infrastructure	High
4.	Accommodation	High
5.	Guidance	Moderate
6.	Language	Moderate
7.	Transport facilities	Moderate
8.	Seasonal Effect	High
9.	Public washrooms	Low
10.	Food	Low
11.	Unwanted expenses	Moderate
12.	Health care	Low
13.	Roads	High

Table 2. Findings from interviews.

Low intensity is given to service, safety, public washrooms, food and health care. The table below shows the problems and their intensity.

To support our data, a HP PWD officer said that the roads we build is of 20mm layer which is very less as compared to army roads of 3 inches. This layer as being thinner gets easily damaged by water due to heavy rainfall and snowfall in these areas. For information related problems we also went to **TOURIST INFORMATION CENTRE** in Manali who said that only 2% of the total tourists come to the Himachal tourist information centre which is a major concern (i.e. lack of public awareness). They also told that if we find cases of cheating then we can help them get the refund and take proper action. Further we found private taxis doing illegal business in Himachal. We also saw that the drivers once associated with a union can't change this in his lifetime. The problems are also with the brokers who book taxis online and then take the passenger of local taxi drivers. There is no parking space in Mandi for the taxis which is also a big issue for the drivers.

Project Outcomes

The problem intensity experienced by tourists differs depending on various factors influencing tour environment and demographic conditions. Also, the problem intensity differs significantly based on respondents' state such as

gender, age, nationality, education, profession, income, geographical location, family size and frequency of tour made. The discussed situation with the intensity of problems requires more attention and policy efforts to develop tourism development. There are major hindrances during tour which are to be attended step by step based on its intensity, so as to reduce the problem during their tour. The study is basically exploratory in nature. The study attempts to analyze the tourist's responses regarding various factors of tourism in Himachal Pradesh. It was done with the help of a questionnaire analysis. The collection of data in this study has been through the survey method.

The present study has been done based on primary data and secondary data. The primary data was collected by administering questionnaires to tourists who have been to Himachal Pradesh. Secondary data was used, to support the primary data. The major sources of information were the various journals, newspaper reports, research articles, market research agencies and the World Wide Web. The primary objective of the questionnaire survey was to obtain an insight into the tourist perceptions about Himachal tourism. The questions asked pertained to various factors that affect their stay in Himachal Pradesh. The raw data collected from the questionnaires was suitably coded and tabulated to make statistical inference. After making statistical inferences from the data, we gave recommendations like coming up with the app and the booklet. A Band of educated unemployed could be selected from within Himachal and trained to be Excellent Professional Guides who can speak in fluent English and Hindi. Their services could be utilized by the Tourists. Also, there are some other solutions like building public washrooms, improve the condition of roads, develop remote tourist areas, provide better amenities.

A possible solution is to build an app which have features such as sharing fares with other passengers so that this may cost less to the passengers and to provide the tourists information about visiting places, hotels, and adventurous activities. Further for security of passengers we thought of having a send status button in the app to send real time location and other data to the reliable contacts in case if the person feels trouble. We also thought to implement panic button in taxis to handle any such situation. Further we can have a travelling card so that the person pay one time and enjoy riding in any government vehicle for the limited time which will obviously cost less to the passenger.

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IIT Mandi Community Radio

Abstract

Community Radio in India, as a campaign started in 1990's. It's a great medium to bridge gap between various communities and their sub-classes. IIT Mandi Community Radio intends to work towards the same objective. It is also one of the low-cost and effective way of transmitting information to the community, which includes nearby Kamand region apart from the very diverse IIT Mandi campus community. This is a very simple yet a powerful initiative which will expand into terrestrial radio at the final stage.

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An Interactive Qualifying Project/ Interdisciplinary Sociotechnical Project submitted to:

Indian Institute of Technology Mandi

Why Community Radio?

The idea of Community Radio gained strength during the mid-nineties in India. Community Radio was placed somewhere between commercial and public broadcasting radio stations and became quite popular.

Setting up a community radio is one of the most empowering actions that any community can do as it serves not only local, geographic communities but can also link communities on the internet. These stations create a platform for listeners to share their ideas and address their problems. It provides a mechanism for empowering individuals, groups, and communities.

Figure 1 shows the South Campus of IIT Mandi and the area nearby. The desirability of a community radio station to serve the campus and the surrounding communities was established by a previous IIT team through a field survey (Batch 2014 ISTP Radio Team, Final Report).

Figure 1. IIT Mandi South Campus overview.

Goals and Objectives

Our project goal was to make community radio at IIT a reality. To meet this goal, we set the following objectives:

- Demonstrate technical feasibility by setting up a web-based community radio.
- Start and operate pilot broadcasts with the help of external gadgets, broadcasting live as well as recorded programmes.
- Demonstrate our work in nearby communities and analyze their feedback.
- Study the requirements of setting up a fully functional radio and the options to apply for funding to add terrestrial FM Radio broadcasting capability in the future.

Purpose of Community Radio and its History in India

Community radio is a radio service that caters the need of a particular community. It is not the same as mass media broadcasting but it has its own perks. The most important thing about a community radio is that it provides useful content for a specific community that is generally not provided by commercial radio (taken from Community Radio, Wikipedia).

Community radio serves two major purposes. First is to serve the community and second is to get active participation of its audience. Community stations usually follow a regional programme schedule (regional songs, regional language talk shows), while other mass broadcasting radio stations might follow a very standard programme schedule.

In India, a campaign to legitimize a community radio began in 1990's and soon after that a judgment was passed to legalize community radio. The Supreme Court declared at that time that "*airwaves are public property*". This was a revolutionary phase, but initially only educational institutions were allowed to broadcast; other community stations didn't boom until 2009, after which, *Ministry of Information and Broadcasting issued* **a** *Grant of Permission Agreements (GOPA*) for [0] 6 community radio stations (https://www.idolgu.in/student_support/radio_luit_FM_90.8). These days there are ample community radio stations around country, dedicated for very particular organizations like *NGO's or DDC.* These radio stations help to provide aid where any other form of broadcast is not easily (or even remotely) accessible. Also, many educational institutes started community radio for professional training in surrounding communities or to promote cultural awareness. *Anna University Chennai* was [D]irst college in In-

dia to set up community radio in its own domain. This concept gained so much appreciation that the government started paying attention, following the suggestion by UNESCO. They even formulated guidelines to be followed to set up community radio in 2006 as shown in Policy Guidelines for setting up Community Radio stations in India (CRFC, 2006). There is a detailed license procedure provided by Ministry of telecommunication for setting up community radio. Figure. 2 identifies upcoming community radio stations in various states of India.

Most of the field work for setting up community radio was done by a previous year's ISTP group. They visited nearby community radio stations, large and small scale, those having different functionalities and schedules, and those targeting very specific sections of the community. Field visits were made in *Solan* and *Dharamshala.* Both of these stations nurture different communities and have entirely different kind of programmes scheduled. Solan Radio station was launched in 2009 with the motive to promote responsible and dynamic citizens. Their major broadcast is educational and traditional, with programmes in local dialect. *Dharamshala* Radio targets the Tibetan community in Himachal Pradesh. This is an *NGO* radio station for that community. Most of its programmes are for health and welfare of the community. This group found different reasons why listeners tuned in (Figure 3).

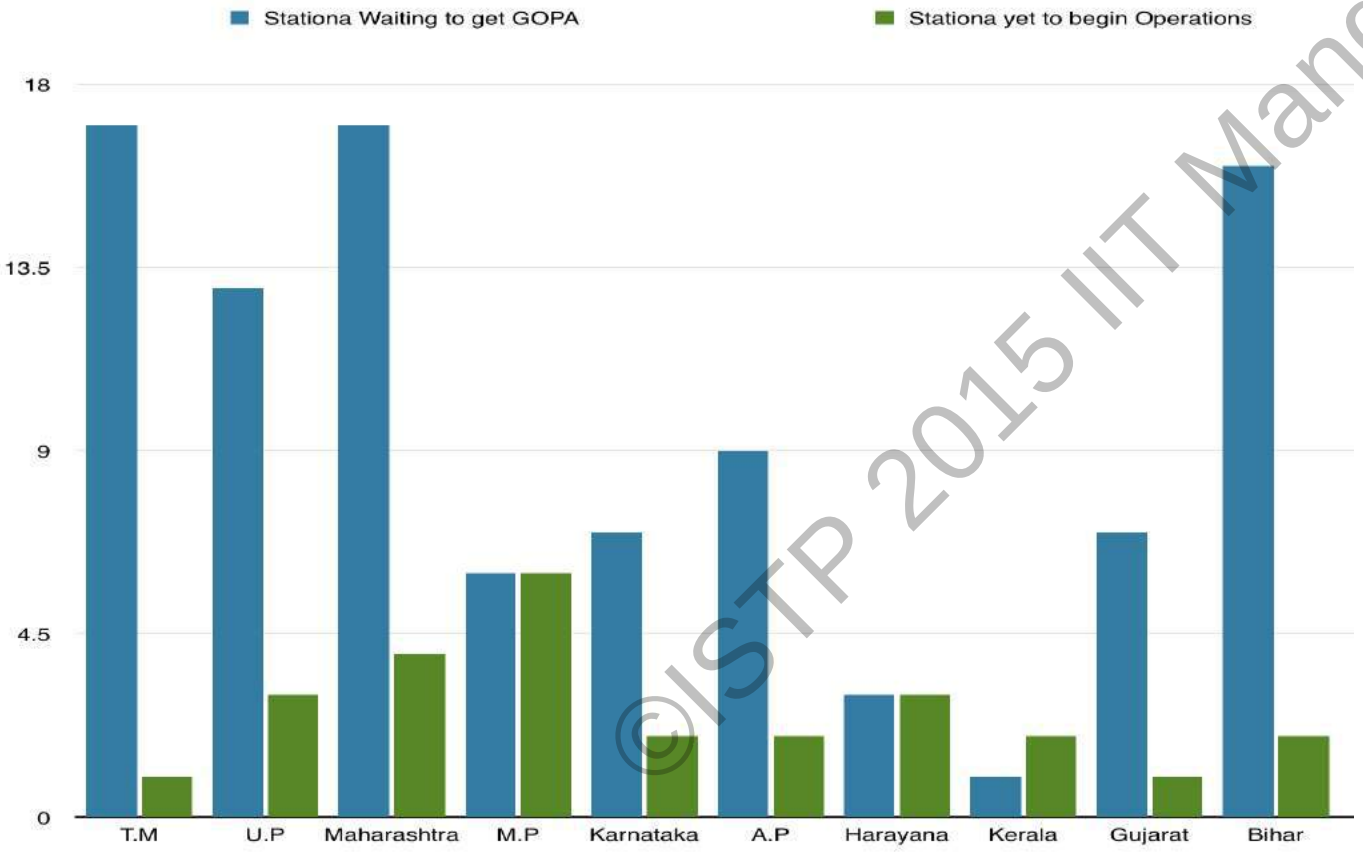

Figure 2. Upcoming community radio stations in India.

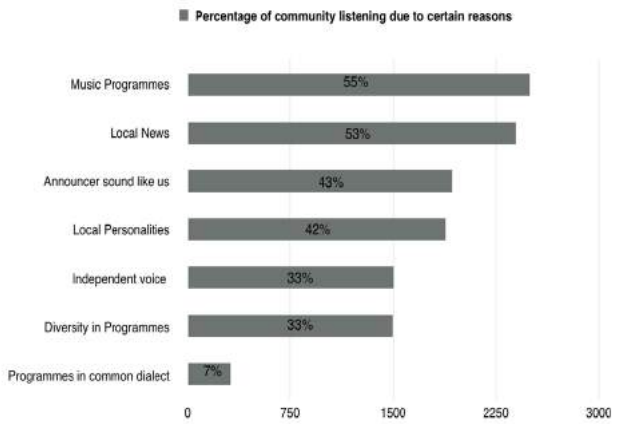

Figure 3. Percentage of listeners' mentioned reasons

Methodology

- As we have gone through various web based radio stations in India, we figured some of the attributes needed to set up a web based radio. For our community radio, we considered few of those attributes which includes live broadcasting, tele calling system, SMS facility.
- After the finalization of the attributes, we looked for software. These attributes and softwares are compiled in Table 1.
- We had contacted with couple of experts who were the developers of these software's, they helped us in finding the best software with all the attributes.
- As per the survey conducted pervious year we created our criteria and the evaluation of the software was done.
- A user interface was developed through which we can provide the user a platform to listen to the ongoing programs being broadcast.
- A survey was conducted in order to understand the priority of the content for the programmes. We asked for opinions of probable users within IIT Mandi and some of the local community members. People residing around Kamand area were very much interested after listening that there would be a radio station which would help them in one or the other way. We have interviewed 20-25 people asking the following questions:

	Softwares/ Attributes	Gramvaani	RadioDJ	Jazler	NextKast	Mixtime
1.	Provider:	Gramvaani (India)		Jazlersoftware(Greece)	Winston Potgieter(USA)	Ettore (Italy)
2.	Cost	Free	Free	Paid(Onetime Payment)	Paid(Onetime Payment)	Paid(Onetime Payment)
3.	OS supported	Ubuntu	Windows+ubuntu	Windows+ubuntu	Windows	Windows
4.	Live Broadcasting	Yes	No	Yes	Yes	yes
5.	Call facility (users)	Yes	No	No	Yes	No
6.	SMS facility (users)	Yes	No	No	Yes	Yes
7.	Re-broadcasting	No	No	No	Yes	Yes
8.	Track of no of listeners	Yes	Yes	Yes	Yes	yes
9.	Audio file supported	.MP3,.WAV, .WMA, etc.	.MP3,.WAV, .WMA, etc.	.MP3, .WAV, etc.	.MP3, .WAV, etc.	.MP3, .WAV, etc.
10.	Hardware Requirements	a. Sound card b. GSM modem	Sound card	Sound card	a. Sound card b. GSM modem	Sound card

Table 1. Members of team working on testing of software in PC lab.

- Software for setting up the web radio system was installed on a few computers with the goal of creating a base from where the broadcasting can be done.

Figure 4 shows team members testing software in the computer lab. As part of this project, we made calls to other radio stations. There are community stations installed in some colleges to maintain regular curriculum and there are other college community radios which are much similar to the one which we are planning – one that will broadcast college events as well as programmes that will help nearby communities.

Steps followed to achieve our Goals

Since this project was continued from the last year, we developed the criteria to deliver the functionalities we want in our software (which we will use for broadcast) based on the previous team's work and conclusions. We evaluated various software based on the desired functionalities by reading the software documentation and/or by contacting the developer of each software. In figure 5, star represents the best suitable software for the particular attributes in each column. From figure 5, it can be concluded that Gramvaani is the best web based radio software.

We first contacted Mr. Rohit Jain from Gramvaani (one of the developer of this software). Subsequently, we had discussions with one of his seniors, Mr. Kapil Dadheech, which included our faculty advisors. Our aim was to convince Gramvaani to let IIT Mandi have the source code for the software so that improvements may be made in the software in the future at IIT Mandi. Gramvaani has agreed to give the source code to IIT Mandi in return for access to any future improvements.

We first set up the software in our laptops locally for testing and later on in one of the computers in PC-lab to keep it safe and secured. We performed a few test live broadcasts on web.

We demonstrated our radio to people in Kamand and interviewed them using a set of questions and analyzed their feedback. The picture in Figure 5 was taken while interviewing people residing in Katindi.

Figure 4. Members of team working on testing of software in PC lab.

Results and Discussion

We selected a software named GRINS and broadcasted live on 17th Apr and 27th Apr using this software though regular testing was done since 10th Apr. It meets our requirements efficiently. We used this software because it offers the following advantages:

- It is used by almost all of these community radio stations (*GRINS*) and the best part about this software is its free, open source and easy to setup.
- There are certain glitches that we are trying to fix but eventually this is going to be the software chosen for community radio of IIT Mandi.

During the visit to nearby area of Kamand, the following are the answers which we have got from the people whom we have interviewed.

- We have got some good answers from people and they have also suggested us with what they are expecting from a community radio.
- People are very much interested in listening to old/devotional songs in morning and they wanted us to be updated with the news and also suggested us it would be good if we broadcast news for every 1hr interval.
- Some people were interested in getting experts' advice regarding hygiene problems, post-harvest losses any many more issues.
- Mostly the teenagers are interested in knowing the updates of the cricket, football etc. at regular intervals whenever there is a tournament going around.
- We have also interviewed alumni of IIT Mandi, they were really interested in IIT Mandi community radio. They have requested for the updates of extracurricular activities (e.g. Fests, sports events, convocation ceremony) to be broadcasted. Further improvements in the software or in the community radio will be continued by the next batch who will be taking this project.

Figure 5. Team members interacting with people in Katindi.

Project Outcomes: A Web-Based Radio

The fully operational web-based radio is set up in PC lab using GRINS software (Figure 6) which includes following functionalities:

Live Broadcast:
Where the speaker needs to be at a server computer (in PC lab); on-spot programmes will be broadcasted on web.

Pre-Recorded Broadcast:
This requires the audio file (.mp3) which can be uploaded on the software and played for listeners.

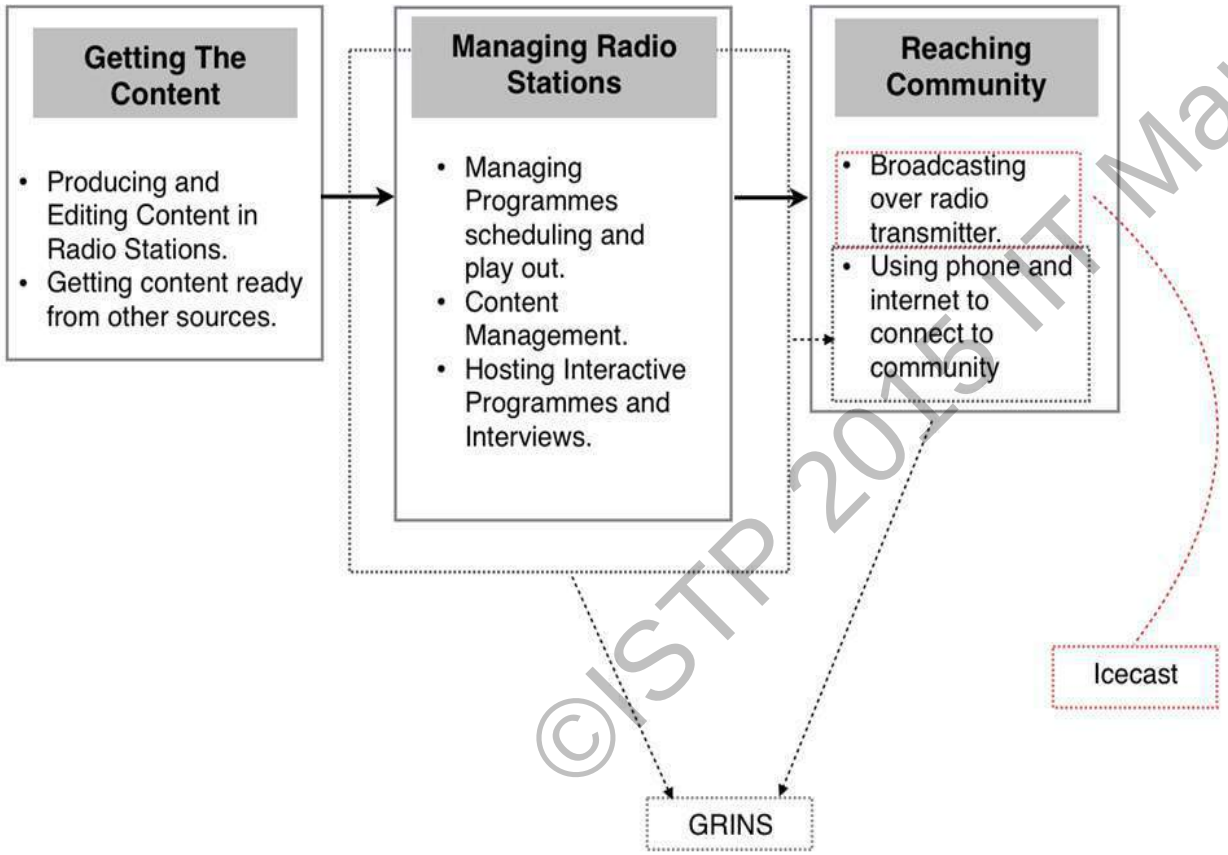

Figure 6. Schema of working community radio station.

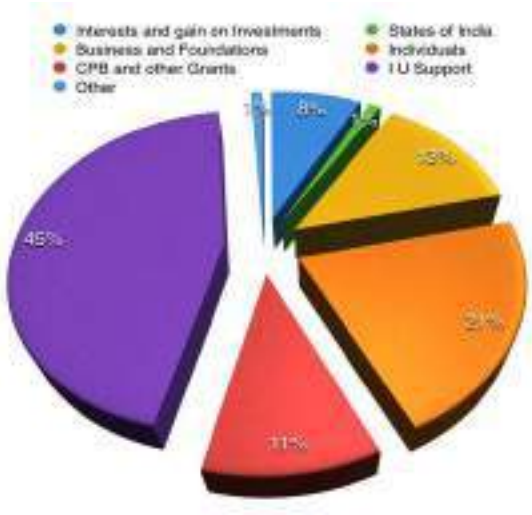

Figure 7. Different funding resources for Community Radio.

Scheduling of Programmes:
Our Community Radio also allows scheduling of programmes at a required specific time. This feature will ensure that we don't need a person for whole day to operate it. We can specify the time at which we want to broadcast an audio track. Scheduling was finalized on 26th Apr but content is yet to be finalized.

Mobile Calling:
A call can be made between the Radio Jockey and a caller (community person asking ques-

tions/requesting songs or any guest on call) which will be heard by listeners live. The software has functionality of offline as well as online calling. Also one can switch between both of them at any time.
Modem and software compatibility for this facility is ready though general setup and testing is still in progress.

SMS Facility:
Listeners can provide us with their valuable response via SMS also. This facility can be used for feedback purpose or for polling purpose. It can be also used as a channel to make a request from listeners' end regarding the content of next programme.

Tracking number of listeners:
The Radio will support the feature of tracking the no. of listeners while broadcasting. This can be helpful in analysing the popularity of a particular type of content among the listeners. This is done by managing the IP address count on the server side.

A screenshot of the UI of the software depicting all the above mentioned features appears in Figure 8.

The first goal was to research different setups of community radio and rule out the best and most compatible one with our environment . This was done by the last year batch.

This year's team finalized the software and completed the setup and installation procedure for web based Radio. The team successfully obtained the source code of software and made some desired changes to improve its functionality and add new features. This work will be continued by the future batches too, undertaking this project.

Several people were interviewed from nearby communities regarding the category of programmes they would like to listen on Radio.

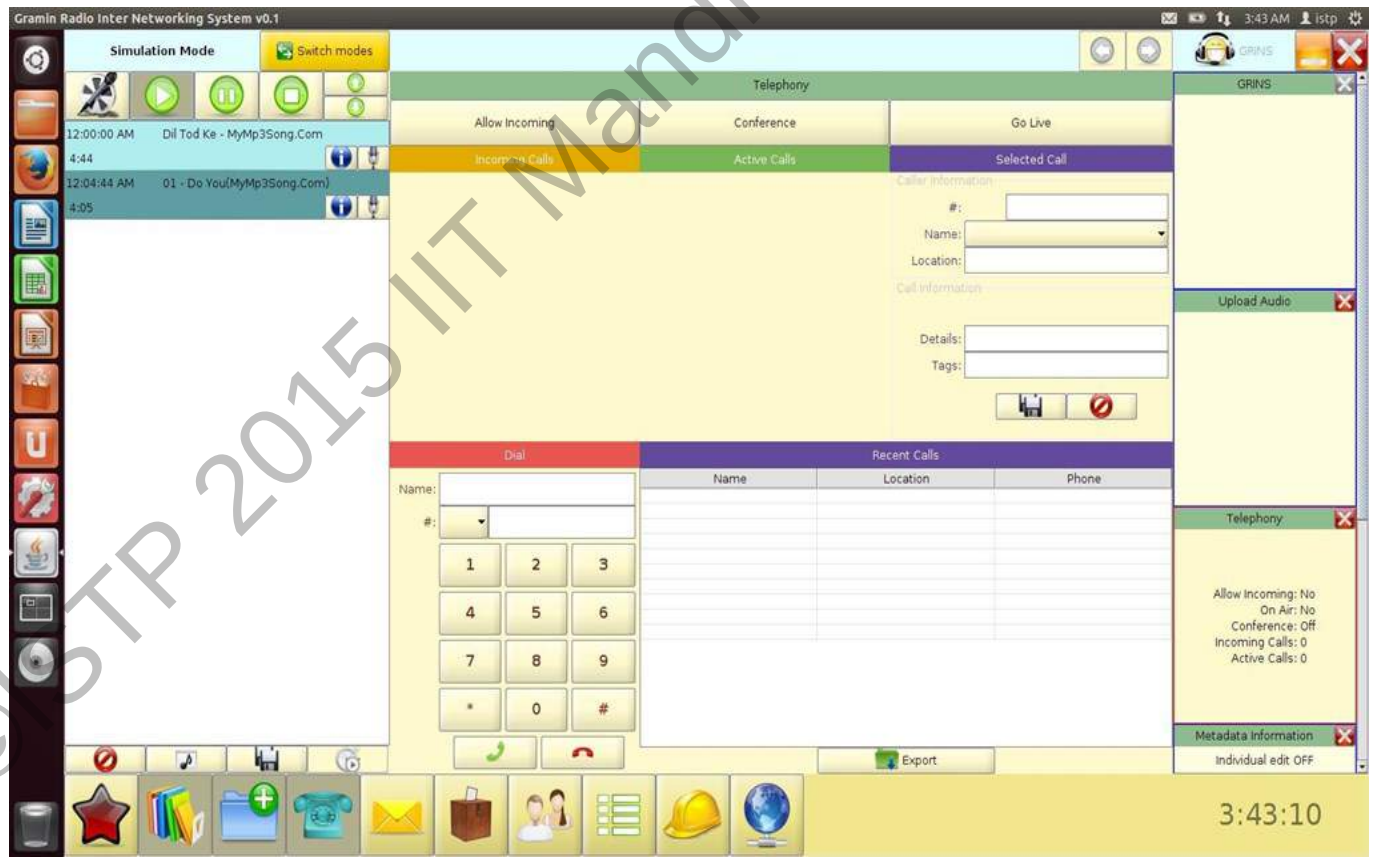

Figure 8. UI of the software used for IIT Mandi Community Radio.

Calling and SMS facility is implemented for community radio so that people can call to make some requests or to get information in particular areas.

Various channels to apply for funding of equipment were explored. The next step in this project will be to now setup a terrestrial based community radio and expand it for large audience. This is going to be done by the next upcoming batch.

Acknowledgements

We would like to extend our gratitude towards Mr. Rohit Jain and Mr. Kapil Dadheech from Gramvaani office, to senior Mr. Mohit Kumar, who had previously worked on this project, and our colleague Mr. Sandesh Kumar Singh. We would also like to thank our friends from IIT who showed keen interest in deciding upon the initial content for broadcasting. On an ending note, we could not have completed this project with this ease if our mentors, Dr. Bhavender Paul and Dr Arnav Bhavsar, hadn't been there to guide us.

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