# 2017 WPI/IIT Project Center: Annual Report

## Kamand, Himachal Pradesh, India

### 15 March - 03 May 2017

# The Editorial Team

Raghav Sethi

IIT Mandi

Vadluri Vivek

IIT Mandi

Thomas Brown

WPI

Trevor Gehring

WPI

**Credits**:

Thanks to Connor Hoeckele and Kent Fong for their hand in making this booklet. They were a massive help in time of need. All credits for front and back pictures goes to Chandan Purbia. Also we would like to thank Devika Sethi for her immense help.

# Welcome from the Project Coordinators

The partnership between the Indian Institute of Technology (IIT) Mandi, India, and the Worcester Polytechnic Institute (WPI), Massachusetts, USA, is a prime example of the potential that cross-cultural academic engagement holds in a globalized world. From small beginnings in 2013, the joint projects -- termed the "Interactive Socio-Technical Practicum" or ISTP course in IIT Mandi and the "Interactive Qualifying Project" or IQP in WPI -- this year involved 10 teams, 28 IIT Students, 24 WPI students, 17 IIT faculty mentors, 10 Teaching Assistants, 5 Coordinators, and a number of stakeholders, study participants and support staff from from the local communities too numerous to count!

The programme is motivated by a number of factors: the vision of IIT Mandi that mandates constructive and positive engagement with the local community; WPI's aspiration to foster well-rounded engineers and change agents through project-based learning; the emphasis on interdisciplinarity in both institutions that encourages exploration of the social context in which technology operates; and, of course, the idea that students and mentors working in tandem can apply their technical knowledge to bring about social change.

This year's teams have worked on projects (proposals, prototypes, or both) under the broad theme of **Mountain Ecology and Sustainable Development**. These include projects as diverse as a proposal for the development of a riverside walkway in Mandi town, documentation of food processing and preservation techniques including a solar food dryer, a proposal for the creation of seed banks to preserve indigenous plants, creation of a prototype of a smokeless stove, assessment of drinking water in the region, suggestions for food waste management on campus, awareness raising about natural disasters such as earthquakes and human-caused road accidents, and development of a pebble-bed thermal energy storage system. The reports of these projects are compiled together in this booklet.

We hope that these reports will serve not only to document the work done by these teams, but that they will also become important research resources filling the gaps in under-researched areas of vital importance to the Mandi region. We hope these studies will contribute to the sustainable development of this mountainous region of Himachal Pradesh and beyond. We also hope that students who have participated in these projects will be inspired to set up social enterprises and launch initiatives for the benefit of their communities in the years to come and will cherish the lessons and memories of their cross-cultural collaboration.

**Project Centre Coordinators 2017**

WPI: Dr. Fabio Carrera and Dr. Svetlana Nikitina

IIT Mandi: Dr. Devika Sethi, Dr. Dericks P. Shukla and Dr. Aditi Halder .

# Greetings from the Director of IIT Mandi

This booklet containing 10 project reports is the result of collaboration between IIT Mandi and WPI students and represents their joint ISTP-IQP projects. Two elements of the culture of IIT Mandi find full and creative expression in their collaboration: the emphasis on partnership, and the focus on interdisciplinarity. IIT mentors drawn from all four Schools of IIT Mandi have, since 2013, proposed projects on which third year students from both Institutes have focused their energy and attention. This has resulted in the development of prototypes as well as proposals, all derived after extensive field research in rural areas of Mandi disrict and beyond. It has also provided all participating students with an invaluable experience of working in an inter-cultural environment, of getting deeply involved in the lives of the people among whom they will spend formative years or memorable weeks, and of developing sensitivity to the close linkages between society and technology. With the support of Catalyst (IIT Mandi's technology-business incubator), it is both desirable and likely that several of these projects will outlive the duration of the ISTP course, and will find new avatars as social enterprises geared towards social

good. The EWOK (Enabling Women of Kamand) project, which has its origins in two ISTP projects, has come to fruition this year as campus residents patronize services (ranging from catering to tailoring) provided by women of the local community. This is the first major real-world outcome of the ISTP, and I hope it will serve as a source of inspiration to students participating in the course.

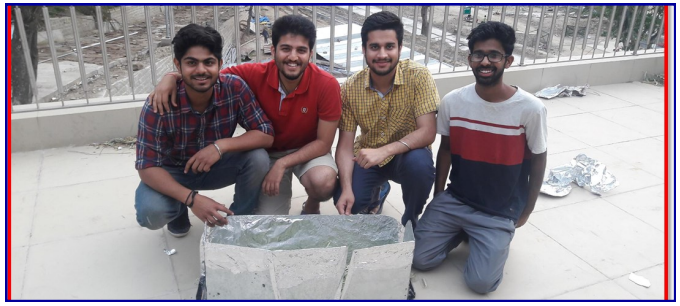
I am sure that participating WPI students from the USA will cherish the memories of this unique 'participant observation' that they have undertaken, immersed as they have been in an academic culture and way of life very different from their own, in a uniquely beautiful part of India. I hope IIT students will, armed with a deeper knowledge of rural India that they have acquired through this course, apply their technological expertise to benefit causes larger than themselves.

I convey my best wishes to all participating students, and congratulate faculty mentors and the coordination team on the successful culmination of the programme.

- Timothy A. Gonsalves

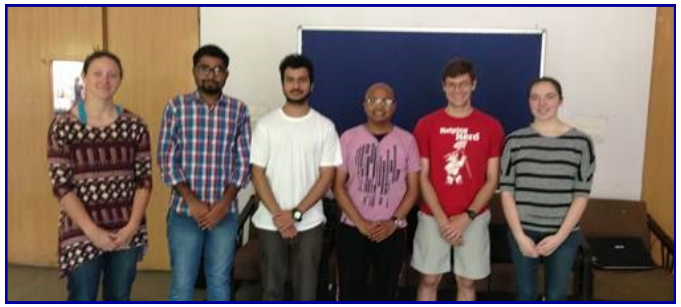
(Director of IIT Mandi)

# Table of Contents

# Table of Contents

# Table of Contents



# Improving Water Quality Treatment and Monitoring Techniques in Rural Himachal Pradesh Villages


## Abstract

The goal of our project was to assess water quality, monitoring, and treatment methods in rural Himachal Pradesh villages. To realize this goal we assessed local perceptions and behaviors regarding drinking water. We then investigated the relationship between local water quality and regional health. Finally, we assessed the levels of water contamination. This project resulted in recommendations to revise current water quality monitoring, a public awareness prototype to increase accessibility of water quality data, and a water treatment prototype that aims to improve water quality within two villages.



***Team Members:***

Amod Choudhary, IIT

Rishabh Kumar, IIT

Kent Fong ,WPI

Evelyn Grainger , WPI

Randy Melanson, WPI

Daniel Salisbury, WPI

***Advisors:***

Dr. Aditi Halder, IIT

Dr. Ramna Thakur, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

WPI

Indian Institute of Technology Mandi

## Introduction

India has significant ground and surface water pollution in both rural and urban areas. Agricultural and industrial chemical runoff and improper sewage treatment are major contributors to this pollution. It is estimated that water contamination causes the death of up to 500,000 children under the age of five annually (Ganapati, Mudur). It is necessary to control pollution and to set up a more strict water quality monitoring system to reduce the instance of disease. Developing communities, especially in rural areas in India, often lack the ability to effectively monitor and maintain good quality drinking water.

There are many rural villages in the Mandi district of Himachal Pradesh that currently lack the infrastructure to monitor and maintain drinking water quality. The Irrigation and Public Health department (IPH) is responsible for testing and monitoring for twelve potential water contaminants annually or biannually. With only one to two yearly tests, it is not feasible to get a clear and consistent view of the overall water quality in these villages.

Many rural villages depend on three main sources for drinking water: groundwater from government hand pumps, tap water from the government distribution system, and untreated natural water from springs. Despite public preference for untreated natural sources, the government only treats and monitors hand pumps and the distribution system. Untreated natural sources may contain dangerous contaminants unknown to the residents. Thus, in rural villages, there is a need for monitoring of untreated natural water sources to determine if public water supplies are safe to drink.

These three results have the potential to be scaled up to the block or regional level to improve water quality treatment in additional rural villages in Himachal Pradesh. **This study is intended to assess water quality treatment and monitoring in rural Himachal Pradesh villages.** To accomplish this goal we **assessed local perceptions and behaviors regarding drinking water**. We then **investigated the relationship between local water quality and regional health**. Finally we **quantified the levels of water contamination**. By accomplishing these three objectives we provide a more complete water quality assessment of rural villages than is possible through the current practices. From this information we **developed and implemented a public awareness campaign**, **provided recommendations to improve current testing**, and **designed a water treatment prototype** that aims to improve water quality within the two villages.

## Background

Two rural villages of the Mandi district were identified for the purposes of this study: Salgi and Neri. The yellow and purple faucets on Figure 1 represent the locations of Salgi and Neri respectively while IIT Mandi South Campus is represented by the blue faucet. The rural villages depend on the government distribution system, ground water, and untreated natural sources for their drinking water. Table 1 provides additional information regarding population size and number of drinking water sources by type.


Figure 1: *Map identifying locations of Salgi, Neri, & IIT-Mandi*

| Village | Approximate Population | Identified Water Sources |
|---|---|---|
| Salgi | 160 | • 1 government distribution system from natural spring<br>• 3 ground water hand pumps |
| Neri | 100 | • 2 natural springs<br>• 1 ground water hand pump<br>• 1 surface water (tributary of Uhl River)<br>• 1 government distribution system |

*Table 1: Community population & water sources*

The map in Figure 2 indicates the locations of the three major types of drinking water sources: government distribution systems, ground water hand pumps, and untreated natural sources.

*Figure 2: (Left) Map of Salgi, (Right) Map of Neri*

Water contamination for these drinking water sources can be categorized as bacteriological, chemical, or physical. Given that bacteria and chemicals are the more dangerous and problematic contaminants we elected to only focus on those.

### *Bacteriological Contamination*

The number of harmful and benign microorganisms within a water sample defines bacteriological contamination. Many harmful microorganisms originate from human and animal fecal waste, causing gastrointestinal illnesses. One gram of feces can contain 10 million viruses, 1,000,000 bacteria, 1,000 parasite cysts and 100 parasite eggs that can have detrimental human health impacts if ingested (Mihelcic, 2009). E. coli is a bacterium that is exclusively found in mammal digestive tracts and can be used to indicate the presence of other disease-causing microorganisms. This study measured bacteriological contamination by determining the presence of E. coli in drinking water sources in Salgi and Neri.

### *Chemical Contamination*

This study also quantified chemical contamination. Organic chemicals are often found in water as a result of human activities that include agriculture and industry. Inorganic chemicals are often present in water due to drilling and mining that releases naturally occurring, but toxic, heavy metals. Organic and inorganic chemicals are dangerous to health and result in a multitude of diseases, generally from long-term exposure. We focused on the chemicals parameters tested by the Irrigation and Public Health (IPH) that are dependent on the concentration of organic and inorganic ions in water. The parameters chosen from the IPH included hardness, alkalinity, and conductivity.

### *IPH Water Quality Monitoring in Mandi District*

Water quality standards created by local or national governing bodies regulate the maximum levels of contamination allowed in drinking water sources. In the Mandi region, the IPH is in charge of monitoring water sources for contamination levels. To measure water quality, the IPH conducts a chemical analysis twice a year, and a bacterial analysis once a year. This testing includes three sampling sites in Salgi and two sampling sites in Neri. The IPH, however, only conducts water quality testing on official government-operated water sources. Government sources include tanks, distribution systems and hand pumps but not the untreated natural waters sources.

### *Known Water Treatment Techniques in Mandi District*

In developing rural areas such as Salgi and Neri, people often collect drinking water from untreated natural water sources. Untreated sources are risky because they frequently contain bacteriological contamination that manifests in gastrointestinal illnesses. To reduce morbidity, the water source itself may be purified, or contamination may be reduced at the point of use. Methods of treatment that purify contaminants at the point of use have been proven to be more effective and economically effective at reducing diarrheal illnesses than treatment at the water source. In Mandi District, chlorine and heat are two locally available technologies that disinfect water. These technologies are considered for the water treatment prototype discussed in the recommendations.

#### *Chlorine*

Chlorine is an effective and affordable disinfection method. Chlorination is most effective at treating water sources with a low turbidity and a pH lower than 8. Disinfection by chlorine occurs via primary disinfection and secondary disinfection. The primary disinfection inactivates microbiological activity and the secondary disinfection refers to the residual chlorine that remains in treated water. Residual chlorine is preferable to protect against future contamination.

#### *Heat*

Heat is another effective disinfection method and it does not require the use of chemicals such as bleach that can leave an undesirable taste. Boiling water destroys all types of microorganisms by raising the water temperature to 100°C. This approach ensures that the water is safe but requires enough energy to effectively heat the water sample. Additionally, it does not prevent future biological growth.

Water only has to reach 70°C to kill most microorganisms. The point at which bacteria die is called the pasteurization temperature. Devices have been created that help indicate when water has reached the pasteurization temperature. These devices have solidified wax that is situated at the top end of a tube. Once water has reached 70°C, the wax falls and the heat has killed the bacterial contamination in the water, indicating that the water has been pasteurized. A water pasteurization indicator (WPI) is considered for a water treatment design in the Recommendations section.

## Methodology

Three objectives were identified in order to complete an assessment of drinking water quality in Salgi and Neri. The three primary objectives investigate the perceptions and behaviors regarding water quality, the water-health relationship in the villages, and the water quality of the various sources. The objectives and methodologies can be found in Figure 3.

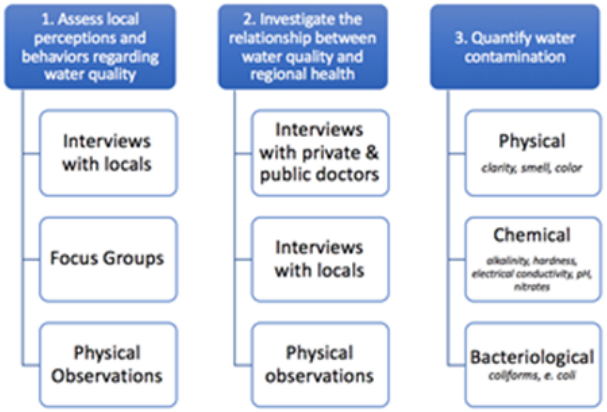



*Figure 3: Objectives and Methodologies*

### *Assessing Local Perceptions and Behaviors Regarding Drinking Water Quality*

Local perceptions of drinking water can help reveal behaviors that may be affecting water quality. To assess the perceptions and behaviors of the villages, we conducted interviews, a men's focus group, surveys with local schools and IIT-Mandi students and faculty, and recorded observations of how people interacted with their water sources.

### *Assessing the Government Approach to Water Quality*

The IPH is responsible for the development, operation, and maintenance of drinking water supply schemes. We interviewed two people, Mr. Hemraj Thakur, senior chemist, and Miss Aprajita, consultant chemist, at the IPH to learn more about the government's involvement in protecting water quality.

### *Perceptions in Rural Villages (Salgi & Neri)*

Surveys and physical observations were conducted at nineteen homes in the rural villages of Salgi and Neri. Figure 4 outlines the objectives and types of questions asked within the household interviews. Physical observations provided supplementary information to our interviews.

### *Investigating the Relationship Between Water Quality and Health*

To understand the relationship between water quality and local health we interviewed doctors at three medical clinics: a private medical doctor in Salgi, a doctor at IIT-Mandi Medical Unit, and a few medical doctors and lab technicians at the Community Health Center in Kataula. The medical doctor in Salgi provided information about the frequency of waterborne diseases in the immediate area. Dr. Neha Sood at the IIT-Mandi Medical Unit provided insight into regional health concerns. In addition, the doctors and lab technicians at the Community Health Center in Kataula shared information about the frequency of waterborne diseases and explained the existing public awareness campaigns that prevent these diseases. From these interviews we gathered a holistic perspective on how water quality may be impacting regional health and the measures currently being taken to prevent these diseases.


*Figure 4: Interview objectives and example questions used to achieve the objectives of each inter-*

## Assessing Water Contamination

Drinking water from a variety of different sources was collected and tested for overall quality. Our testing included existing sampling sites from the government testing program and also expanded to include untreated natural sources. Figure 5 shows a map of the sampling locations for chemical and bacterial testing.


*Figure 5: (Left) Testing locations of Salgi, (Right) Testing locations of Neri*

To quantify water chemical contamination our study analyzed existing government data and tested nineteen sources pre and post rain for four different chemical parameters. Tests were conducted within the IIT-Mandi Kamand chemistry lab with the assistance of IIT PhD teaching assistant, Ashwin Sharma. The standard methods for water quality testing were followed for alkalinity and hardness via titration. pH and electrical conductivity were measured using probes.

Bacteriological contamination was assessed based on Bactaslyde Microbe Detection (BMD) devices. The BMD devices to measured total bacterial colonies and E. coli colonies. The total bacteria test was measured by red dots on a yellow medium while E. coli was measured by yellow or clear dots on a purple medium. Counting the colonies on each medium allowed bacteriological contamination to be quantified. An example of the BMD devices can be seen in Figure 6. The six tests and information about each test can be found in Table 2.

*Figure 6: (Top) Total Bacteria indicator (Bottom) Total E. coli indicator*

| Water Quality Parameters | |
|---|---|
| **Alkalinity**<br>**Rationale:** Indicates the ability of water to buffer pH changes<br>**Limit:** 600 mg/L<br>**Health Impact:** Reduce stomach acid which reduces the ability for the stomach to prevent harmful pathogens from entering blood-stream, can degrade pipes lead- | **Hardness**<br>**Rationale:** Measurement of magnesium, calcium, and other dissolved ions concentrations<br>**Limit:** 600 mg/L as $CaCO_3$<br>**Health Impact**: No known health impacts unless water is soft & causes degradation of pipes leading to metal contamination |
| **pH**<br>**Rationale:** Indicates how acidic or basic water is, can be indicator of large chemical contamination<br>**Limit:** 6.5-8.5<br>**Health Impact:** N/A, indicator of other contamination | **Electrical Conductivity**<br>**Rationale:** Large increases or decreases can be indicative of contamination<br>**Limit:** 800<br>**Health Impact:** N/A, Indicator of other contamination |
| **Total Bacteria**<br>**Rationale:** An indicator for potentially harmful bacterial contamination<br>**Limit:** N/A<br>**Health Impact:** Potential gastro-enteritis, cholera, typhoid, vomiting depending on type of bacte- | **E. Coli**<br>**Rationale:** An indicator for fecal contamination that carries harmful bacteria<br>**Limit:** 0<br>**Health Impact:** Potential gastroenteritis, cholera, typhoid, vomiting, diarrhea |

*Table 2: Water Quality Parameters*

## Results

The results of our seven-week study indicate a **community dependence on drinking water that is not treated or monitored.** This conclusion is based upon our findings of:

**1. Village dependence on untreated natural water**

**2. Failure of the government to monitor untreated natural sources.**

**3. Natural sources have significant levels of bacteriological contamination**

**4. Lack regular water treatment practices**

### *Village Dependence on Untreated Natural Water*

74% of people in Salgi and Neri rely on untreated natural sources for their drinking water. When residents were surveyed about drinking water, they indicated a strong satisfaction with drinking water. 92% of village members in Salgi and 100% of village members in Neri liked the taste of their drinking water. Additionally, the majority of residents positively ranked water quality, indicated by green, as a 4 or higher on a scale from 1-5 as seen in Figure 7. Many residents noted that families have relied on untreated natural water sources for generations and that saw no apparent need to break this habit.

*Figure 7: When asked to rank their drinking water on a scale of 1-5, with 5 being the best, most village members ranked their water a 4 or above.*


### *Lack of Government Monitoring of Natural Sources*

Upon surveying villagers and comparing the results to government data, it is clear that the IPH is not monitoring an important source of drinking water, the untreated natural sources. Government data suggests that drinking water quality for Salig and Neri is of good quality, but it fails to monitor untreated natural sources. This gives an incomplete and inaccurate representation of water quality in Salgi and Neri. Figure 8 shows the government testing locations.

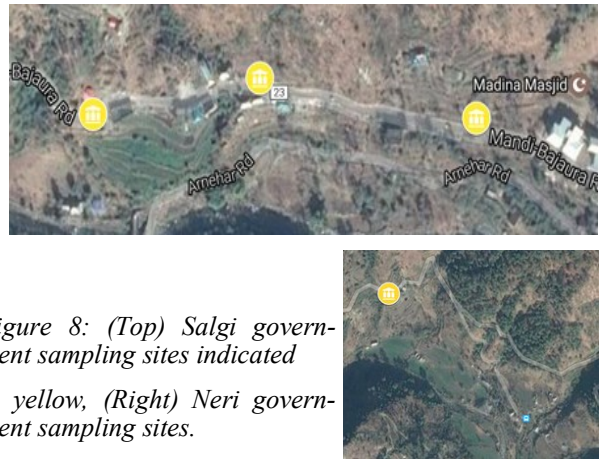



*Figure 8: (Top) Salgi government sampling sites indicated in yellow, (Right) Neri government sampling sites.*

### *Natural Sources Have Significant Levels of Bacteriological Contamination*

Bacteriological testing for E. coli and total bacteria indicated harmful contamination for natural water sources in Salgi and Neri. While the study was limited to five coliform and five E. coli tests, the results show an alarming and significant difference between the levels contamination in natural sources from the levels of contamination in government and groundwater sources.

Total bacteria tests indicate low bacterial contamination in Neri Natural Source A and Salgi Natural Source B, and high total bacterial contamination in Salgi Natural Source A. The government

and hand pump sources, however, did not show any bacterial contamination. Figure 9 depicts the results of the total bacteria tests, with colonies indicated by red dots on the yellow testing medium.

E. coli appeared only in natural water sources. Similar to the total bacteria test, the E. coli test yielded no contamination for the government or groundwater sources. Salgi Natural Source B had no E. coli contamination, but the other two natural sources had high levels of contamination. The results of the bacteriological tests and the corresponding health risks for each source are shown in Figure 9 and Table 3 respectively.

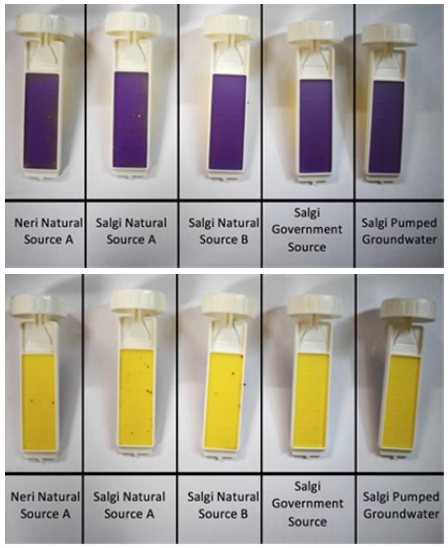



*Figure 9: (Top) Results of Total Bacteria Test, (Bottom) Results of E.Coli Test*

| Source | Total Bacteria (# colonies) | Total E. Coli (# colonies) | Risk Level from Bacteriological Contami- |
|---|---|---|---|
| **Neri Natural** | 2 | 11 | High |
| **Salgi Natural** | 33 | 51 | Very High |
| **Salgi Natural** | 3 | 0 | Low |
| **Salgi Government** | 0 | 0 | None |
| **Salgi Pumped Groundwater** | 0 | 0 | None |

*Table 3: Bacterial Contamination and Corre-*

### *Chemical Tests Suggest Possible Nitrate or Iron Contamination*

Chemical testing results indicated **soft water**, with results suggesting **potential additional contamination such as iron and nitrates.** All drinking water sources had hardness values ranging from 16 to 46 ppm. Table 4 shows levels of hardness as ranked by the World Health Organization. Very soft water can be corrosive to metal pipes and storage containers. Many of the pipes observed in the villages that contained running water were brown and rusted on the inside. When compared to alkalinity, the hardness was much higher which indicated possible contamination of nitrates from human waste and fertilizers or iron from rusty pipes. This hypothesis is also supported by the high readings for conductivity. Conductivity is usually twice the magnitude of hardness, but was found to be 6.8 times the hardness. This again points to contamination from nitrates or iron. These tests show **possible chemical contamination but the primary health concern still lies in bacteriological contamination.**

| Water Hardness | |
|---|---|
| **Calcium car-** | **Designation** |
| 0-43 | Soft |
| 43-150 | Slightly Hard |
| 150-300 | Moderately Hard |
| 300-450 | Hard |
| 450 | Very Hard |

*Table 4: Water Hardness levels by ppm of calcium*

### *Lack of Regular Water Treatment*

While both our chemical and bacteriological water quality testing have indicated that some contamination exists in natural sources, villagers in both Salgi and Neri infrequently treat their water. As shown in Figure 10, the majority of villagers do not regularly boil. However, more than 75% of the village has reported boiling water for various reasons within the last year. This suggests that the **village residents have the technical capacity to regularly boil drinking water but choose not to.**

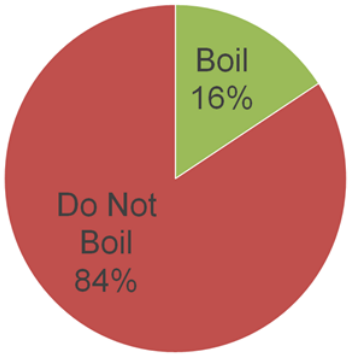



*Figure 10: Majority of villagers do not boil regularly*

### *Medical Officials Encourage Boiling Water*

All **medical officials** interviewed in this study believed a **relationship between water quality and public health is evident**. Although none of the medical officials reported any cases of cholera, they reported many cases of typhoid, gastroenteritis, vomiting, and diarrhea. If a patient were suffering from a waterborne illness, the doctors recommend boiling water to reduce the bacteriological contamination of drinking water. Although each medical official cautioned against drawing a clear and definitive relationship between water quality and health, they indicated observable increases in water-related illnesses during the rainy season due to decreased water quality.

### *Local and National Government Encourage Water Treatment*

Interviews with the Kataula Government Medical Office and the Department of Mass Education indicated how the government encourages regular water treatment. An awareness campaign called *Integrated Diarrhea Control Fortnight* (IDCF) is run during July when waterborne illnesses peak. The campaign focuses on methods of improving water quality through practices such as boiling water, using chlorine tablets, washing hands and storage containers. Local government schools have taken measures to encourage regular water treatment but the village surveys indicate an apparent lack of treatment. It can be concluded that the **lack of treatment is not from insufficient education but rather from lack of awareness about water contamination in untreated natural sources**.

## Recommendations

From the results it is evident that there must be an improved water quality testing program to promote public awareness regarding the safety of untreated water sources. The following recommendations will improve upon current water quality monitoring and treatment:

**1. Revised drinking water testing scheme for IPH**

**2. Effective communication of IPH water quality results to villagers**

While these recommendations are based on data for Salgi and Neri, these recommendations can be extrapolated to improve the drinking water quality of other rural villages in Himachal Pradesh.

### *Revised drinking water testing scheme for IPH*

**We recommend that the IPH department communicate with villages to determine the water sources which are**

**most commonly used.** To identify the water sources that a village relies on, we recommend using similar metrics such as the household surveys used in this study or alternatively to collaborate with the panchayats of each rural village. Although identifying the proper water sources to monitor will be time consuming, it will allow the water quality tests to get a more accurate representation of the drinking water in the villages.

**The IPH should also expand testing parameters to include E. coli and nitrates**. Currently the IPH tests for total coliform but E. coli is a more meaningful indicator for bacterial contamination. Testing for nitrates will also help indicate possible sources of contamination. Identifying the source of contamination will allow villages to reduce pollution in drinking water.

**Drinking water sources should be tested and monitored more frequently**. Currently the IPH test water sources annually or biannually, but bacteriological contamination can vary greatly with seasonal shifts. Thus, it is recommended that the IPH test drinking water sources at the beginning of every season in order to properly track pollution throughout the year.

*Effective Communication of IPH Water Quality Results to Villagers*

**The IPH should work with the local panchayat to publish results of water quality data**. Many residents are knowledgeable about boiling water but do not practice this treatment method because water may appear safe. For communities relying on natural sources, the IIT-WPI designed **Water Quality Stoplight** should be implemented. This design will include the most recent and future dates of the IPH tests. Based on the most previous test, the water will be assigned a color, green for safe, yellow for caution, and red for unsafe. Beside this sign will be a legend that reminds community members to properly treat water if the sign reads yellow or red. This design will effectively **inform the villages about the risks of drinking water from untreated natural water sources**.

### *Future Testing*

The chemical tests of drinking water sources in Salgi and Neri show evidence of soft water. Soft water is generally safe but can be corrosive to pipes and hand pumps. Based on the physical observation in the villages, many of the pipes were rusted which may have resulted from the water hardness. A degraded pipe can be viewed in Figure 11. A further study should **investigate if pipes are corroding faster than expected** due to this chemical property of the water.

Physical observations showed that villagers stored water in recycled chemical barrels. **Testing for heavy metals should be conducted** on these barrels to ensure safety. To eliminate the need for testing, the **local panchayat should ensure that no residents are using these barrels** to store water. Figure 12 shows an image of a barrel that one resident was using to store drinking water.

*Figure 11: Rusting pipes*

*Figure 12: Chemical barrels*

If communities still rely on untreated natural water sources after implementation of the Water Quality Stoplight there should be an investigation into a home-level water treatment device. Potential water treatment devices for the household level include: water pasteurization indicator (WPI) using local materials, solar filtration (SOFI) prototype, and chlorine tablets. A preliminary design and decision matrix of these technologies is can be seen in Table 5.

| Drinking Water Treatment Method | Water Pasteurization using WPI Prototype | SOFI Water Treatment | Chlorination |
|---|---|---|---|
| Description | Small plastic tubing with local wax on the interior, weighted on one end to be placed in water to indicate when water has reached pasteurization point | 3 part system (1) a black holding compartment for solar treatment (2) plastic container with sand, gravel, and activated charcoal filter, (3) clay pot holding container | Tablets that are designed to be used per specified number of liters |
| Cost | ~$2 for WPI<br>Energy for boiling depends on heating | ~$15 for initial<br>~$1.50 every 3-4 weeks for activated | Free at government hospital<br>*(transportation* |
| Time for Treatment | 10 minutes, additional time for water to cool to room temperature | 1/2 day | 30 minutes |
| Difficulty to Properly Treat | Low: need to know how to properly use indicator | Medium/Hard: need to know how to clean/ change multiple layers, valve and maintenance | Medium: need to use proper amount of chemical per volume of |
| Taste | No change in taste | No change in taste | Changes the taste of water sources |

*Table 5: Decision matrix for future investigation into at home treatment methods*

## Acknowledgments


- Our team would like to thank the following people for their assistance and guidance during the course of our project:
- Our mentors Dr. Fabio Carrera, Dr. Aditi Haldar, Dr. Svetlana Nikitina, and Dr. Ramna Thakur for their valuable guidance during the course of this study
- Our teaching assistant Ashwin Sharma for his assistance in the laboratories
- Technical assistant Pallavi Sharma for guiding us in the IIT-Mandi chemistry laboratory
- The villagers of Salgi and Neri who generously donated their time to participate in this study

## References


Department of Drinking Water and Sanitation, India. (n.d.). *Strategic Plan 2011-2022*.

Droste, R. L. (1997). *Theory and practice of water and wastewater treatment*. John Wiley & Sons Incorporated.

Gray, N.F. (2010) Water technology (third edition): An introduction for environmental scientists and engineers. Waltham, Massachusetts: Butterworth-heinemann

Chuang, P. (2010). *Comparison of EC-Kit with Quanti-Trayo: Testing, Verification, and Drinking Water Quality Mapping in Capiz Province, Philippines* (Doctoral dissertation, Massachusetts Institute of Technology).

Mihelcic, James R. Fry, Lauren M. Myre, Elizabeth A. Phillips, Linda D. Barkdoll, Brian D.. (2009). Field Guide to Environmental Engineering for Development Workers - Water, Sanitation, and Indoor Air. American Society of Civil Engineers (ASCE).

Ministry of Drinking Water and Sanitation (2013) *Movement towards ensuring people's drinking water security in rural India framework for implementation* 2011-2022.

Ministry of Drinking Water and Sanitation (2007). *Movement towards ensuring people's drinking water security in rural India framework for implementation* 2008-2012.

National Rural Drinking Water Program. (2016). *Format C17 B-Newly Emerged Contamination Wise Report* [Data file] Retrieved from http://indiawater.gov.in/IMISReports/Reports/WaterQuality/rpt_WQM_HeavyMetalsContminatedHabs_S.aspx?Rep=0&RP=Y

Planning Commission. (2014). Himachal Pradesh Development Report. Government of India, Chapters, 1(3), 13.

# Viability of Improved Chulhas in Himachal Pradesh


## Abstract

Generations of rural village inhabitants of Himachal Pradesh have used "chulhas," a traditional cook stove, often homemade from clay and cow dung, that burns wood as fuel for cooking and heating homes. Our project investigates the viability of improved prototype chulhas in Himachal Pradesh. We tested two prototype chulhas ourselves before asking local stakeholders to test them and provide us feedback about its design and usability. We then designed and assembled a prototype chulha, based on the feedback received from locals about the existing prototypes and our own test results. Finally, we questioned the practicality of improved chulhas in this region based on our findings, India's increasing LPG use, and India's ongoing infrastructure development.



***Team Members:***

Varun Bansal, IIT
Shane Bell, WPI
Trevor Gehring, WPI
Akash Kushwaha, IIT
Connor Hoeckele, WPI

***Advisors:***

Professor Fabio Carrera, WPI
Professor Svetlana Nikitina, WPI
Dr. Atul Dhar, IIT
Dr. Satvasheel Powar, IIT



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

WPI

Indian Institute of Technology Mandi

## Introduction

Even today, in many parts of the world, the simple act of cooking a meal poses a health risk to people as well as the environment. The World Health Organization (WHO) estimates that over four million people die prematurely from illnesses due to smoke inhalation produced by cooking fires.

In India, according to a 2004 study, most rural households burn biomass fuels for cooking. Biomass fuels, such as wood, are conventionally burned in homemade clay stoves or steel stoves, called 'chulhas' (Anuj, 2004). The combustion of these biomass fuels is often incomplete because of the inefficient design of traditional chulhas. Cooking with chulhas in the home generates pollutants that, unvented, can cause a plethora of life-threatening diseases.

Organizations and businesses have brought a range of safer and cleaner burning stoves to market. An effort has been made to sell these stoves at a range of prices to the rural Indian population. Progress in the private sector has been slow, and to date these efforts have not been successful (Bhojvaid, 2014). Recent government subsidies on liquefied petroleum gas (LPG) stoves have increased improved cook stove use throughout the country (Jain, 2016).

The district of Mandi, Himachal Pradesh, India, is made up of a primarily rural population who seem to gravitate towards traditional cooking methods using "unsafe" chulhas (Jeuland, 2015). To offset the negative effects of chulhas and increase the accessibility of improved cook stoves, the Indian government launched the social welfare program *Pradhan Mantri Ujjwala Yojana* on May 1st, 2016. The act provides government subsidies on LPG canisters and stoves to families below the poverty line. The act ultimately aims to transition at least fifty million people to cleaner and safer cooking technologies (Indian Government, 2016).

One previous Interactive Socio-Technical Practicum (ISTP) study at the Indian Institute of Technology Mandi (IIT Mandi) addressed the health effects related to chulha use. However, this study did not address the practicality of chulhas in a changing Indian society. The goal of our project is to assist in determining the viability of improved chulhas in Himachal Pradesh. We laid out three objectives that will guide us to the successful completion of our goal:

1. Assess the demand for an improved chulha
2. Identify low cost enhancements to improve a chulha
3. Test and implement chulha enhancements.

## Background

Before conducting fieldwork for this project, we completed background research regarding the current methods of cooking in Himachal Pradesh and the issues associated with them. We also investigated how the region of Himachal Pradesh is changing with respect to LPG use and infrastructure.

In Himachal Pradesh, the traditional stove used for cooking is called the *chulha*. Chulhas are typically placed on the floor inside the home. Some, but not all, households have a separate room for cooking. The most basic form of the chulha is a bowl with a u-shaped slot. Chulhas are commonly constructed from a mixture of clay and cow dung. An example of a traditional chulha can be seen in Figure 1. Note that there is no ventilation of the smoke produced from burning biomass fuels within the homes. The main fuels used in chulhas are wood and cow dung, both considered biomass fuels. Biomass fuel types produce a wide range of pollutants that can affect everyone inside the home, whether they are the ones cooking or not (UNDP, 1997). A more advanced chulha design can be seen in Figure 2. It is a hollow block with several openings allowing for multiple cooking surfaces. This design also includes an oven. Some more advanced chulhas include chimneys to help ventilate smoke out of the home. Neither traditional design is effective or efficient. The basic chulha's main flaw is its open fire cooking, requiring large amounts of wood to maintain cooking temperature. The more advanced chulha addresses this flaw, but has limited airflow. Chulhas have now been surpassed in design by other types of stoves that use cleaner burning fuel sources and are far more efficient.

*Figure 1. Basic Chulha*

*Figure 2. Advanced Chulha With Chimney* **(chulha.org)**

### *LPG Stoves – Increasing in Popularity*

In Himachal Pradesh, LPG stoves have become the desired improved cook stove to use alongside traditional chulhas. In our visit to Bagi Village, where no families currently had access to LPG stoves, some families said they would prefer to use an LPG stove. It shows that the families knew about LPG stoves, but they simply did not have the means to acquire one. The PMUY social welfare act subsidizes LPG canisters for Indian households at an affordable rate. The goal of this act is to increase access to LPG cooking for households below the poverty line (BPL) (PTI, 2016).

In March of 2015, Prime Minister Shri Narendra started a campaign called "#giveitup" to persuade those who could pay market price for LPG canisters to give up their government subsidies (Indian Government, 2015). With the upper and middle classes giving up their government subsidies, more and more money was freed up in the national budget for the less fortunate (PTI, 2016). Government subsidies will help BPL households transition from their use of chulhas and biomass fuels to LPG stoves for cooking.

The PMUY act caters directly to BPL families and set requirements to ensure subsidies are exclusive to BPL families. There are three main requirements for the act (BankBazaar, 2016):

1. One subsidy would be provided per household.
2. A female, over the age of 18 from the house must register in her name for the subsidy.
3. The household must be registered as a BPL household with the government.

The PMUY act will be effective from 2016 to 2019 and is projected to influence over 5 million households (Jain, 2016). However, even with the current act and those that have come before it already in place, LPG stoves have not completely phased out chulhas.

A 2015 study has found that the rural population of Himachal Pradesh follows a system called 'stove stacking' (Wang, 2015). The basis of this system is the continued use of traditional biomass burning chulhas, alongside the use of the new improved cook stoves. While conducting surveys, we found that 63% indeed follow this practice of owning both an LPG and a chulha, a much greater percentage than we anticipated.

There are several different theories as to why LPG stoves have not completely superseded chulhas as the primary stove used by the rural population of Himachal Pradesh. One theory is that the rural population does not know the environmental and health effects of burning biomass fuels. The population assumes that renewably harvested biomass fuels do not harm their surrounding environment. According to a study at the beginning of the century, they believe carbon released through the burning of biomass fuels is entirely recycled through photosynthesis (Smith, 2000). Additional theories take into account economic, geographic, and social factors that prevent LPG stoves from entirely replacing the chulha.

Even with government subsidies, LPG prices can be still too high for BPL families. According to a recent survey, 95% of BPL households without LPG connections cite their inability to pay as the main reason for not using an LPG stove (Jain, 2016). Most households survive on a subsistence level. The yearly income per household for the Himachal Pradesh region is about 1000 USD (India Census, 2015).

Another reason why LPG's have not completely replaced chulhas has to do with the geography of Himachal Pradesh. Traveling in Himachal Pradesh can be time consuming due to the mountainous terrain. Furthermore, during monsoon season, many roads become dangerous to the point that driving is not feasible. Delivering LPG canisters to remote villages is always difficult and occasionally impossible (Jain, 2016). Availability and access can make the preference for chulhas over LPGs for a rural household easy.

Social factors also play into why the region has not converted to LPG stoves exclusively. Lack of awareness about the PMUY act is negatively impacting the conversions in the most rural areas of the region. About 40% of households in the rural regions of the country that do not have LPG stoves entirely lack the information about the act and its benefits or lack the information pertaining ways of obtaining a subsidized LPG connection (Jain, 2016).

Finally, LPG stoves can also fail to meet households' culinary preferences, which are tied to the use of traditional chulhas. The chulha is valued for its perception that food cooked on the chulha has superior taste, an opinion strongly held especially by elders (Wang, Y., 2015). This social factor can possibly explain why some households in Himachal Pradesh still retain a chulha even though they also own an LPG stove.

### *Health Risks Associated with Burning Biomass Fuels*

India's indoor air pollution is an environmental problem and a major health problem. In developing countries, biomass fuels burned in stoves within households create dangerous pollutants (Arora, 2014).

Nearly 50% of the world's population and 75% of Indian households bum biomass fuels - primarily wood and cow dung (Prasad, 2012). The noxious gases produced from burning biomass fuels in high volumes is a primary contributor to indoor air pollution. The noxious gases also contribute to greenhouse gas emissions in northern India.

Biomass fuels are inefficient, meaning they must be bumed in large quantities to maintain a cooking fire. The efficiency of biomass fuels when burnt in traditional chulhas is typically as low as 10-15% (Perez-Padilla, 2010). In other words, this means that up to 90% of the energy produced by burning biomass fuels is not used for cooking.

Women and children are at the greatest risk for health complications, as they are tasked with cooking in the home. There are many diseases and health effects caused by exposure to pollutants produced by traditional chulha use. Health effects include: chronic obstructive pulmonary disease (COPD), lung cancer, tuberculosis, acute lower respiratory infection, and asthma (Perez-Padilla, 2010, and Forum of International Respiratory Societies Report, 2016). Acute lower respiratory infections and asthma are the two main health complications seen in children. Unbom children in women exposed to pollutants can also develop health issues (Perez-Padilla, 2010). COPD and lung cancer can be diagnosed in individuals as early as 30 years of age. COPD is a major contributor to premature deaths due to smoke inhalation from burned biomass fuels. Lung cancer is primarily found in those who smoke tobacco products and cook with biomass fuels (Perez-Padilla, 2010).

***Difficulties in Supplying LPG's to Rural Villages***

LPG stove users in the region of Himachal Pradesh rely on the availability of LPG canisters. Availability is determined largely by the quality of roads that connect users and suppliers. We believe India's infrastructure, at least in Himachal Pradesh, will continue to develop, which will open the door for those who want to make the switch from chulha to LPG.

In the past five years, hundreds of millions of dollars have been spent for the improvement of Himachal Pradesh roads. Improvements include the paving and widening of existing roads and the construction of new roads. The state government in Himachal Pradesh proposed 188 road projects to receive funding under the *Pradhan Manrti Gramin Sadak Yojana* (PMGSY) act in December of 2015 (Bhandari, 2015).

The PMGSY act is under the authority of the Ministry of Rural Development and aims to provide roads to villages (Government of India, 2004).

1. with a population of 1000 persons and above by 2003
2. with a population of 500 persons and above by 2007
3. in hill states, tribal and desert areas with a population of 500 persons and above by 2003
4. in hill states, tribal and desert areas with a population of 250 persons and above by 2007.

PMGSY is still currently being completed, and its progress can be monitored on *omms.nic.in*. To date, 12,200 kilometers of roads have been built in Himachal Pradesh as a result of PMGSY act (Indian Government, 2017).

In May of 2016, approval was obtained for 17 new national highways in Himachal Pradesh (Press Trust of India, 2016). These 17 national highways will undergo much needed improvements to improve their quality. At the conclusion of the project, the highways will meet the

country's national highway standards.

India's infrastructure is improving, but there is no clear timeline as to when projects like those described above will be completed. However, it is almost certain there will be similar projects in the future. These projects will greatly improve LPG access to the villages of Himachal Pradesh. With increased access to LPG canisters, life in the region will continue to evolve. As more improvements to infrastructure are completed, the once rural region of Himachal Pradesh may become more modernized.

## Methodology

The goal of our project was to assist in determining the viability of improved chulhas in Himachal Pradesh. We laid out three objectives that guided us to the successful completion of our mission:

**Objectives**

1. Assess the demand of an improved chulha
2. Identify low cost enhancements to improve a chulha
3. Test and implement chulha enchancements

### *Assessing the Demand of an Improved Chulha*

To assess the demand for an improved chulha our team, with the help of our teaching assistant Vipul Sharma, identified eight villages to survey. These surveys allowed us to identify what type of stove individuals were using to cook, if the government's subsidies were benefitting the area, and the price that individuals interested in the prototype would be willing to pay. Each interview was conducted in Hindi, a popular local language. Our IIT teammates would translate the responses to our survey questions as the interview was conducted. As we moved from village to village our team made quantitative and qualitative observations of the location and condition of the household. These observations included distance from a main road/India highway, stacks of firewood, new house constructions, LPG canisters, and visual signs of smoke.

### *Identifying Low Cost Enhancements to Improve a Chulha*

We started our testing with two existing prototypes. Prototype #2 has higher air flow rate compared to prototype #1. After initial study, prototype #3 was designed with the intention of further improving the original design. The redesign was based on the feedback received from stakeholder testing and was guided by two primary goals: lowering the price to build the prototype and increasing its manufacturability.

Our group conducted baseline tests of the two existing prototypes to identify strengths and weakness in each design. The data from the testing was compared to determine the more suitable prototype for stakeholder testing and for further improvement. Prototype 2 was determined to be more efficient and was chosen to be used for stakeholder testing. Three tests were performed on the primary burn chamber in each chulha. This consisted of timing how long it took for one liter of water boil over the burn chamber.

Before each test, each stove was brought to cooking temperature. This was determined when the syphons were visually directing smoke up the chimneys. Each test would begin when the smoke exiting the chimney became clear and almost invisible, indicating a good burn. The total time and total weight (in grams) of wood require to complete each test was recorded. At our altitude, which is about 3,500 feet above sea level, we estimated that water boils at ninety-six degrees Celsius. Data was recorded in a notebook. To ensure accuracy between tests each stove was tested once per day to allow each stove to cool down completely after each test. Data was transferred at the conclusion of the testing day into an Excel spreadsheet. The estimated energy output was calculated in this spreadsheet using the recorded data and the specific heat of water.

Stakeholder testing was conducted with construction workers at IIT Mandi's construction site and with local villagers who use chulhas on a daily basis. Each stakeholder household was given prototype 2 for a minimum of 24 hours. Stakeholders were interviewed after the completion of their testing to find out how user-friendly the design was, what benefits and liabilities stakeholders associated with the prototype, and what they would like modified.

### *Testing and Implementing Chulha Enhancements*

While testing was being conducted in stakeholders' homes, our team began building prototype 3 based on testing and user feedback of earlier prototypes. Baseline testing allowed us to determine the better of the two existing prototypes. We had planned to allow stakeholders to test both prototypes, but because of the significant difference in how much wood was burnt and how long each took to get to temperature, we decided only to use prototype 2 for stakeholder tests. The first draft of the design focused on manufacturability of the prototype. Improving manufacturability helped us reduce the cost of prototype 3. The final design also factored in stakeholder feedback of prototype 2.

Prototype 3 was built in the machine shop located on the IIT Kamand campus. Overall construction took about twenty-one hours for a single person. Materials used to build the prototype were sourced from the machine shop or obtained in Mandi Town. Final estimates of the cost to build the prototype were made on the basis of building a single product.

## Results and Discussion

Some of our results from surveying and fieldwork didn't yield what we expected. In fact, what we found from completing our initial field work surprised us. We found that most of the local population uses both chulhas and LPG stoves, contrary to what most previous studies suggested. LPG stoves are used as the primary method for cooking, while chulhas are used seasonally – primarily in the winter when chulhas are needed for heating the home.

### *Objective 1: Demand for Improved Chulhas*

We engaged with stakeholders from forty-three households in eight different villages. The map in (Figure 3) shows seven of the eight locations.

*Figure 3. Map of Survey Locations (Google Maps). 2017.*

In response to a question asking if they use a chulha or LPG stove for cooking, we found that only 2% of households use solely LPG for cooking, whereas 35% of stakeholders use only chulhas. 63% of stakeholders surveyed use both a chulha and LPG stove for cooking (see Figure 4). Therefore, 98% of the households we engaged with use a chulha for some kind of cooking. We then became curious as to why families would use both a chulha and an LPG stove. Most families responded by stating the chulha is only used for boiling water used to make tea or preparing small snacks. In these households with both chulhas and LPGs, chulhas are used as a backup, especially when a household needs something to cook on while they wait for their next LPG cylinder to be delivered. Furthermore, these households increase the number of hours spent cooking per day on the chulha in the winter, since it is cheaper to heat their home by burning free firewood.


*Figure 4. Reported cook stove used in homes*

Additionally, we asked all households that use LPGs to share with us how many LPG cylinders they purchase each year. Our results indicated that every household purchases subsidized cylinders. Of the twenty-six homes using LPG stoves, the average number of cylinders consumed per year was six. One household informed us they use twenty-four LPG cylinders per year, which we confirmed later in the interview. This household represented the 2% of those interviewed who use only LPG stoves. Additionally, we asked families whether or not they would be interested in an improved prototype chulha. We did **not** inform them of the current manufacturing cost of the chulha, which is about INR 3,000. This was done to determine their overall interest in the concept, but also to establish an unbiased price range that stakeholders would be willing to pay for the improved chulha. Figure 5 represents the interest of households in an improved chulha. 60% were immediately interested and 40% were not interested. While we were satisfied the majority of those interviewed were interested in potentially owning an improved chulha, we had believed that far more than 60% would be interested. It is important to note that more families who were initially hesitant could become interested if allowed to test a working prototype. We asked families who replied that they were not interested to provide us with justification so we could address their concerns and make our prototype suitable for everyone. Some families cited low income as the main reason they were not interested. Others claimed they were more comfortable cooking on the traditional clay-made chulhas they were accustomed to.

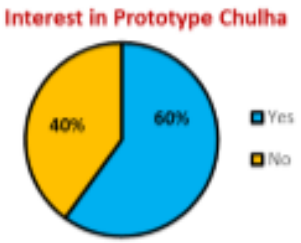



Figure 5. Reported interest in improved chulha

We asked families who replied that they were interested if they could give us a price range that seemed reasonable to them. We found a general range of about INR 1000-2000 to be the most acceptable. Some asked for a cheap model to be available in the range of INR 1,000 or below. Figure 6 (below) shows the preferred price of an improved chulha among stakeholders. The current manufacturing cost of IIT's prototype is INR 3000, which was well out of the range stated by most

stakeholders. If the manufacturing cost alone is well above what consumers want to pay, the product will most likely not be commercially successful nor helpful to consumers.

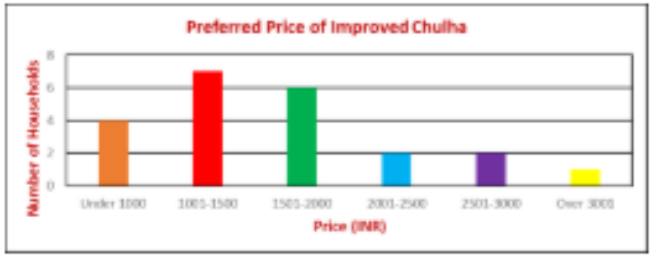



*Figure 6 Stakeholder preferred price of improved chulha*

### *Objective 2: Low-Cost Enhancements to Improve a Chulha*

To determine enhancements for prototype 3, we first performed baseline tests of prototypes 1 and 2 to give us an idea of how well each chulha performed. Figure 7 shows a picture of prototype 1. Prototype 2 can be viewed in Figure 8. Two notable attributes of prototype 2 are that it is wider and much heavier than prototype 1. Internal differences from prototype 1 to prototype 2 include large air flow pipes, the removal of a funneled ash collection, and a larger burn chamber.

*Figure 7. Prototype 1*

The average test results to boil one liter of water using prototypes 1 and 2 are compared below in Table 1. Compared to prototype 2, prototype 1 used about 200 grams more wood and took about twice as long to boil a liter of water. After determining how many kilojoules (kJ) were produced by each stove during testing, the kJ produced per second and kJ produced per kilogram of wood for each prototype could be calculated. Looking at kilojoules produced per second for both stoves, prototype 2 yielded almost double that of prototype 1. In terms of energy output vs weight of wood, prototype 2 again bested prototype 1, with an average of 632 kJ/kg.

*Figure 8. Prototype 2*

| | Wood (g) | Total Time (mins) | KJ/sec | KJ/kg |
|---|---|---|---|---|
| Prototype 1 | 690 | 31.1 | 0.19 | 458.6 |
| Prototype 2 | 491 | 14.9 | 0.35 | 632.2 |

Based on our baseline test results, we decided to only test prototype 2 with stakeholders. Our initial stakeholder assessments took place on IIT's campus, where we were fortunate to enlist three households to test prototype 2 and provide us feedback, which was used in the later design stages of prototype 3.

Stakeholder testing was completed on the campus of IIT and in Bari Village. Three households located on IIT's campus tested and provided feedback about prototype 2. Additionally, one household in Bari tested the prototype, which included friends they invited to test it. Although we were satisfied, prototype 2 used less wood and allowed for faster cooking, there are still many improvements that could be made.

Many suggestions by stakeholders were taken into consideration when we began construction of prototype 3. One recommendation we included in our design is making the wood inlet horizontal. This will allow users to insert larger sticks into the chulha.

Some other recommendations included: a net to be placed in the chimney to catch newspaper when lighting the flue, a chulha made of a different material that would not give off heat in the summer time while cooking, and a container located inside the chulha that could store water and dispense it when cooking.

*Objective 3: Implementation and Testing Results*

To implement the enhancements identified with our tests and surveys, we built a third prototype chulha. A 3D computer model of prototype 3 was designed in Solidworks. Over the course of our study, the design of prototype 3 was altered almost daily. Prototype 3 is based on the design of Prototype 2, with some modifications. One person (with moderate assistance) was able to construct prototype 3 in about twenty-one hours of work. We believe this time can be reduced, especially by someone who has had practice building prototype 3 with proper instructions.

Perhaps our most significant "enhancement" in the design of prototype 3 is the cost. Prototype 2 costs about 3000 INR to manufacture, which is higher than the preferred amount for 83% of the households surveyed. If people can't afford the chulha, it doesn't matter how well it works or what additional features it has. Our initial surveys helped us identify a reasonable price that stakeholders would be willing to pay for a smokeless metal chulha. The cost of materials for prototype 2 is about 2500 INR.

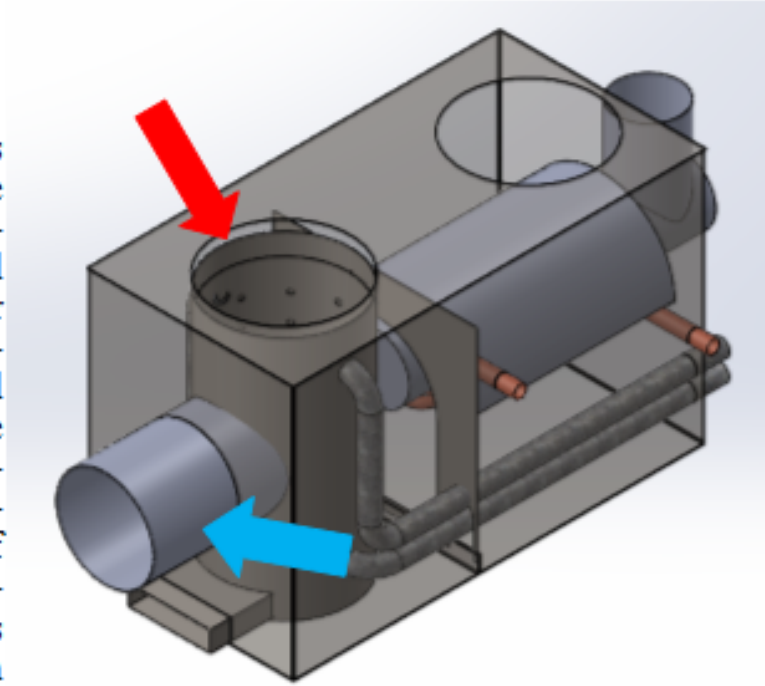


*Figure 9. Final design of Prototype 3 – blue arrow indicates wood inlet and red arrow points to burn chamber*

Figure 9 shows our final design for prototype 3. Some notable modifications from prototype 2 are a cylindrical inlet for biomass fuels and the cylindrical burn chamber. These two features are emphasized by the blue and red arrows. We modified the fuel inlet to be both horizontal and cylindrical, which neither of the previous two chulhas adopted. This feature was implemented based off of feedback from two households that tested prototype 2. Eliminating the angled wood inlet will allow users to slide larger pieces of wood into the burn chamber. An additional reason for making both of these parts cylindrical is for better manufacturability. Instead of having to bend and weld materials into a square prism shape, it is much easier just to use prefabricated cylindrical pipe. Additionally, the small holes, located inside the burn cylinder, allow additional air to enter the chamber and fuel the fire. Prototypes 1 and 2 also featured air inlet holes similar to these, but ran air tubes through the center of the burn chamber at varying levels. This resulted in a cluttered burn chamber and made adding biomass fuel somewhat difficult for stakeholders.

Figure 10 is a closer view of the CAD design which shows a copper coil. The coil was integrated in prototypes 1 and 2 but in a vertical orientation. We placed the coil horizontally to investigate whether or not it would work better than the vertical alignment in earlier prototypes. The copper coil allows stakeholders to heat water using heat transferred from smoke produced from the main burn chamber while they cook. Prototype 3 retained the copper coil since the ability to heat water while cooking is an added incentive for the purchase of the prototype. A picture of the completed prototype 3 can be seen below in Figure 11, alongside the previous images of prototypes 1 and 2.

*Figure 10. Copper coil to heat water while cooking*

## Discussion

When we arrived at the IIT Mandi campus it was apparent that the background research our group had completed in the United States was no longer up-to-date.

Through our research, we identified two factors that had made our background information less relevant, the first being that the Indian government had subsidized LPG stoves for BPL families. This gave many households in the region access to improved cook stoves. The second factor was the road network improvements being carried out in Himachal Pradesh. Understanding these two factors impacted how we conducted our fieldwork and how we would analyze the data we collected.

The data collected from our surveys showed that chulhas are still in use in almost every household in the area. In these households, chulhas had become seasonal cook stoves, reserved for cooking traditional meals or just for hot water heating. It became apparent that an improved chulha that could heat water and cook more efficiently was best suited for those households that used chulhas exclusively. Though households who used both LPG stoves and chulha did express an interest in a smokeless chulha, we do not believe an improved prototype would have a substantial benefit for these households due to their limited use of chulhas.

For the success of our prototype we needed to offer incentives for the stakeholders to buy the prototype. Our prototype was designed to be economically competitive, provide the ability to heat water while cooking, and provide a smokeless environment for the user.

*Figure 11. From left to right: prototype 1, prototype 2, and prototype 3*

To understand our design decisions, it is important to understand the basis on which our prototype chulha has was built. Prototype 3 was created in an attempt to improve upon prototype 2. Prototype 3 is smaller and easier to manufacture on a larger scale. The ease of manufacturing was the main focal point in our team's design for prototype 3. Improving manufacturability results in a lower cost per unit, making the prototype economically competitive. The final design was also influenced by feedback from stakeholder testing of prototype 2.

Of course, prototype 3 is far from perfect and still needs to be tested. Prototype 1 has an expected lifetime of about three years. Traditional, homemade chulhas can last longer than a decade, although maintenance needs to be performed up to three times a week, according to locals. Because of the time constraint in our study, we unfortunately cannot accurately provide any kind of estimate about the durability or expected lifetime of prototype 3.

While prototype 3 can be a competitive and beneficial product to the state of Himachal Pradesh, the future for chulha use is unclear. While completing surveys and traveling throughout the region our group observed the improving infrastructure, which completely changed our outlook. With improving infrastructure our group feels that LPG use will only increase as access to LPG's and the knowledge of govemment subsidies increases. This effectually addresses two of the key factors highlighted in our background research for why households did not obtain LPG stoves.

We do not believe, however, that chulhas will be done away with completely. In the single homes and villages that are very remote we believe traditional chulhas will continue to be used almost exclusively. This market of chulha users will eventually become a very niche market and our prototype would have the biggest impact in such niche markets only. In more urban areas, we believe people will continue to stove stack. Using chulhas for simple tasks such as hot water heating and small space heating in the winters is an intelligent way to use traditional technology.

We do not see this prototype becoming a need for the population of Himachal Pradesh. Overall, we believe this prototype and its future iterations will be a "band-aid" for a significant percentage of those who don't yet have LPG stoves due to low income or lack of accessibility.

## Project Outcomes

*Prototype Recommendations*

Because of time restraints, we recommend testing prototype 3 for several weeks. These tests can be used to produce additional prototypes that can better meet the specifications of users. Additional modifications should be made as the team sees necessary. Perfoming tests in the homes of villages will help expose improved chulhas to the population of northem India.

The following recommendation comes directly from feedback we received during stakeholder testing. A household recommended making a smaller prototype, about half the size of all three existing models. The ideal prototype should be light, easy to move, contain one bum chamber, and cost between no more than 2000 INR. It would be best suited for workers who need to travel often. We would like to recommend further investigation about the feasibility of this idea. A major recommendation we would like to discuss is to make the body of the prototype out of traditional materials such as clay and cow dung.

A large part of the cost comes from the steel body of prototype 3. The intemal design of prototype 3 allows for adaptation of the body walls to be replaced with clay.

By replacing the steel body with traditional materials, the overall cost of prototype 3 is drastically reduced. Some stakeholders also recommended a body not made out of metal because of how hot it gets during the summer. The chulha would heat the room even more because of the metal body. It must be noted that the ability to move the chulha is greatly reduced when the body is made out of traditional materials. A prototype made of traditional materials would need to be tested as well prior to stakeholder testing. While we do not believe the traditional design of chulhas has much of an impact on the younger generation, this more traditional design of an improved cook stove may be more popular among the elderly, as we found the elders tend to prefer traditional methods of cooking in our surveys.

## Conclusion

Although chulhas have long been a part of the culture in rural Himachal Pradesh, the region's ever changing infrastructure as well as the recent government subsidies on LPG canisters have jeopardized chulha popularity in the region. LPG use is growing, and for those who are able to afford the cost of subsidized cylinders, the decision to switch is easy. Our surveys indicated that (contrary to popular belief) most households in the region own both an LPG stove and a chulha. Because of this, we believe as infrastructure continues to develop and more households become aware of the government subsidies, stove stacking will continue to increase.

We set out to determine if improved chulhas were a practical necessity for residents of Himachal Pradesh, and we believe improved chulhas will be practical for a small percentage of the population, at least for some time. Keeping in mind our limited time, reducing the cost and making an easier-to-manufacture prototype were our team's main focuses in creating an improved chulha. We successfully accomplished both of those goals. Increasing efficiency significantly could take years of testing and slight modifications. In conclusion, we believe improved chulhas are a "band-aid" fix that will prove useful, but only to a very niche market of households who will struggle to obtain access to LPG stoves.

## Acknowledgments

Our team would like to thank the following individuals for their significant contributions throughout our study:

- **Mr. Stephan Marchal**, for sharing his experience and giving us insight on relevance of challah and design requirements in Himalayan region.
- **Mr. Sham Lal,** for escorting us around his village during surveying and agreeing to test prototype 2 for a period of 4 days
- **Raj Singh Raghan, Ankush Kapil, Anish Dhiman, Bhuji Singh, Kushal Deep Jagota, Raj Kumar, Jonty Sharma,** and **Dharmpaul Singh,** for their assistance in welding, cutting, and the construction of prototype 3 in IIT Mandi's machine shop
- **Vipul Sharma,** for helping us arrange surveying trips and providing us many insights during our study

- **Dr. Atul Dhar, Dr. Satvasheel Powar, Professor Fabio Carrera and Professor Svetlana Nikitina** for their continuous guidance and support throughout the term and pushing us to "make the leap"
- **Indian Institute of Technology Mandi** and **Worcester Polytechnic Institute**, for providing us with the opportunity to complete this project.


*The full report and supplemental materials for this project (raw data, relevant case studies, the instruction pamphlet, and additional resources) can be found using key words from our project title at http://www.wpi.edu/E-project-db/Eproject-search/search and further information can be found at the IIT's ISTP page: http://www.iitmandi.ac.in/istp/projects.html*

# References


Baker, A., Codding, K., Gupta V., Sharma, V., Verma, S., Zhang, E.M. (2016). *Mitigating Noxious Gases Produced by Traditional Cooking Methods.* Unpublished Interactive Qualifying Project. Worcester Polytechnic Institute.

BankBazaar, (2016, March 21). How to Get Free LPG Connection for BPL Families. https://www.bankbazaar.com/gas-connection.html

Bhandari, R. (2015, December 31). Himachal proposes 188 road projects under PMGSY. The News Himachal. www.thenewshimachal.com

Bhargava, Anuj (2004). "Exposure risk to carcinogenic PAHs in indoor-air during biomass combustion whilst cooking in rural India". Atmospheric environment (1994) (1352-2310), 38 (28), p. 4761.

Bhojvaid, Vasundhara, et al. "How do People in Rural India Perceive Improved Stoves and Clean Fuel? Evidence from Uttar Pradesh and Uttarakhand." International Journal of Environmental Research and Public Health 11.2 (2014): 1341-58. ProQuest. Web. 3 Feb. 2017.

Duque CT, Maldonado D, Padilla RP, Ezatti M, Viegi G. Biomass fuels and respiratory diseases: Forum of International respiratory societies report. Proc Am Thorac Soc 2008; 5:577-90.

Government, India. (2015, March), Give it Up. http://www.givitup.in/

Indian Government. (2014). PRADHAN MANTRI GRAM SADAK YOJANA. http://omms.nic.in/

Indian Government, Ministry of Rural Development, P-12025/8/2001-RC, 2004

Http://www.pmgsy.nic.in/pmg31.asp (enacted)

Jain, A. (2016, October 18). LPG for Every Indian Household. The Hindu .http://www.thehindu.com

Jeuland, M. A., Bhojvaid, V., Kar, A., Lewis, J. J., Patange, O., Pattanayak, S. K., . . . Ramanathan, V. (2015). Preferences for improved cook stoves: Evidence from rural villages in north India. Energy Economics, 52, 287-298.

Perez-Padilla, R., Schilmann, A., & Riojas-Rodriguez, H. (2010). Respiratory health effects of indoor air pollution. The International Journal of Tuberculosis and Lung Disease : The Official Journal of the International Union Against Tuberculosis and Lung Disease, 14(9), 1079.

Press Trust of India. (2016, May 6). 17 new National Highways announced for Himachal Pradesh. Business Standard. http://www.business-standard.com

PTI. (2016, April 21). Give-it-Up: Over 1 crore LPG users gave up their subsidies. The Economic Times. http://economictimes.indiatimes.com/news/industry/energy/oil-gas

Smith KR, Uma R, Kishore VVN, Lata K, Joshi V, Zhang J, et al. Greenhouse gases from small-scale combustion devices in developing countries. Report No.: EPA/600/ R-00/052. Washington D.C.: United States Environmental Protection Agency; 2000

Census of India 2011 HIMACHAL PRADESH SERIES-03 PART XII-B DISTRICT CENSUS HANDBOOK MANDI. Pg. 3,29,30 http://www.censusindia.gov.in/2011census/dchb/0205_PART_B_DCHB_MANDI.pdf

UNDP. 1997 Energy After Rio: Energy for Sustainable Development New York,

# Preservation of Perishable Agricultural Food Produces Using a Solar Food Dryer


## Abstract

In rural India the major population is into Agriculture, which forms a great part of the country's economy. The harvest produced has to be dried for further processing or preserving. The current methods for drying are inefficient and time consuming. We focused on understanding the types of available perishable food produces, quantum of perishable food to be preserved, currently employed methods, time taken for drying, wastage due to existing methods, and so on. We then interviewed stakeholders and collected data and developed a prototype of a solar food dryer and tested it for reduction in drying time and prevention of wastage. It is a portable and very cheap device which can be scaled for larger purpose. It can also be used as a solar cooker for boiling rice or dal (pulses).



***Team Members:***

Maeghel Puri, IIT

Sachin Dhariwal, IIT

Arpit Karwasara, IIT

Prashant Mundotia, IIT

***Advisors:***

Dr. Tushar Jain, IIT

Dr. Dhiraj Patil, IIT

Dr. Satvasheel Powar, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

WPI

Indian Institute of Technology Mandi

## Harvest Drying in rural India

In rural areas, most of the population is involved in agriculture. In Himalayan villages crops are grown to suffice a full season (due to its unpredictable weather conditions) and also to be exported, which adds to the major occupation of the people here. The crops grown here, specially some fruit which are exported out of the country and also to many Indian states, need to be kept fresh for their usage and this calls for proper preservation methods. So the harvest needs to be preserved in one or the other way. This calls for proper drying techniques which is the first step for preservation. When the harvest is cut, it is dried both before and after threshing which tells us the importance of using proper drying techniques.

Our project focused on understanding the types of available perishable cash crops grown, quantity of perishable food to be dried, currently used techniques for drying and the amount of crops wasted if they are not dried properly. Basically we will study the methods used for drying the crops and try to develop a prototype that efficiently and quickly dries the harvest to be preserved using solar energy, called a Solar Food Dryer.

The main aim of our project was to find the most efficient way of post-harvest crop drying method and in order to achieve that make an efficient food dryer using solar energy, which is cheap and affordable and that can be used for preservation of crops that used to be wasted or couldn't be grown due to inefficient preservation techniques. This device sis portable and can also be used as a solar oven.

*Figure 1: Open Sun Drying (google images)*

Currently most farmers use open sun drying method. It is highly inefficient, specially in the Himalayas where the weather is very unpredictable and wild animals destroy the harvest if kept in open. Our goal is to provide something more efficient and cheap so that this benefits farmers.

In order to be successful in our research we followed a methodology consisting of some objectives- (1) enquired about cash crops grown, and their selling and storing percentage,
(2) asked about current drying and preservation techniques and crop wastage due to poor drying, (3) construction of a prototype according to the needs,(4) field testing of the prototype.

We focused on the need and usage of the dryer in this region and also people come up with a response of a community dryer rather than an individual thing. Various crops could be dried in it and also rice was cooked in it; this was comparable to pressure cooker cooking.

## Available Food Drying Techniques

Food preservation has become an important topic of research from the last decades. With the increasing world population along with advanced agricultural techniques, the preservation of agricultural outcomes has also become important. In countries like India with a population of around 1.25 billion, efficient food preservation techniques can be a boon for the farmers as well as for the economy of the country.

Increasing population has created the need for increasing the efficiency of post-harvest food processing in India. Presently a number of solar dryers and concentrators being used to preserve food products. To prevent spoilage of food for long duration, dehydration is the most important and preliminary step. High temperature increases efficiency of dehydration but it also changes in the physical and chemical properties of food, such as loss of nutrients and colour. The total expense of dehydration is about 30% of total cost of processing food.

In this project the prime focus is on finding alternative of traditional food preservation techniques used in Himachal Pradesh. Presently, Himachal Pradesh comprises of 12 districts having an area of 55,673 sq. km. and a population of 68,64,602. The total cropped area in Himachal Pradesh is 9,38,625 Hectare out of which 2,24352 Hectares are used for the production of Horticulture and related activities by the stakeholders. (Source:http://admis.hp.nic.in/himachal/economics/REPORTS/HPinFigures_2015_16.pdf). Also according to the survey conducted by Economics and Statics department of Government of Himachal Pradesh, "The economy of Himachal Pradesh is predominantly dependent upon agriculture with about 14.42 percent of state income been contributed by agriculture sector alone." Due to lack of Industries, the majority of population in rural areas is dependent on agriculture for its income but due to hilly terrain and dynamic weather conditions, the transportation of these agricultural produces from distant places is not that much feasible as compared to plains hence, there is a need for preservation of these produces.

## Traditional Food Drying And Preservation Techniques

- Direct sun drying
- Cooling and Freezing
- Salting
- Pickling
- Fermentation

## Modern Food Drying Techniques

With the advancement in technology, traditional direct solar drying method has been replaced by modern solar dryers [Figure 2], which are fast and more efficient. [Table 1] gives an overview of advantages and disadvantages of using traditional open sun drying method and modern day solar dryers. Solar dryers can be classified broadly in two different categories as active and passive solar dryers which are further modified according to the climatic, geographical conditions of the region.

**1) Active Solar Dryers** In Active solar dryers, external means such as fans, pumps are required to move the heated air from collector area to the drying chamber. They are also known as forced convection dryer.This kind of dryers are faster than passive dryers due to increased rate of heating by external means.

**2) Passive Solar Dryers** In the passive solar dryers no external sources are used to drive air into the drying chamber. In these kind of dryers either the sunrays are

used directly or indirectly to dry the food items placed in drying chamber.

**3) Mixed Mode Solar Dryers** Mixed mode solar dryer is common for both active and passive solar dryers. In this type, the heated air from the separate solar collector is passed through a drying chamber and the same time, the drying chamber will absorbs a solar energy directly through a transparent cover. The product is dried simultaneously by both radiation with conduction of heat through the transparent cover and the convection of the heat from the solar air heater.

| Method | Advantages | Disadvantages |
|---|---|---|
| Open Sun Drying | 1) Capacity of drying at a time is more.<br>2) Simplest and cheapest method.<br>3) No skilled person is required. | 1) It is dependent on the weather condition.<br>2) Poor in quality as a result of grit and dirt.<br>3) Loss of nutritional value UV radiation can damage food. |
| Solar Dryer | 1) Running cost is low, once set up.<br>2) It shortens the drying period.<br>3) Offer protection from rain, debris etc Can be operated at high temperature. | 1) Lower capacity compared to open drying system.<br>2) Drying is possible only on sunny days.<br>3) Dependent on the ambient climatic conditions. |

*Table 1: Comparison between open sun drying and modern sun*

## *Inferences From Available Methods*

The various types and designs of solar dryers were reviewed with the purpose of finding the dryers with suitable for different conditions along with their advantages, drawbacks and performance evaluation and we found that the performance of solar dryers depend on the food products to be dried. It varies according to the food products placed in the drying chamber. Also no single method or dryer is suitable for all conditions as the performance of solar dryers varies due to different factors like climatic, geographical conditions. Although a lot of research has been done in the field of solar drying across worldwide but still there is scope of improving efficiencies of different methods as well as providing a broad model which can be used for most of the situations.

## Methodology: Fieldwork and Prototype Development

Our aim is to develop an efficient and cheap dryer for drying the harvest. In the below figure 3 we summarize our objectives.

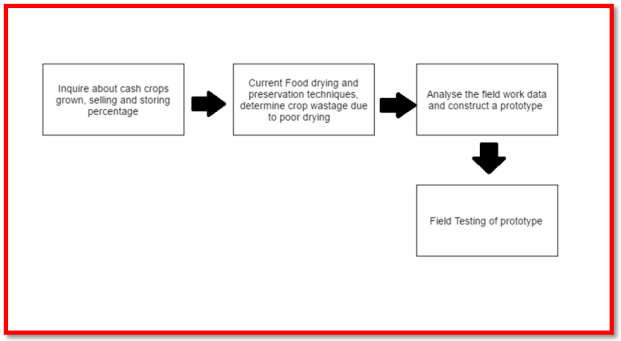



*Figure 3: Objectives*

### 3.1: Inquiry about various cash crops grown, their selling and storing percentage

We identified 4 villages- Neri, Navlay, Kataula and Sandoa for our survey and in which we interviewed 30 farmers in total. We interviewed them about the kind of cash crops they grow, what quantity they store and what do they sell. The medium of interview was Hindi. Photographs and videos/audios were recorded of the farmers. Somewhere individual farmers were interviewed and somewhere a group of them were interviewed.

*Figure 4: Interviewing a farmer in Neri(Arpit,2017)*

### 3.2:Current drying and preservation techniques and crop wastage due to poor drying

We also inquired about the methods which they use for drying the harvest both before and after threshing. All of them used open sun drying technique which they said was quite inefficient and time consuming. Also we inquired about the quantity of major harvest wasted due to open sun drying. Wastage reasons were also noted down.

### 3.3: Construction of the prototype

From the information that was gathered and analyzed we came up with a design in order to dry the crops more efficiently and quickly. To test our design we performed an experiment, we kept the dryer in sunlight and calculated the input heat that we are getting by using thermocouples(for temperature data) and pyranometer (for intensity data). But the input heat that we were getting was less due to conduction losses, poor reflection from walls, less heat absorbed on base. To counter these problems we modified our design for better heat input. Then we tested the design 2 and heat input was increased. After getting the heat input we conducted an experiment to get the time required for drying wheat. To broaden the use of our prototype we conducted an experiment to cook rice inside the dryer.

### 3.4: Field testing of the food dryer

From the surveys and interviews we gathered the information that wheat and maize are the major cash crops in the nearby regions. March-April is the harvesting season of wheat. So to test our prototype we kept 330g of wheat having 13% (42.3g) of moisture in the dryer and calculated the time of removing all the moisture from the wheat. Then we compared the theoretical time (from the heat calculation) and the experimental time (by drying wheat in the dryer) to check the error in our dryer and the efficiency of our dryer by comparing it with the time taken in open sun drying.

*Figure 5: Interviewing a group of farmers in Kataula (Arpit,2017)*

## Results and Discussions

The fieldwork interviews were conducted and the data collected was analyzed. What we could imagine as the problems that might be faced by farmers were more or less confirmed by the data from the interviews. The data collected is presented as follows objective wise.

### *Objective 1: Inquire about various cash crops grown, their selling and storing percentage*

We visited 4 villages and 30 farmers were interviewed in total. All the farmers were men.

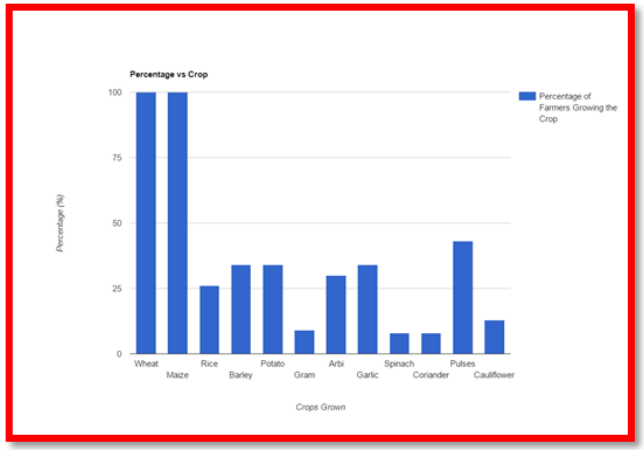



*Figure 6: Percentage of farmers vs crops grown*

Figure 6 shows the percentage of farmers growing particular kind of crop. From here we inferred that Wheat and Maize are crops which every farmer grows followed by garlic, pulses and barley.

For further classification we divide the crops into Kharif (Summer) and Rabi (Winter) season. We see from the figure 7 that Maize is the major crop in Kharif season and followed by Arbi. Figure 8 shows that in the Rabi season Wheat is the major crop followed by garlic. Garlic is also the most expensive crop sold in these areas, and so drying of it was done carefully.

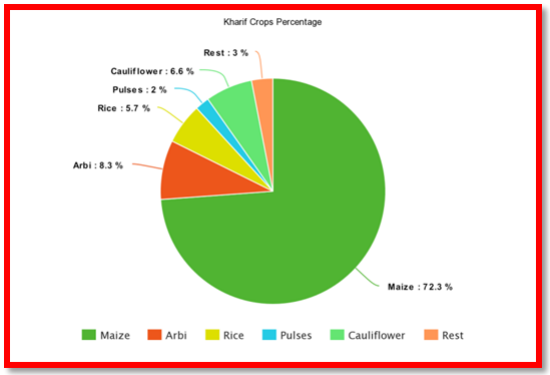



*Figure 7 : Percentage of different crops grown in Kharif Season*

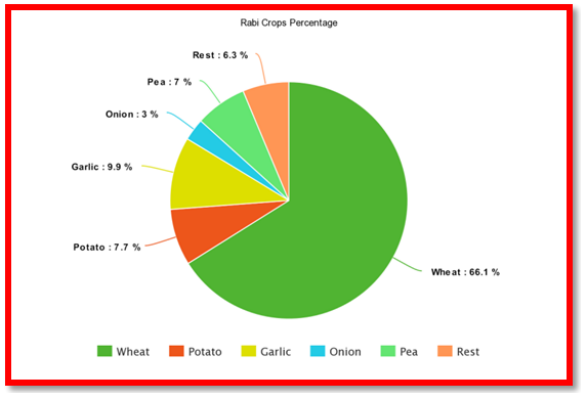



*Figure 8: Percentage of different crops grown in Rabi Season*

### *Objective 2: Current drying and preservation techniques and crop wastage due to poor drying*

After studying the types of crops and the percentage of distribution we found out the time taken for each crop to be dried. The time taken is only before threshing which is taken for drying. The figure 9 shows it. For the major crops we found that Wheat takes 7-8 days and Maize takes 17-18 days to be dried. Rice and barley takes 4 days but they are not of that large quantity in produce. Next we inquired about the wastage of crops due to drying. The data was available for only wheat and maize as they were the major crops. Figure 10 tells about the percentage of wheat wasted only in the drying

phase. Similarly figure 11 tells about the percentage of maize wasted only in the drying phase.

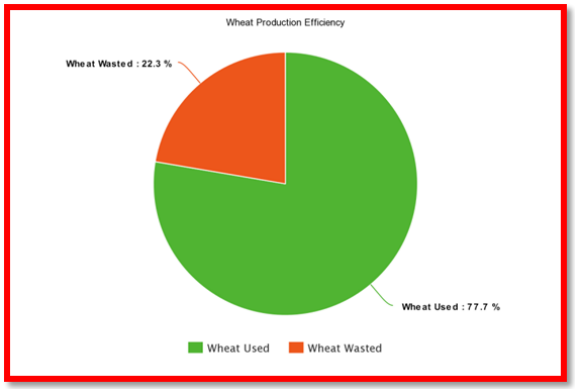



*Figure 10 : Percentage of Wheat Wasted*

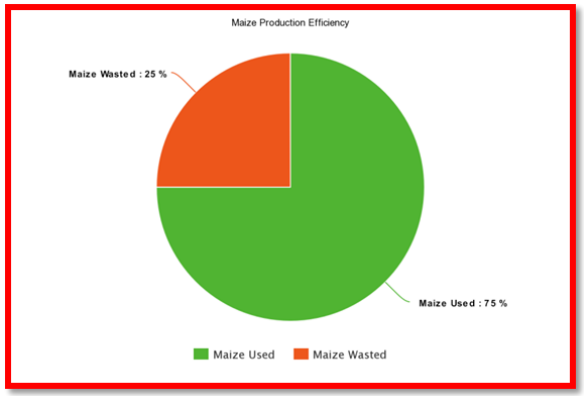



*Figure 11 : Percentage of Maize Wasted*

When we asked about the reasons for this wastage the farmers only gave 2 reasons: (1) moisture due to rain and (2) attack by wild animals (monkeys). They said that every day laying down and collecting the harvest for drying is inefficient job. When we inquired about whether they are interested in such a thing/device called a Solar Dryer, only 3 out of 10 responded in favor for a personal use.

## *Objective 3: Construction of the prototype*

After the field data we got our technical skills into play and constructed a prototype using heat and solar properties. Version 2 was the final version in which the material is metal (Gi) sheet in which the inside walls are covered with aluminum foils. The base of area 2500 $cm^2$ is painted black which is non-reflective. The below surface is covered with fibre glass to less loss of heat.

To test our prototype we conducted one experiment where we calculated the amount of heat (solar energy) received by the dryer on a fine sunny day. This also gives us the temperature distribution attained by the dryer.

The figure 12 shows the experimental setup

*Figure 12: Experiment heat setup-(a) The placement of the components.(b)Measurement of parameters(Maeghel,2017)*

We started our first experiment at 10:30 IST in the morning and completed at 17:30 IST in the evening. We divided the base of the dryer into a 9 cell grid and noted temperature of each cell , temperature attained by the big and small vessel placed inside the dryer as shown in figure 13 by thermocouples. We measured the sun intensity (maximum intensity at a particular time) and also the intensity received by dryer at the same time shown in figure 14. So from these intensity data we can calculate the average heat input to the dryer from 10:30 IST in the morning to 17:30 IST in the evening.

Heat of solar energy which is intensity*time*area of base.

area of base= 2500 $cm^2$=0.25 $m^2$.

Efficiency of collection of solar radiation (efficiency of dryer, absorptivity) =15% (Generally assumed for these dryers)

Time= 3600*7=25200 sec(duration of experiment)
intensity(average)= 855.42 $W/m^2$

Heat by solar energy= 5.389 X $10^6$ X 0.15=0.808 X $10^6$ Joules.

| TIME | GRID TEMP(C) | | | AMBIENT TEMP© | BIG VESSEL TEMP(C) | SMALL VESSEL TEMP(C) | INTENSITY TOWARDS DRYER(W/M2) | INTENSITY FACING SUN(W/M2) |
|---|---|---|---|---|---|---|---|---|
| | 37 | 48 | 35 | | | | | |
| | 34 | 52 | 36 | | | | | |
| 10:30 am | 39 | 47 | 34 | 29 | 44 | 35 | 938 | 1074 |
| | 45 | 47 | 40 | | | | | |
| | 46 | 58 | 49 | | | | | |
| 11:30AM | 45 | 48 | 41 | 29 | 47 | 47 | 1015 | 1101 |
| | 47 | 46 | 37 | | | | | |
| | 57 | 59 | 47 | | | | | |
| 12:30 am | 57 | 37 | 38 | 32 | 48 | 47 | 1025 | 1060 |
| | 42 | 38 | 37 | | | | | |
| | 49 | 57 | 48 | | | | | |
| 1:30PM | 37 | 36 | 35 | 33 | 57 | 51 | 990 | 1090 |
| | 40 | 36 | 36 | | | | | |
| | 37 | 50 | 44 | | | | | |
| 2:30PM | 36 | 37 | 36 | 32 | 51 | 45 | 870 | 1046 |
| | 37 | 45 | 42 | | | | | |
| | 35 | 43 | 45 | | | | | |
| 3:30PM | 36 | 39 | 42 | 33 | 46 | 44 | 670 | 1000 |
| | 32 | 38 | 37 | | | | | |
| | 32 | 37 | 38 | | | | | |
| 4:30PM | 32 | 36 | 39 | 33 | 37 | 39 | 480 | 960 |
| | 28 | 29 | 28 | | | | | |
| | 28 | 29 | 28 | | | | | |
| 5:30PM | 29 | 30 | 29 | 27 | 29 | 29 | 40 | 58 |

*Table 2: Experiment 1(heat calculation) Data*

Theoretical time calculated from this heat= 1 hour 11 minutes.

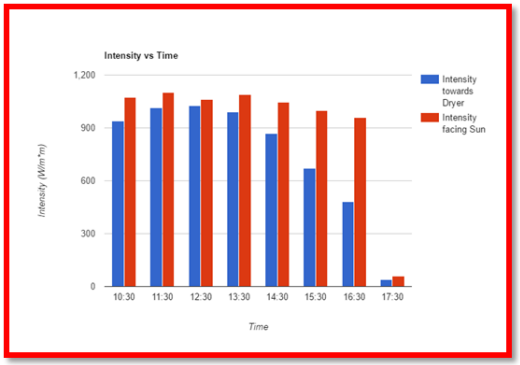



*Figure 13 : Intensity vs Time Graph*

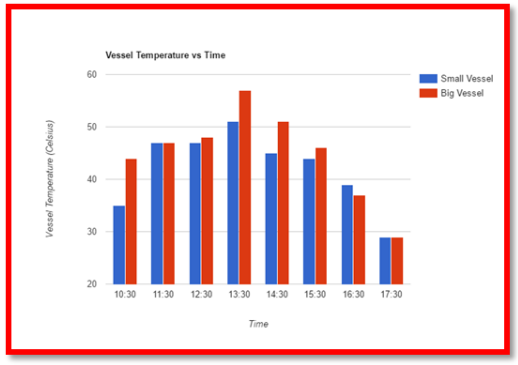



*Figure 14: Vessel Temperature vs Time Graph*

So the above calculated heat is the heat received by the dryer. Next we conducted an experiment in which the dryer was made into a solar cooker or oven. We took 200g of rice and poured water and set the vessel out in the dryer. The rice were ready in 5 hours. The before and after photos of the rice experiment are shown below (figure 15).

*Figure 15: Rice Experiment-(a) initial setup (b) final cooked rice (Sachin,2017)*

## Objective 4: Field testing of the food dryer

The time for drying was calculated by an experiment (figure 16) taking 330g of harvest of wheat which has 13% moisture (42.9 g) and kept in the dryer at 12:30 pm IST and was approximately dried after 3 hours (3:30 pm IST). Theoretically we find it to be 1 hour 11 min.

This time is more than the theoretical time calculated from the heat calculation. For some crops time for drying is given in the following table 3. This is the theoretical time given not the experimental one.

*Figure 16: Harvest experiment for time calculation: (a) Before 12:30pm (b) After 3:30pm*

| CROP | MOISTURE CONTENT(%) | TIME REQUIRED TO DRY 1000 gm |
|---|---|---|
| WHEAT | 13 | 3 hr 5min |
| MAIZE | 13.5 | 3 hr 20min |
| BARLEY | 12.5 | 2 hr 53 min |
| RICE | 14 | 3 hr 38 min |

*Table 3: Moisture content and Time required to Dry for some Major Crops (Theoretical)*

## *Discussion*

The above data and experiments really showed us the difference between theoretical and practical analyses. The interactions with the farmers showed us that open sun drying has some problems. As they are small scale farmers so even a small wastage of their produce harms them in a large way. Still only 3/10 farmers showed interest in the dryer. The question is why ?

Basically these farmers are rigid in terms of their agricultural practices and don't favor change. Some feel the device would add an extra expense, however small it may be. But some showed interest in a community dryer. The heat calculation experiment showed the time that the dryer would take if no losses and perfect condition is taken into account. But the harvest experiment showed the result with the non-idealities included. There was a time difference of 1 hour 49 min between the real and ideal values. This could be because of the conduction losses, weather changes, fluctuation of intensity etc. But the dryer was still able to reduce the time and increase efficiency of drying compared to the open sun drying. It is also safe from animals because of the temperature the dryer rises to will harm the animals. So it can be bought as a community owned asset after scaling it to a marketable use. Also farmers using the food dryer would not have to worry about the harvest time and again, but collect it only after drying.

The other use of the dryer was displayed by the rice experiment which showed that it can also be used as an alternative cooking source. The rice was tasty and can be compared to the ones cooked in a kitchen.

The dryer still has some shortcomings. It can be made more efficient by reducing the losses and by making it equivalent to the time we got theoretically. It can be done by making the dryer rotatable depending on the movement of the sun path. Also it can have a proper ventilation system for drying the contents fast.

The overall prototype is satisfactory as conveyed by the experimental results. The real picture however will be given by the end users or the farmers. The shift from open sun drying to use of a device will surely benefit them economically, but only after the prototype has been improved further as recommended.

## Conclusion

Although today a variety of solar dryers have been developed worldwide to dry different food produces but the main problem lies with their availability and costs due to which most farmers prefer traditional open sun drying technique to dry their crops instead of modern sun dryers. Our project focused on solving the major issues faced by local farmers during open sun drying in Himachal Pradesh which were destruction of crops due to bad weather conditions like rain, storm etc. and factors like monkeys, cows etc. While making the prototype we kept the cost factor in mind and tried to present cost efficient solution for these problems. The other issue that we found while interviewing the locals was the time taken for drying the two major crops grown in the region: wheat and maize. The dryer was made to reduce the time taken for drying as much as possible along with keeping in mind the other problems. While working on the basic prototype, by making some modifications we found that the solar dryer could also be used to cook rice and pulses so, the dryer can also be used as a solar cooker.

While making the prototype we tried to eliminate most of the major problems faced by the local farmers and present a practical solution as much as possible but there can be further improvements. In the future models of the prototype, there will always be a scope of increasing the efficiency of the dryer and reduce the cost

further this means that the future models can further decrease the time taken for drying keeping the cost factor in mind.

## Project Outcomes

The project led us to make a prototype which can be used to solve major problems faced by the local farmers of Himachal Pradesh while drying their crops after harvesting. We made our prototype using metal sheets in order to make it cheap, light weight and foldable. In our first prototype we designed the angles of the walls in such a way that maximum heat can be received from the sun irrespective of the sun location. But the heat input we received in our first prototype was less because of poor reflection from walls due to metal sheet surface and less absorption of heat on base. In our version 2 of prototype (figure 17) we painted the base of dryer black in order to absorb more heat and covered the walls of the dryer with aluminum foil for better reflection of sunlight in the middle of the dryer. These two modifications increased the input heat and the efficiency of our dryer. To minimize heat loses from the dryer we also covered the base with the fibre glass so that minimum heat is lost from the base.

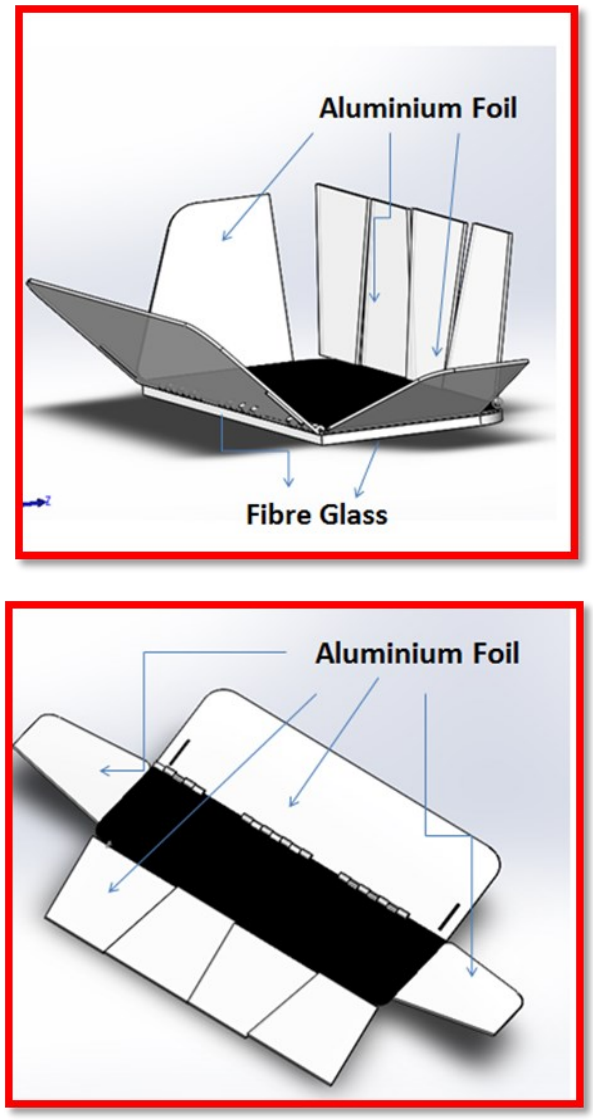



*Figure 17 : CAD design of version 2*

This prototype is able to protect the crops from bad weather conditions as well as factors like monkeys, cows etc. due to which every year a large portion of crops was getting damaged. The project is fully cost efficient so that a local farmer can afford to buy it and once set up it requires no additional cost to run or maintain it. The number of days taken for drying are significantly reduced by using the solar dryer instead of using open sun drying technique.

### *Recommendations For Farmers*

Every year farmers has to suffer a great loss while drying the harvested crops due to a number of factors but still solar dryer is not that much popular among Indian farmers. The reasons for this unpopularity can be anything but still we tried to make a prototype which can be according to the needs of farmers. The various factors like cost, efficiency, durability etc. are completely taken care of, and the solution provided is feasible according to most of the needs of farmers. This is why we recommend farmers to use this product instead of traditional open sun drying technique.

## *Recommendations For Future Researchers Of Solar Dryer*

Future researchers are recommended to work on the prototype keeping efficiency in mind. This is because whereas other factors like cost, durability were taken care of by us while making the product, there is always scope for increasing the efficiency in these kind of dryers. By increasing efficiency we mean decreasing the time taken for drying the crops and increasing the amount of crops that can be dried at any particular time. Also additional means like fans, pumps can also be installed in the dryer to increase the rate of drying but the cost factor should also be kept in mind. Also the base of the dryer can be made automatically rotatable in order to track the movement of sun so that at any instant our dryer will receive the maximum intensity of the sun.

## Acknowledgements

We would like express our sincerest gratitude to the following institutions and people, without whom we could not have completed this project:

Indian Institute of Technology-Mandi for providing us with the opportunity to complete this project.

Dr. Satvasheel Powar, for his mentorship throughout our project, especially for experiments conducted with the dryer.

Dr. Tushar Jain and Dr. Dhiraj Patil, for their mentorship throughout our project.

Dr. Fabio Carrera and Dr. Svetlana Nikitina, for advising our project and providing constant guidance every step of the way.

Deepak Sharma (PhD Scholar IIT Mandi), for helping us during our fieldwork and surveys.

Dr. Devika Sethi, for her constant support and mentorship.

IIT Mandi guards, for helping us getting the harvest and help during our fieldwork in the villages.

## References

1) Report by Mr.Nabilah Binti Harmain, University Of Malaysia http://umpir.ump.edu.my/4599/1/cd6654_76.pdf

2) Publications by Economics and Statistics Department, Himachal Pradesh http://admis.hp.nic.in/himachal/economics/pub.htm

3) Department of Agriculture, Himachal Pradesh http://www.hpagriculture.com/

4) Statistics from https://www.himachalpradeshstat.com

5) Wikipedia https://en.wikipedia.org/wiki/Food_preservation

6) Research by Chen, et al., 2009

7) Journal by Amruta R. Eswara and M. Ramakrishnarao https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3550910/

8) Encyclopedia http://www.encyclopedia.com/sports-and-everyday-life/food-and-drink/food-and-cooking/food-preservation

9) Images taken from www.google.com

# Extending the Apple Season: Cold Storage in Himachal Pradesh, India


## Abstract

In Himachal Pradesh, India, farmers are forced to sell immediately after harvest or lose their crop to disease and rot. This project attempted to understand problems affecting fruit and vegetable farmers and identify ways to alleviate them. To this end, we interviewed farmers, storage facilities, and a local non-profit organization, and conducted research into modern farming practices. Our work resulted in multiple recommendations for improving farmers' livelihoods in addition to the development of an app and pamphlet for their benefit.



***Team Members:***

Mohit Jain, IIT
Nimit Kalal, IIT

Virginia Massa, WPI
Peter Melendez , WPI

James Muller, WPI
Kunal Shah, WPI

***Advisors:***

Dr. Jaspreet Kaur, IIT

Dr. Rik Rani, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

WPI

Indian Institute of Technology Mandi

## Helping Farmers Preserve Crops in Himachal Pradesh

Agriculture is a very significant part of the economy in Himachal Pradesh, yet farmers have few means to preserve their crops. According to a 2012-2013 report submitted by the Economics and Statistics Department of Himachal Pradesh, about 69% of workers in the region are employed in agriculture. In addition, 87% of farmers are small-scale (Choudhary, 2016) and own, on average, two acres of land (Singh et al., 1997). With few options in terms of long term storage or preservation of crops, farmers often use relatively ineffective home-constructed storage methods (Overview of grain drying, 2017). As a result, farmers often need to push most of their goods to market immediately, driving prices down and leading to lower profits (Sidhu, 2005, and Bhandari, 2016). Figure 1 demonstrates this vicious cycle.

Our mission was to design and evaluate a solution empowering farmers in Himachal Pradesh to better preserve their crops and extend their seasons, improving their profit potential. In our research, we analyzed ways we could either help farmers avoid crop damage, or increase shelf-life. Each of these methods could potentially help farmers increase profits by either minimizing loss or maximizing the sale price.

Our first objective in achieving this goal was to investigate current food preservation practices in areas near Mandi by interviewing farmers and markets, and determine the problems farmers face. Our second objective was to research and assess alternative preservation plans that would benefit farmers. Our final objective was to select one optimal plan that would maximize farmers' profits, and devise a way for farmers to take advantage of that plan.


*Figure 1. The cycle trapping farmers in this region.*

## Challenges Faced by Himachal Pradesh Farmers

Himachal Pradesh is one of the northernmost states of India. In this fairly temperate region, a variety of fruits and nuts are grown (State Department of Horticulture, 2016). The weather in Himachal Pradesh is hot and dry in the summer, rainy during the monsoon season, and chilly during the winter. According to the Koppen classification system, much of Himachal Pradesh has a "cwa" climate (Grieser, Rubel, Beck, Kottek, & Rudolf, 2006). This is known as a humid subtropical climate, with relatively dry winters and warm summers (Arnfield, 2016).

The region of Himachal Pradesh borders the Himalayas and consists mostly of hills interspersed with river valleys. A case study by Singh et al. in 1997 found that both terraces and paddies dot the region, such as those in Figure 2. Pandey (2009) notes that apple orchards are especially common, with production of apples comprising 88% of fruit production.

*Figure 2. Terracing style of three farms in Kataula, Himachal Pradesh.*

### *Benefits of Cold Storage*

The climate and geography of this region is conducive to large harvests. The warm weather and rain make the area very suitable for growing fruits and vegetables. The monsoon season, from July until September, brings plentiful rain to needy crops, hastening growth (Arnfield, 2016). However, these conditions are very poor for storing crops in the open or in makeshift storage. Refrigerated or controlled atmosphere (CA) storage can extend the life of crops a great deal, especially in the case of the ubiquitous apple (Refrigeration, 2015). While apples in the open may be lucky to last a week, Fischbacher and Marsden (1966) indicate that refrigerated or controlled atmosphere storage can preserve them up to six months, as shown in Figure 3. If apple farmers are able to use this technology, they can safeguard their crops from the weather and other dangers, and have a better chance to sell at market.

*Figure 3. Apples stored in controlled atmosphere storage, still crisp after six months*

### *Lack of Storage Leads to Waste*

Faced with a bumper crop, many small-scale farmers, are unable to find adequate storage before their crops can be brought to market (Bodh, 2015). As of May 2015, there are only 7 cold storage facilities in the region (Bodhi, 2015, Sharma, 2013, and Sally, 2011). Figure 4 demonstrates that Himachal Pradesh is in desperate need of cold chain infrastructure as compared to other Indian states.

According to a book by Batt, P. and Cadilhon, J. (2007), Himachal Pradesh is the second largest producer of apples in India. However, the lack of infrastructure and failure to properly handle goods leads inefficiency and crop loss. Apples often become bruised or punctured during harvest, making them rot faster. Even short-term storage arrangements such as trenches and small cellars are vulnerable to attacks by monkeys and other destructive animals or insects. This type of storage also does little to prevent normal spoilage, as it is at nearly ambient temperature. Single trucks are packed to the brim for a two-day journey, leading to further bruising, deformation, and other types of damage. A single farmer might lose more than half the crop before it even has a chance to sell. Even after arrival at market, apples are often improperly stored before they are sold.


*Figure 4. Map of cold storage capacity in India. Note Himachal Pradesh, second from top*

The myriad of problems plaguing apple farmers is similar to problems for many other crops in Himachal Pradesh; high-temperature storage and lack of care during transport leads to crop decay and loss. The skin and peel of fruit provide a physical barrier keeping bacteria out of the inside flesh. If their stems are randomly placed, however, peels could be punctured in transit. The fresh opening in the fruit will rot more quickly (Harvesting and Food Handling). Furthermore, the fruit becomes a food safety issue, as consuming fruit which has been punctured and exposed can cause illness (Parasites, 2013).

## Methodology

This project was geared toward discovering problems with crop preservation faced by farmers in Himachal Pradesh and ways to alleviate them. The end result is meant as one improvement on their situation, alongside several recommendations for further work. An overview of our project's strategies can be seen in Figure 5.

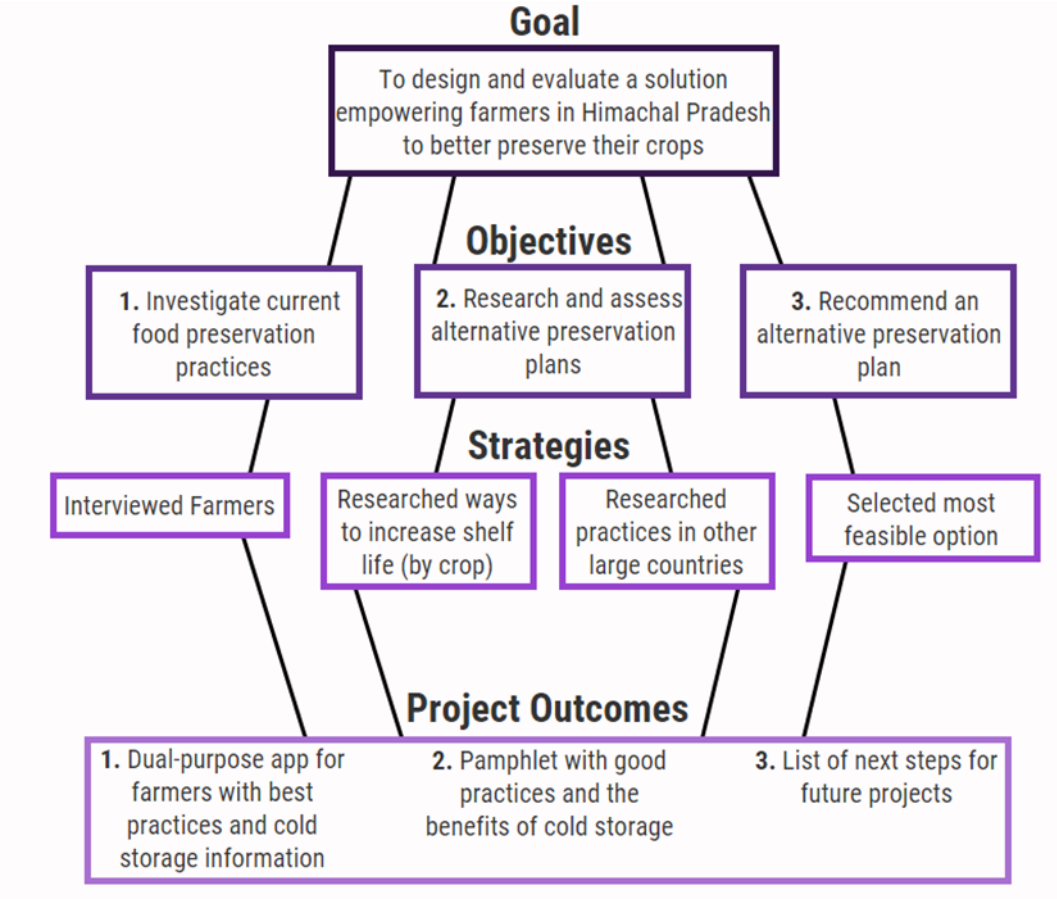



*Figure 5. Our project flowchart.*

### *Objective 1: Investigating current practices*

We began by conducting interviews with small-scale fruit and vegetable farmers near the IIT Mandi campus in order to understand what types of problems they face in the **post-harvest handling** or **preservation** of their crops. We interviewed vegetable farmers in Kataula, pomegranate farmers in Bajaura, mango farmers in Budhar, and apple farmers in Patlikuhal, see a map of locations in Figure 6. We also conducted an interview with the president of the Kullu Fruit Growers' Association in Patlikuhal to gain insight on problems faced by the apple farmers residing in this region. Interviews were conducted in Hindi, and simultaneously translated to English on

paper.

In addition, we interviewed owners of market stalls in Mandi to determine **crop prices** both in and off season. These interviews were meant to build our perspective on the economic situation of farmers in the area and the problems they faced in terms of crop loss.

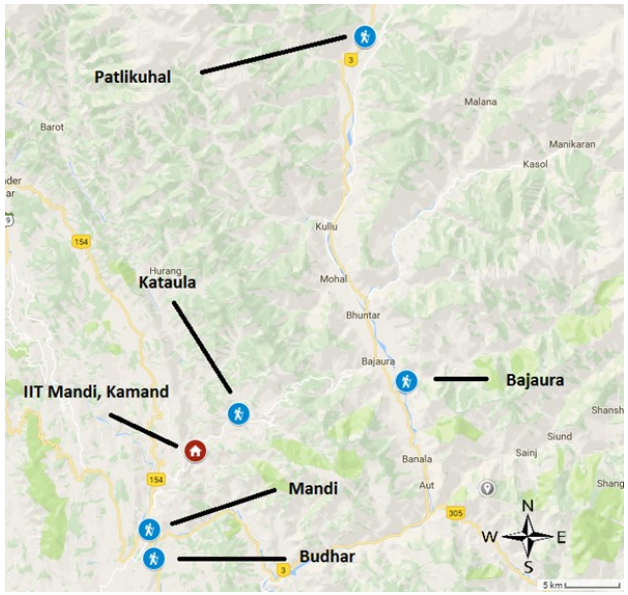



*Figure 6. Map of Interview Locations.*

### *Objective 2: Researching and assessing alternative preservation plans*

On campus, we conducted research into many different methods of preserving fruits and vegetables. Chemical treatments, changes in packaging, and water treatment were considered. Finally, we also performed considerable research on refrigerated storage for multiple fruits and vegetables. Cold storage is known to be most effective on apples, so we performed a cost-benefit analysis for farmers to store fruit for several months before selling it at market.

Furthermore, we traveled to Patlikuhal, north of Kullu to conduct research on whether or not apple farmers in the area could benefit from nearby cold-storage opportunities. While there, we talked with owners of Aromatrix Flora Private Limited, a small private **cold-storage facility**, and HPMC Patlikuhal, a large government funded **cold-storage facility.** We obtained a broad overview of their operation, how fruit or vegetable farmers in the region might benefit from cold-storage, and the cost to rent these facilities. Our research helped us determine exactly how we could assist farmers in this region and what methods would be best to recommend.

### *Objective 3: Recommending an alternative preservation plan*

In order to craft solid recommendations for farmers, we assessed all the information available to us and identified the most reasonable preservation plan on the basis of feasibility and cost-effectiveness. We then discussed the merits and flaws of our plan with the stakeholders involved, ascertaining from them ways to improve on our design. Finally, we crafted a **mobile Android application** and **pamphlet** to **help improve communication between farmers and cold storage facilities**, and brainstormed a number of further steps, so others might continue our work.

## Results and Discussion

The interviews we conducted with fruit farmers helped us identify causes of crop loss and current methods farmers use to extend shelf life. We researched globally used preservation methods, and discussed cold storage at two facilities in Patlikuhal. Information gathered from visiting markets in Mandi allowed us to analyze the costs and benefits of these methods and select an optimal plan.

### *Preservation Methods Currently Used by Farmers*

Both apples and mangoes suffered losses from bruising and rot, while all fruit farmers needed to contend with diseases (see Table 1). In order to avoid further loss, every farmer attempted to sell their crops as quickly as possible.

In every case, however, these fruits were left outside, under a tarp, or in crates for nearly a day. Most took precautions such as destroying or burying fruit that is bruised, rotting, or diseased before loading it for transport. Every farmer shipped in wooden cartons or plastic crates, but relatively few took further packing measures such as using newspaper to line individual fruit or wrap crates. Some mango farmers used pesticides to help control infestations of their crops, but no other farmers used chemical treatment of any sort, some believing it degrades quality.

| Crop | # of Interviews | Reported Loss before Sale | Primary Cited Reasons | Average Wait |
|---|---|---|---|---|
| **Apple** | 3 | 15-20% | Bruising, rot, disease | 1 day |
| **Mango** | 3 | 25% | Bruising, rot, disease, infes- | 1-2 days |
| **Pomegran-** | 6 | 5-10% | Disease | <1 day |
| **Vegetables** | 2 | 10% | Rot (unseasonal rain) | 12 hours |

*Table 1. Loss percentages, cited reasons, and time before sale for several types of crops.*

### *Established Methods to Increase Shelf Life*

Once we understood the problems faced by farmers, we researched methods scientifically proven to extend shelf life. We considered four main types of techniques: **chemical** treatment methods, **water** treatment, improved **packaging**, and **refrigeration**.

**Chemical treatments** sprayed or coated on fruit some time before harvest can preserve them for up to another two weeks. Most treatments either slow ripening or kill bacteria and harmful insects. While effective in helping fruit reach market, these treatments are costly without adding any value to fruit, making them **cost-prohibitive** for farmers.

**Soaking** freshly picked fruit, especially the vulnerable mango, in **hot water** (near 100° C) for about one hour will kill bacteria and infestations, and discourage other pests from attacking them. This method can help mangoes remain fresh for two to five days longer. However, this treatment requires a great deal of **energy**, rendering it **too costly** for farmers.

**Packaging improvements** can reduce losses and preserve them for another few days. Inexpensive improvements such as the use of corrugated fiberboard boxes, as well as cushioning fruit with material such as dry grass or old newspaper, will ensure more fruit survives to be brought to market. These methods are both **effective** and **within farmers' means** for crops sold immediately to market.

**Refrigeration** is a way to greatly extend the life of certain crops, and to increase the profits of farmers through selling off-season.

Our interviews with produce vendors in Mandi markets indicated major price fluctuations during the year (see Figure 7). If stored for several months, fruit might be sold for anywhere from 2-5 times the original price.

### *Extending shelf-life with Cold Storage and Controlled Atmosphere*

Our research into refrigeration indicated that of all fruits and vegetables, the storage life of **apples is extended six months**, well into the off-season where they can be sold for more (see Table 2). Other fruits and vegetables, however, do not benefit significantly enough to be sold off-season (see Figure 7). However, none of the apple farmers we interviewed north of Kullu actually stored their crops in the two controlled atmosphere facilities available nearby. When we interviewed staff at those storage facilities, both indicated that they would like to rent space, but currently **cannot find interested farmers**, despite **low costs**. Our interview with the Kullu Fruit Growers' Association revealed that farmers have difficulty organizing to rent a large chamber; furthermore, storing the **minimum 150 days** that such controlled atmosphere facilities require poses a financial difficulty for them.

### *Cold Storage vs. Controlled Atmosphere*

The controlled atmosphere facilities indicated that their space could be rented for just under **1 rupee per kilogram per month**, but would need **at least 200 metric tons** in order to fill a chamber. Alternatively, these facilities could purchase apples from individual farmers at **3-4 rupees more per kilogram than market price**, and sell the apples themselves off-season; when purchasing in this fashion, they will buy a **minimum of 50 kg** from each farmer. Both these options pose a potential profit for farmers, provided they can bring enough good quality apples that the facility will accept (see Figure 8).

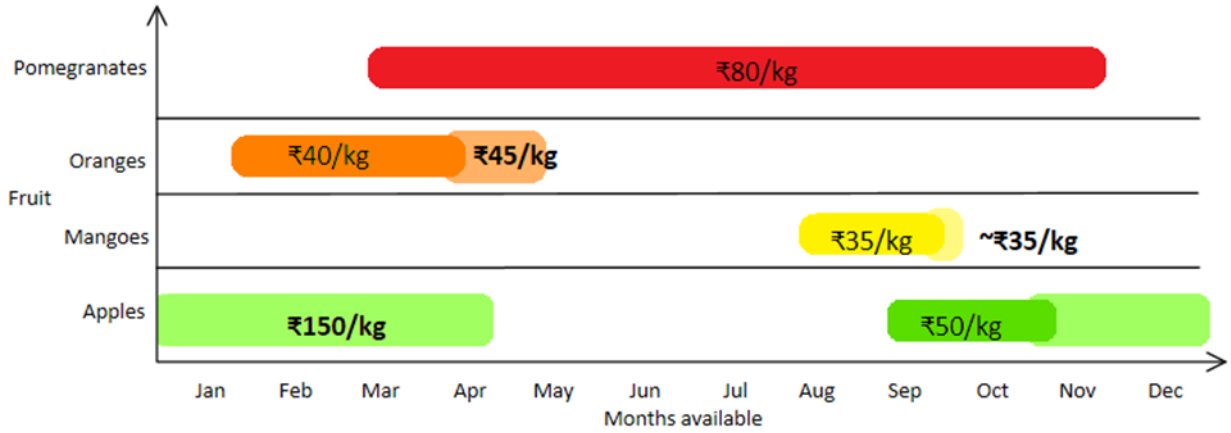



*Figure 7. Demonstration of exceptionally long cold storage life of apples compared to other fruits grown locally. Normal fruit season is shown in*

## *Discussion: Lack of Communication and Awareness*

Although it is the government's policy to help farmers by spurring the construction of cold storage through subsidies, there appears to be a disconnect between storage and farmers. The government prefers to construct large controlled atmosphere storage facilities, which are difficult for farmers to make use of. This policy may indicate failure to understand farmers' needs and means in the region. Furthermore, there is a lack of awareness on the part of the farmer both about the benefits of cold storage and about the existence of such facilities nearby.

Opportunities for farmers to learn are sparse. The Kullu Fruit Growers' Association indicated they conducted training events and workshops.

No one we interviewed knew of any government-run workshops, indicating that they may be insufficiently marketed. If farmers had more opportunity to connect and learn, they could improve their techniques, make use of storage, turn greater profits both in and out of season, eventually break the cycle currently trapping the, and improve their economic situation.

Multiple limitations on our work made it more difficult to draw relevant conclusions. The major limitation has been the language barrier, as farmers and officials alike spoke little English. This barrier has made it difficult to ask exactly the questions we wanted, and may have skewed the information we obtained; for instance, we needed to call back the controlled atmosphere facilities multiple times for clarification.

Moreover, because we gathered data exclusively through interviews, we needed to account for personal bias. Farmers may not have been inclined to be entirely honest with us, fudging numbers to inflate production or downplay losses. In addition, our small sample size, due to time constraints and difficulty in finding farmers willing to interview with us, means our data does not necessarily capture average farm size and amount produced.

## Conclusions

Cold storage is gradually expanding within Himachal Pradesh, but farmers still are struggling to use the resources at their disposal. Since many farmers are small-scale in nature, our research indicates that they are struggling to profit not only because they have few ways to ensure crops reach market in good condition, but also because they cannot afford to use things such as cold storage to their advantage. Several farmers indicated that they were aware that cold storage existed, but that they believed it was of little benefit to them. Moreover, farmers have very few means of communication with each other and potential buyers, including cold storage facilities. In order to rectify the situation, and increase the standard of living for farmers across the Himalayan foothills, better communication channels should be established.

Our many interviews indicate that farmers would greatly benefit from outreach in addition to current training programs, improving their access to useful knowledge about both caring for crops and storing them until they can be sold for higher profit. Unfortunately, a major obstacle to farmers is their relative lack of funds. The proper way to remedy the situation is to move slowly, step by step, and give farmers the tools they need to improve their livelihoods over time. If farmers were to find a way to organize and act as a group (e.g. a coop), they would be able to have greater influence over market prices and better ability to store and sell their crops when it is most beneficial to them. With greater communication and more opportunities to work together, the formation of such farming cooperatives may come to pass. In time, farmers may claim a better place in the economy of Himachal Pradesh.

## Project Outcomes

In order to help farmers coordinate and increase awareness of both good practices and cold storage, we have created **two major deliverables**. The first of these is a **pamphlet** geared at apple farmers describing good practices for handling and packaging the fragile fruit. The pamphlet also contains details of cold storage and its benefits, notably the ability for greater profit from each harvest. These pamphlets can be distributed by the Kullu Fruit Growers' Association or the government in addition to their normal workshops, as a guide to farmers.

The second deliverable is a dual purpose **mobile Android application**, also geared toward apple farmers. Part of this app will be educational, informing farmers of good agricultural practices and how to handle and care for the apple fruit. The app also will contain information on cold storage and its benefits, and how farmers can work together to rent even large cold or controlled atmosphere storage spaces collectively. The other major part will **allow farmers to find cold storage facilities nearby** and share their interest in storing there to other farmers. In this way, multiple farmers who are interested can collaborate and rent a single unit which none of them would have been able to fill individually. Through this app, cold storage facilities would be able to send updates and announcements to farmers, and help organize space rental. See Table 3 for an outline of all our project goals and how our deliverables and recommendations tackle them.

| ***Goals*** | *Increase farmer* | *Increase **Communica-*** | *Increase **Accessibility** for small* |
|---|---|---|---|
| ***Deliverables*** | · Android Application | · Android Application | · Android Application |
| ***Recommendations for the future*** | · Sign at cold storage<br>· Workshops | · Push SMS notifications | · Farming cooperatives<br>· Expanding cold storage<br>· Smaller facilities<br>· Compartmentalization |

*Table 3. Overview of project outcomes.*

### *Recommendation for Expanding and Improving Cold Storage*

We would like to encourage the government of Himachal Pradesh and private companies to attempt to set up relatively small cold storage facilities. Costs to maintain such smaller facilities will be higher than current, so work will need to be done in the local community to ensure farmers are aware of them and they are used extensively. The primary use of this cold storage will be to allow farmers to reap the benefits of off-season prices. The extra storage space will be another step in bringing fresh fruit to Himachal Pradesh year-round. As a further step, when funds become available, refrigerated trucks ought to be gradually phased in to maintain fruit quality. Moreover, new and existing storage can look into compartmentalization for greater access to smaller farmers, and ensure they have a sign out front advertising their presence.

### *Recommendations to Decrease Crop Loss*

There are a few cheap methods available to help apple and mango farmers deliver their harvest to market unharmed. Both fruits are easily bruised, even though apples may seem firm; care should be taken during harvest and storage not to drop or bounce them around. **Corrugated fiberboard boxes stuffed with dry grass or hay** is an effective way to package and transport crops. These materials give a boost to survivability in transport, and have a negligible cost.

## *Future Project Recommendations*

Further projects might be undertaken at IIT in order to continue our work. Our **app** needs further development and community participation to truly become a useful tool for farmers and storage alike. Cold storage and farmers should be able to register and find each other. Farmers should also be able to communicate and work together to bring goods to market at better times or store them together to reduce costs. Some obstacles to be overcome include understanding farmers' needs thoroughly and spreading the word to many different villages. As another possibility, a push SMS plan for farmers without smartphones could work to help them coordinate to meet needs. We are aware of at least one established network, *mKisan*, which offers such notifications to farmers.

A second possible project would be looking into the possibility of forming farming **cooperatives** in this region. Farmers usually work within their families and have wildly varying practices and associates. As a cooperative, farmers have an easier time storing crops, can support each other, and can work together to improve their livelihoods. Overall, the formation of cooperatives would be a major next step for farmers in Himachal Pradesh both financially and socially. Some major problems that need to be overcome are linking enough farmers, generating interest, and distrust and disagreements between farmers. While apple farmers may benefit the most from cooperatives in this way, any group of farmers can work together and improve their conditions.

## *Acknowledgement :*

We would to thank our advisors, Professors Jaspreet Kaur, Rik Rani, Fabio Carrera, and Svetlana Nikitina for all of their support and feedback, especially with all the twists and turns this project has taken. We would also like to Devika Sethi for all of her help and information and our TA, Vipul Sharma, for the assistance with finding and getting in contact with farmers.

**Our Website:**

https://sites.google.com/site/in17food/

**ISTP Website:**

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

# References


- Beaudry, R., & Watkins, C. (2001). Use of 1-MCP on Apples. *Perishables Handling Quarterly*, *108*, 12-16.
- Bhandari, A. K., & Vipin, V. (2016). Efficiency and related technological aspects of the indian food processing industry: A non-parametric analysis. *The Journal of Developing Areas, 50*(6), 227-243. doi:10.1353/jda.2016.0123
- Chaves, A. L. S., & Mello-Farias, P. C. D. (2006). Ethylene and fruit ripening: from illumination gas to the control of gene expression, more than a century of discoveries. *Genetics and Molecular Biology*, *29*(3), 508-515
- Choudhary, A. K. (2016). Scaling-up of protected cultivation in himachal pradesh, india. *Current Science, 111*(2), 272-277. Retrieved from http://www.currentscience.ac.in/Volumes/111/02/0272.pdf
- Fischbacher, C. A., and K. J. Marsden. "Progress in Refrigeration Science and Technology." *Physics Bulletin* 17.6 (1966): 205.
- Kalyanasundaram, J. J. (2015, June 27). Managing fruit fly in mango. Retrieved April 18, 2017, from http://www.thehindu.com/sci-tech/science/managing-fruit-fly-in-mango/article7130611.ece
- Khan, M. S. (2013). Storage Life Extension of Plum Fruit with Different Colored Packaging and Storage Temperatures. *IOSR Journal Of Environmental Science, Toxicology And Food Technology, 7*(3), 86-93. Retrieved April 18, 2017.
- Kim, T. J., Corbitt, M. P., Silva, J. L., Wang, D. S., Jung, Y., & Spencer, B. (2011). Optimization of Hot Water Treatment for Removing Microbial Colonies on Fresh Blueberry Surface. *Journal of Food Science, 76*(6).
- Kirmani, S. N., Wani, G. M., Wani, M. S., Ghani, M. Y., Abid, M., Muzamil, S., . . . Malik, A. R. (2013). Effect of preharvest application of calcium chloride (CaCl2), Gibberlic acid (GA3) and Napthelenic acetic acid (NAA) on storage of Plum (Prunus salicina L.) cv. Santa Rosa under ambient storage conditions. *African Journal of Agricultural Research, 8*(9), 812-818. Retrieved April 18, 2017.
- Mishra, S. (2002). Calcium Chloride Treatment of Fruits and Vegetables. Retrieved April 18, 2017.
- *mKisan* http://mkisan.gov.in/
- Research and development issues in grain postharvest problems in Asia - Overview of grain drying and storage problems in India (cont.). Retrieved February 05, 2017, from http://www.fao.org/wairdocs/x5002e/X5002e02.htm#Storage%20of%20food%20grains
- Roy, S. K., & Joshi, G. D. (1985, May). An approach to integrated post-harvest handling of mango. In *II International Symposium on Mango 231* (pp. 649-661).
- Sidhu, M. S. (2005). Fruit and vegetable processing industry in india: An appraisal of the post-reform period. *Economic and Political Weekly, 40*(28), 3056-3061. Retrieved from http://www.jstor.org/stable/4416876
- Singh, G. S., Rao, K. S., & Saxena, K. G. (1997). Energy and economic efficiency of the mountain farming system: A case study in the north-western himalaya. *Journal of Sustainable Agriculture, 9*(2), 26-49. doi:10.1300/J064v09n02_04
- Subramanian, K. S., Sekar, C., Meneka, S. S., & Prakash, L. V. (2014). Reducing post-harvest losses in mango in South Asia. Retrieved April 18, 2017.
- Suseno, N., Savitri, E., Sapei, L., & Padmawijaya, K. S. (2014). Improving Shelf-life of Cavendish Banana Using Chitosan Edible Coating. *Procedia Chemistry, 9*, 113-120.

# “The Footpath of Gods”

Designating a Recreational Walkway for Pedestrians in order to Promote the Quality of Life and Provide a Connectivity of Temples in Mandi Town


## Abstract

Automobiles, autorickshaws, mopeds and other modes of transportation cause congestion and pollution along popular routes beside the Beas and Suketi rivers of Mandi town, and the overcrowding makes pedestrian mobility difficult. In this project, we recommended the preliminary design of a circular recreational walkway which could promote the health of local people and provide a means of navigating the network of temples within Mandi.



***Team Members:***

Sanjay Kumar, IIT

Sandeep Singh, IIT

Madison Beck, WPI

Susannah Gray,WPI

Alima Kargbo, WPI

***Advisors:***

Dr. Bharat Singh Rajurohit, IIT

Dr. Dericks P.Shukla, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

## *Separating the Mobility of Pedestrians and Vehicles in Mandi Town*

The expansion of Indian cities has been unplanned and haphazard for decades. Just as many other cities, Mandi Town, Himachal Pradesh, falls under such criteria. With unstructured urban development, problems such as traffic congestion and pollution become a daily battle. Furthermore, the anticipation of an influx of roughly 6,000 students and supporting faculty within the next ten years will place new demands on an already strained town. In order to combat this, Mandi's urban planners must look to provide solutions via low cost infrastructure. For example, the proposal of a recreational walkway within Mandi would not only positively impact the quality of life of local residents, but also help improve transport standards and boost economic growth.

The goal of this project is to research and propose the preliminary design of a recreational walkway on the banks of the Beas river. By proposing this walkway, we hope to create a solely pedestrian space, free from motor and bike traffic, which will enrich local tourism and promote the health and wellbeing of Mandi's residents and visitors.

In order to complete this mission, we focused on three objectives. First, we determined the need for the walkway by Mandi's residents and visitors. In doing so, we were able to gauge interest from local people, as well as identify whether a walkway would best promote health and wellbeing as opposed to an alternative approach. Next, after we had garnered interest for the project, we explored and determined various design specification for the walkway. We identified these specifications by utilizing information gathered from informal surveys as well as interviews. Lastly, using data from the aforementioned objectives and drone technology, we created a preliminary design of how the walkway might appear if it were built along the Beas and Suketi Rivers in Mandi.

### *Benefits of Walkway Development*

Urban walkways have become quite popular in recent years. These paths provide a safe means of navigation for pedestrians, as well as offer residents a pleasant place to exercise and commune with nature. Improving connectivity through the use of walkways benefits automobiles and pedestrians alike. In *Sidewalk Planning and Policies in Small Cities*, it is noted that "[a] transportation system that encourages walking can reduce traffic congestion and improve the safety of motorists and quality of life." Urban walkways yield such positive effect because they provide an outlet for foot and bike traffic from already overcrowded motorways. The residents and visitors of Mandi town, Himachal Pradesh, have provided evidence which gives reason to conclude that the local population would greatly benefit from a recreational walkway.

### *Case Study on Walkway Impacts in Cities*

In some respects, Cincinnati, Ohio is similar to Mandi. As a small, densely populated city, it has, for many years, dealt with problems such as pollution that affect the progress and wellbeing of its city. According to the American Lung Association, Greater Cincinnati is the eighth-worst city for year-round pollution. The Mill Creek Watershed has contributed a great deal to this problem.

Over a span of 200 years, the Mill Creek River has provided fertile farmland and water power to support Cincinnati's industrial powerhouse. Unfortunately, the creek began to serve as a dumping ground for industrial and agricultural waste, leading to the creation of a toxic atmosphere; combined sewer overflows, nonpoint source pollution, litter, trash, and other urban refuse began to taint the river. Once city officials acknowledged the negative effects of such over pollution, they banded together to launch the Mill Creek Restoration Project. The objective of this project was to design and implement the Mill Creek Greenway Trail. Before its construction, the walkway was projected to provide community members with a space to engage in physical activity, to economically revitalize the surrounding neighborhoods and most importantly, to restore the health of the river. Following suit, even before its total completion, the first three miles of the Mill Creek Greenway resulted in an uptick in exercise activity and a noticeably healthier surrounding environment. It is estimated that, in a few years, the trail will bring business to the Greater Cincinnati area.

## Methodology: Data Collection and Prototype Development

Completion of the three objectives listed in Table 1 below was essential to the development of a preliminary design for the recreational walkway. Our first objective entails determining a need for a walkway by Mandi's residents and visitors.


*Figure 1. Oasis Bike Trail and Walking path besides the Mill Creek River.*

To do so, we surveyed both residents and visitors in Mandi to gauge whether the implementation of a recreational walkway would best address the issues hindering pedestrian mobility. In order to collect data from a diverse population, we stipulated a sample size of 145 subjects. The survey provided to Mandi's residents and visitors asked for input on their need for a walkway, safety features, preferred aesthetics, as well as which temples one visits most often.

To acquire surveys from a range of demographics, we surveyed subjects from different regions of Mandi. For example, Indira market yielded responses from many visitors to Mandi, while areas near the proposed location yielded responses from people we believe would be most-affected by the implementation of such a walkway.

We also provided an online survey which we requested the IIT Mandi community to complete for input on the preliminary walkway design. In addition to these surveys, we conducted interviews. We first conducted an interview with Hitesh Lakhanpal, the Deputy Superintendent of Police (DSP), who provided us with a unique point of view and data crucial for proper recommendations. Mr. Lakhanpal was able to elaborate on the necessity of certain safety features, provide water levels of the Beas River, as well as information on the current traffic conditions in Mandi.

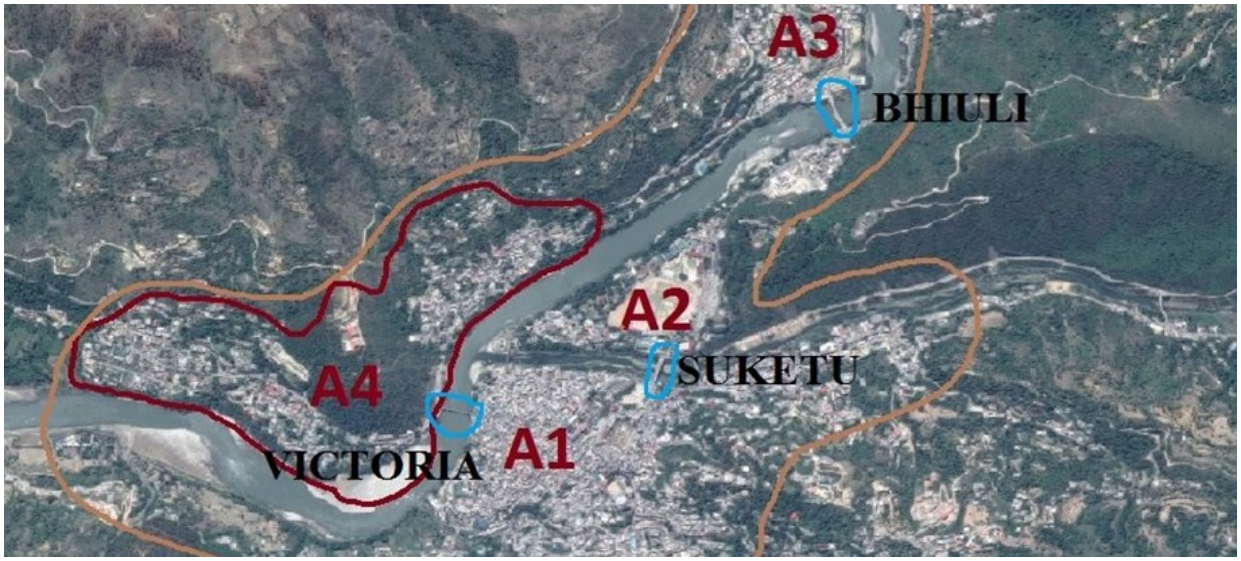



*Figure 2. Detailed map of specific locations in Mandi survey questions were disbursed*

To determine and explore design specifications of the projected walkway, we again looked to the results of the surveys completed by Mandi residents and visitors. This data was used to arbitrate the population's general preferences. In addition, we were able to conduct an interview with Parveen Kumar, a Junior Engineer of Mandi's Municipal Council. Mr. Kumar generously recommended dimensions, materials and additional information regarding permits necessary for construction. The purpose of this methodology was to incorporate design specifications and stipulations that are standard for Mandi town.

In order to complete our final objective, we utilized drone technology to take photos of the geography above areas of the projected walkway.

Using the dimensions of the landscape, we constructed a preliminary 3D design of the walkway. The features of this preliminary design are in most part a product of surveys conducted in Mandi, surveys conducted online, and interviews conducted with Mr. Lakhanpal and Mr. Kumar. Finally, we were able to determine a rough cost estimate for the preliminary design, calculated and given to us by Mr. Kumar of the Municipal Council.

## Results and Discussion

Results from 145 surveys as well as interviews with two government officials have helped us determine the plausibility of and possibilities for a recreational walkway within Mandi town.

### *Purpose for Recreational Walkway in Mandi Town*

To begin, one of the most telling questions of our survey asked for a rating of road congestion within Mandi town. Because a majority of the responses were above "5", we concluded that traffic congestion in Mandi is above average. We then proceeded to ask local people how they commonly navigate Mandi, and the time it takes to commute to various locations. With the knowledge that Mandi is already a densely-populated town for its size, we also inquired if the local people would rather use a recreational walkway instead of the roads, to which 87% of subjects answered "Yes". This verifies that there is an interest and a need for the construction of a walkway in Mandi town. The 13% of subjects who responded, "No," resulted from locals who have either had a bad experience using a walkway or are unsure of the what a walkway is.

Given that there are a large number of Mandyalis who are interested in the construction of a walkway in Mandi town, we further inquired about whether or not they have used a recreational walkway before, as well as how they might describe their experiences. 54% of the responses that answered "Yes" to having used a walkway before were either *Satisfied* or *Very Satisfied*. This data is shown in the figure below.

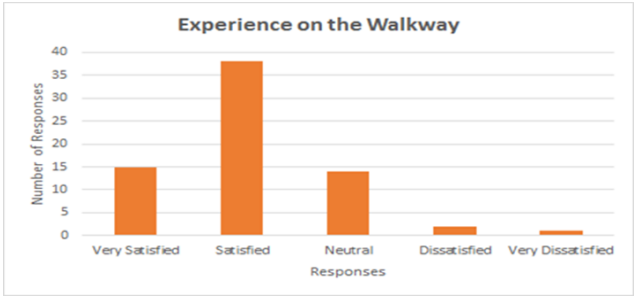



*Figure 2. Experience on Walkway Responses*

After collecting evidence of a want and need for the recreational walkway in Mandi town as outlined by the surveys, we moved forward and conducted an interview with the Deputy Superintendent of Police in Mandi, Hitesh Lakhanpal. When asked to speak about traffic congestion, the DSP remarked that, "Traffic congestion is above average, especially in the months of fairs and festivals. It is a daily problem that Mandi faces." After explaining the goals and objectives which we've undertaken, Mr. Lakhanpal was both receptive and supportive of the construction of a recreational walkway. Mr. Lakhanpal added further that the walkway must add to the beautification of Mandi, and that the walkway must appeal to its daily influx of locals and visitors. This interview facilitated in solidifying the purpose of and need for the recreational walkway.

### *Design Specifications of Recreational Walkway*

With survey responses as our foundation, we formulated a list of design specifications; we made stipulations about aesthetics as well as amenities that will be provided along the path.

One project-defining decision came from the survey question which inquired about how people might use the walkway. 91.4% of subjects answered that they would take advantage of its potential for recreational use, or physical exercise. These responses from locals and visitors express that this walkway will effectively promote healthy lifestyles.

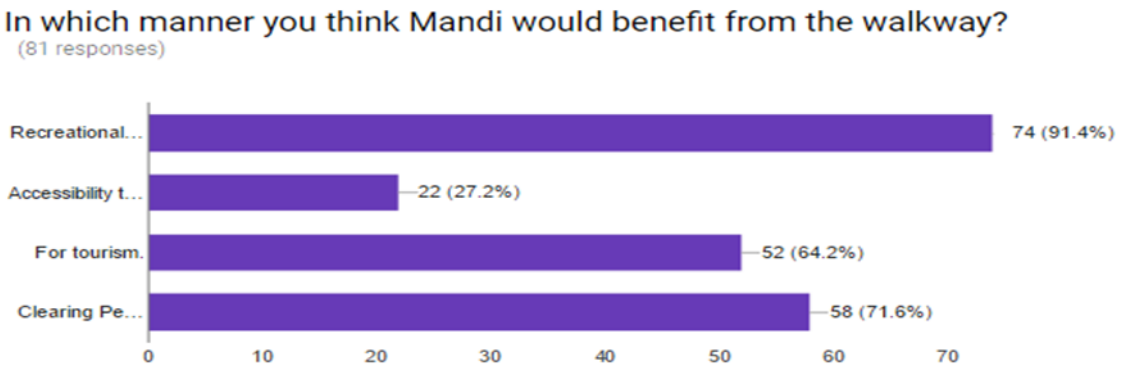



*Figure 3. Subject response on the positive impact the recreational walkway will have in Mandi town*

## *Features and Amenities*

Survey subjects also expressed interest in various recreational features and amenities: benches, street lights, swings, a bicycle lane, etc. The interviews we conducted with the Junior Engineer from the Municipal Council of Mandi and the Deputy Superintendent of Police helped us determine which features were necessary. Table 2 below indicates the suggested numbers for amenities along the recreational walkway. Some of these features will be included in the preliminary design of the walkway.

| Features | Number of Each Feature |
|---|---|
| Benches | 100 |
| Street Lights | 100 |
| Rain Shelters | 10 |
| Toilets | 3 |
| Railing | 1 (4 ft) |

*Table 2. Features suggested for the entirety of the walkway*

### *Commercial Activity*

Throughout consideration of our preliminary design, we entertained the idea of allowing vendors along the walkway. These vendors would not only generate revenue for themselves, but could also contribute to financing the walkway. The feedback we received from the surveys was marginally for the construction of a walkway that *does not* allow vending; 39.5% of subjects responded "No." After receiving such a mixed response, we consulted the DSP and the Junior Engineer of the Municipal Council during their respective interviews. The responses were consistent to the majority rule of the survey question; neither the DSP nor Junior Engineer of the Municipal Council were advocates of allowing vendors on the walkway. The most compelling reason was to avoid overcrowding.

Therefore, our preliminary design does not call for nor allow vending along the walkway. Our aim is to foster a relaxing environment for locals to use the walkway at leisure.

### *Prototype Layout for Walkway*

The preliminary design of the recreational walkway is projected to cross every main bridge in Mandi town. For the visual of the preliminary design, we have chosen to focus on two specific areas of the circular walkway. These parts include the right bank, just north of the Bhiuli bridge and the right bank just south of the Victoria bridge.

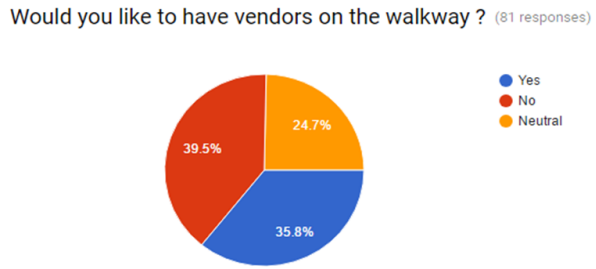



*Figure 4. Local residents/visitors show that this walkway should solely be for pedestrian use*

These areas were not chosen at random, but rather because, at these locations, national highways frame both banks of the Beas River.

These two major highways, NH 154 and NH 3, are constantly congested with vehicles, pedestrians and vendors. This crowdedness makes navigation of Mandi difficult, whether someone is commuting, on a walk for leisure or exercising. The DSP informed us that Mandi's residents typically exercise early in the morning and are often confined to using only small portions of the roads. Furthermore, we have chosen these two locations because of their proximity to the most visited places of worship based off of the 145 surveys. This walkway will not only promote health and provide an alternate commute, but will, just as notably, make it easier for locals to access their respective temples or places of worship.


*Figure 5. Map View of National Highway 154( left side Beas River) and National Highway 3 (right side of Beas River through the middle of Mandi town and crossing the Suketi Khad River)*

## Discussion

The results of our baseline assessment interviews and surveys verified that the visitors and residents of Mandi would benefit from the implementation of a recreational walkway. The responses provided vital information regarding the purpose of the walkway, design specifications, and the prototyped layout for the walkway.

The feedback received from the subjects of our survey questions indicated that residents and visitors of Mandi are highly interested in the construction of a recreational walkway. A majority of the people who participated in our surveys believe that traffic congestion is generally above average, especially during the rush hour times of day. We hypothesize that the congestion consists of people commuting home from work, temples, or other activities in town via car, autorickshaw, bicycle or foot. Initially we had proposed the idea of a bicycle lane to survey subjects, although through speculation and further investigation we recognized that regulating an area solely for bicycles would not be plausible; without 24-hour enforcement by police, the prospect of stopping every motorcycle, moped and other vehicle from entering was not likely. We made the informed decision to maintain the walkway as a solely pedestrian space. Removing motor vehicles and vendors should add to the tranquility of the area, promoting relaxation. It also allows more room for other physical activity, such as running and potential fitness stations.

While analyzing surveys, it was crucial to consider the residents' preferred areas of worship. Having a sense of connectivity between areas of worship makes for a spiritually balanced experience. Not only will the walkway connect religious temples, it will also connect the town as a whole. Although our preliminary design only outlines the proposed walkway along two areas of the Beas river, a final design would consist of similar, more comprehensive graphics.

Every proposed sidewalk must meet a set of requirements in order to fulfill city orders, as well as the needs of the local population. In this case, the local population is in need of a solely pedestrian area that offers a peaceful and healthful environment. After interviewing Mr. Kumar, we came to the conclusion that a 3-m width would best suit the needs of the walkway. The materials used for urban walkways are largely dependent on social needs. Typically, concrete is the most suitable material for urban settings because of its durability, distinct pattern and lighter color. Conversely, on trails, gravel is preferable for walking and running purposes. We decided to use concrete for this project to provide a pleasant aesthetic and promote the longevity of the walkway.

*Figure 6. Pictured on the left is the Victoria Bridge. It is neighbored by the most visited temples based off of survey results: Triloknath Temple, Neelkanth Mahadev Temple, and the Hanuman Temple*

As public spaces, walkways present the local population with a place to exercise, socialize, and navigate their surroundings. Walkways that are well-planned, well-maintained and safe provide a lasting, positive effect on city life.

## Projected Outcomes

### *Recommendations*

We have developed two models from SolidWorks to propose a preliminary design of the walkway based off of information gathered from surveys, interviews and observations of the Beas and Suketi River. Figure 8 shows a model of the recreational walkway by the Victoria Bridge, while figure 9 depicts a model of the recreational walkway by the Bhuili bridge (The appearance of benches and lights used in these images are subject to change based on what appeals most to the people of Mandi and the Municipal Council).

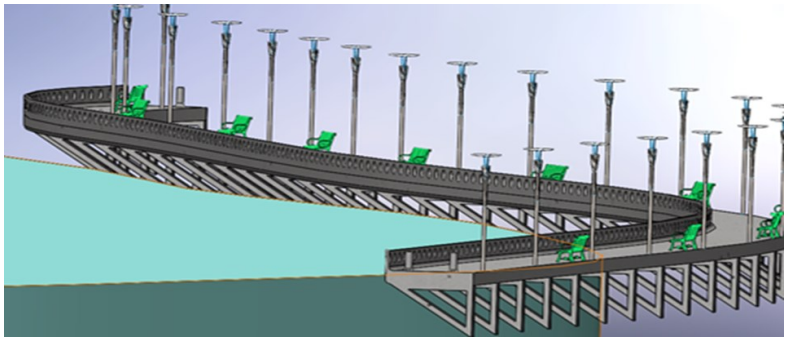
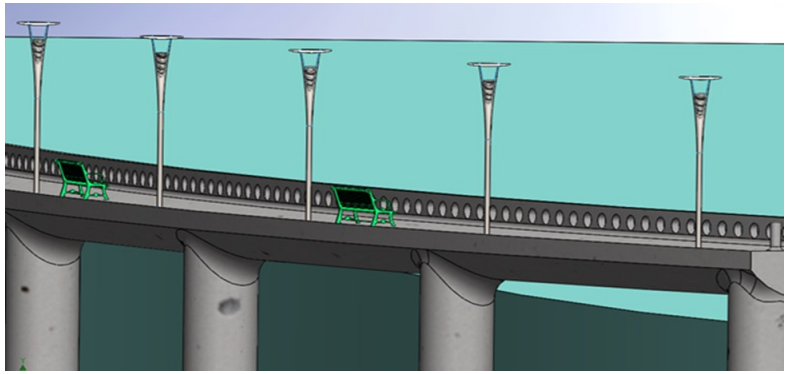


*Figure 8. 3D Model of walkway on the rocky terrain by the Victoria Bridge.*

Estimated measurements based off of data from Municipal Council of Mandi:

- 3m (z- axis)
- 12.2m(y-axis)
- 230 m (x-axis)



Estimated measurements based off of data from Municipal Council of Mandi:

- 3m (z- axis)
- 9.14m (y-axis)
- 220m (x-axis)

The features/amenities of the entire walkway will include:

- 70 benches(20m - 30m apart)
- 70 street lights(20m-30m apart)
- 1 Railing (4 ft/ 1.22m high)
- 10 rain shelters (50m -70m apart, )
- 3 toilets (100 feet apart)
- No Vendors
- Trash bins in between every four benches
- Cow traps at each entrance of the walkway
- 4 Parcourse Workout Stations

Material For Recreational Walkway: Concrete

Total cost of the entire walkway: 20 Crore (2.4 Million USD)

We recommend that the Municipal Council of Mandi take this information into consideration and, within the next year, entertain the construction of the recommended sections of the walkway.

## Conclusion

In the field, surveys of residents and visitors alike identified a want and need for a recreational walkway within Mandi town. The goal is for the walkway to be used recreationally, serving as a means of promoting the health and of Mandi's residents and visitors through physical activity. Alternatively, the walkway is also designed to improve connectivity between various temples within Mandi town, namely the Tarna Temple. Finally, it is our hope that the walkway becomes a popular destination within Mandi, so as to draw visitors and residents alike. In this way, the walkway will contribute to Mandi's economy, not only by the creation of jobs during planning and construction, but afterward, as well. We hope that the city plans on building certain parts of the walkway that would be most beneficial to the people of Mandi.

## References

Evans-Cowley, J. (2006). Sidewalk planning and policies in small cities. *Journal of Urban Planning and Development, 132*(2), 71-75. doi:2 (71)

Greenways. Retrieved from http://groundworkcincinnati.org/greenways/

Mill Creek Watershed Council.History of mill creek watershed. Retrieved from http://millcreekwatershed.org/know-the-mill-creek/history-of-mcw/

Shiv Sankar Baishya, Alyssa Bornstein, Shoubhik Debnath, Jan Keleher, Suraj B. Malode, Lena Pafumi, & Sachin K. Saini.*Traffic congestion alleviation in mandi, himachal pradesh, india*

Why india's urban development is important for the nation? (2011). Retrieved from http://www.sumit4all.com/life/why-indias-urban-development-is-important-for-the-nation#sthash.2Mzryi58.o916cIyj.dpbs

# Increasing Seat-belt Awareness Among Himachali Drivers


## Abstract

The total number of accidents in Germany in the year 2015 were 3459 and in Himachal Pradesh the number was 3010. The numbers show clear sign of lack of road safety awareness among people of India. Seat belts are one of the most important lifesaving safety measures in traffic accidents. Our project aimed at studying the attitudes of people in Mandi towards seat belt use and coming up with measures to increase awareness about seat belt use. We collected seat belt usage data in Mandi to get a rough idea of seat belt usage pattern. Through interactions with people, we determined key gaps in knowledge regarding seatbelt use among the people in Mandi. Further, we developed a real time monitoring system to check whether the passengers are wearing seat belts and to report it to the police department. Finally we devised a road safety module specifically focussed on seat belt usage to increase awareness among local Himachali drivers.



***Team Members:***

Neha Muthiyan, IIT

Siddhant Kumar, IIT

Rahul Singh, IIT

Aryan Kumar, IIT

***Advisors:***

Dr. Varun Dutt, IIT

Dr. Rajeev Kumar , IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

WPI

Indian Institute of Technology Mandi

## Road traffic injuries and fatality rates

More than 1.2 million people die each year on the world's roads making road traffic injuries a leading cause of death globally (WHO, 2015). Road accidents are a major cause of death, followed by suicide, among young people aged between 15 - 29 years (WHO, 2015). Low and middle income countries account for 90% of road traffic deaths. The world's 10 most populous countries have put 4.2 billion lives at risk due to weak road safety laws.

According to official statistics,1,46,133 persons were killed and 500,279 were injured in road traffic accidents in India in 2015 (WHO, 2015). Total fatalities in 2015, as compared to 2014, have increased by 4.6%. A total of 843 people died in road accidents in Himachal Pradesh in 2015, leading to ~3 deaths every day (Road accidents in India, 2015). Four wheeled vehicles such as cars, taxis and trucks account for 51.12% of the total fatal accidents in 2015. Moreover, rural areas of Himachal Pradesh account for 3.5 times more fatal accidents than urban areas (Road accidents in India, 2015).

As road safety is a multi-sectoral and multi-dimensional issue, joint responsibility of the government and its people is required. Road safety measures in all countries succeed by the support, common action and compliance from all stakeholders.

Seat-belts limit the movement of vehicle occupants in the event of a crash, dispersing the force of the restraint to reduce the likelihood of serious or fatal injury. They work as part of the wider occupant restraint system that includes airbags, seats, headrests and the vehicle structure itself (WHO, 2004).

Mandatory use of seat belts by front seat occupants was announced on 18th March 1999 by the Ministry of Road Transport and Highways, India. Non-compliance of the seat belt regulation is punished with a fine of Rs. 100 (~1.54 dollars) in the first instance and Rs. 300 (~4.64 dollars) for subsequent violations. As seen in figure 1 even after 18 years since the regulation of seat belt law, India has a rating of 4 out of 10 for seat belt law enforcement. The seatbelt law enforcement rating of India makes it clear that there is lack of awareness and negligence among the people of India regarding effectiveness of seat belt.

| | |
|---|---|
| National seat-belt law | Yes |
| Applies to front and rear seat occupants | Yes |
| Enforcement | 0 1 2 3 ④ 5 6 7 8 9 10 |

*Figure 1: Seat belt law enforcement rating of India (WHO, 2015)*

Given the poor seat-belt compliance in India and its proven utility, the aim of this project was to increase awareness of seat belt use among local Himachali drivers. In order to investigate the reasons for poor seat belt law compliance, our study focussed on attitudes of people regarding seatbelt use and its effectiveness. We interviewed residents of Mandi town, taxi drivers, bus drivers at Indian Institute of Technology, Mandi (IIT Mandi), traffic police officers, traffic clerk, RTO officers and driving school instructors. Further, we devised a real-time monitoring system, to be fitted in cars, which sends an alert to the traffic police if the passengers are not wearing seat belts. Finally, we devised a road safety module specifically focussed on seat belt usage.

## Effectiveness of seat belts in different types of collision and lack of awareness among people

In this section we explore the different types of collisions and study the effectiveness of seat belts in such crashes. We also explore seat belt effectiveness based on the terrain of Himachal Pradesh.

### *Types of collision*

Overturning, head-on collision, rear-end collision, side-swipe and right-angled collisions are 5 broad types of vehicle collisions. According to the Road Safety report of 2015 by the Ministry of Road Transport and Highways, 55.3% of the total accidents in Himachal Pradesh (in 2015) come under overturning category (see Figure 2). Overturning is followed by head-on collision, accounting to 23.8% of the total accidents.

*Figure 2: Overturning of a bus in Himachal Pradesh (TOI, 2016)*

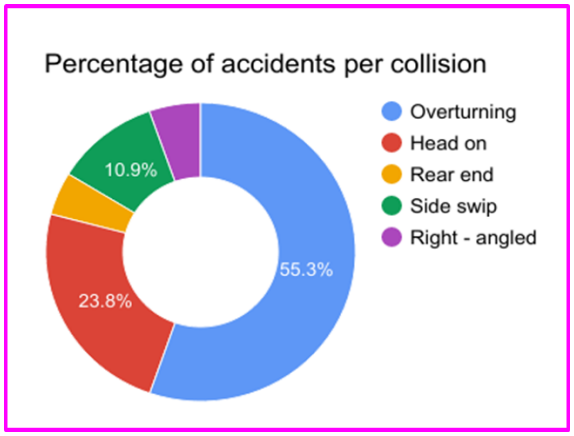



*Figure 3: Percentage of accidents per collision in Himachal Pradesh, 2015 (Road safety report, 2015)*

Further we explain how seat belts can be effective in overturning collisions, the most prominent type of collision in Himachal Pradesh.

### *Effectiveness of seat belts*

One important policy tool that has been used to combat the problem of road accident fatalities and injuries is the passage of mandatory seat belt use. The effectiveness of seat-belts depends upon the type and severity of the crash and the seating position of the passenger (Elvik R, Vaa T, 2004). In case of a crash, car occupants without a seat-belt continue to move at the same speed at which the vehicle was travelling before the crash and will be propelled forward; if the passenger is driving then he/she may bang on the steering wheel; if they are rear seat passengers then he/she may hit the back of the front seats. The passengers also have a possibility of being ejected from the vehicle completely (Elvik R, Vaa T, 2004). In contrast, passengers wearing seat belts will be kept in their seats and thus will reduce speed at the same rate as the car, so that the mechanical energy to

which the body is exposed is greatly reduced.

Seat-belts are most effective in roll-over (overturning) crashes and frontal collisions, and in lower speed crashes (WHO, 2004). As overturning is the most prominent type of collision in Himachal Pradesh and seat belts are most effective in such collisions special emphasis should be given on seat belt usage.

As shown in table 1, seat belts are proven to be effective in reducing possibility of fatalities and severe injuries during accidents. Moreover, the percentage decrease in the possibility of injury and death is also quite high.

| Type of passenger | % decrease in fatalities (if wearing seat belt) | % decrease in minor injuries (if wearing seat belt) | % decrease in serious injuries (if wearing seat belt) |
|---|---|---|---|
| Front seat | 45 - 50 | 20 | 45 |
| Rear seat | 25 | 75 | 25 |

*Table 1. Effectiveness of seat belts*

*(WHO, 2015)*

According to the American College of Emergency Physicians, ejection from a vehicle is one of the most injurious events that can happen to a person in a crash. Seat-belts are effective in preventing ejections: overall, 44% of unrestrained passenger vehicle occupants killed are ejected, partially or completely, from the vehicle, as compared to only 5% of restrained occupants.

## *Common reasons for poor compliance of seat belt law*

The total number of accidents in Germany in the year 2015 were 3459 and in Himachal Pradesh the number was 3010 (OECD, 2015). The numbers show clear sign of lack of road safety awareness among people of India. Figure 4 shows the common reasons for not wearing seat belts in India.

When people give excuse of 'availability of airbags' for not wearing seat belts they are unaware of two important points, first, that airbags are activated only in high impact crashes, so in cases of low impact crashes, passengers are not protected by airbags and though the impact is low they can get severely injured. Secondly, during extreme crashes, airbags can burst and the stakeholders may smash on the dashboard or windshield. Moreover unlike seatbelts, airbags are ineffective in roll-over crashes (Michigan State Police, Services Safety Tips, 2017). Airbags plus seat belts provide the greatest protection for adults.

It is important to remember that most crash deaths occur within 25 miles of home and at speeds of less than 40 miles per hour. This emphasizes that everyday driving from just one neighbour's home to another, to school, or to the corner store poses the greatest danger (Michigan State Police, Services Safety Tips, 2017).

Not wearing seat belts because one's driving skills are perfect ignores the fact that other drivers on the road cannot be controlled. Initially people may find seat belts uncomfortable and restricting because they are not used to wearing them. People who have made buckling up a habit feel that once their use does become a habit, there is no discomfort or inconvenience. It cannot be overemphasized that the serious discomfort and inconvenience of motor vehicle crash injury in no way compares to the imaginary discomfort or the inconvenience in wearing seat belts.

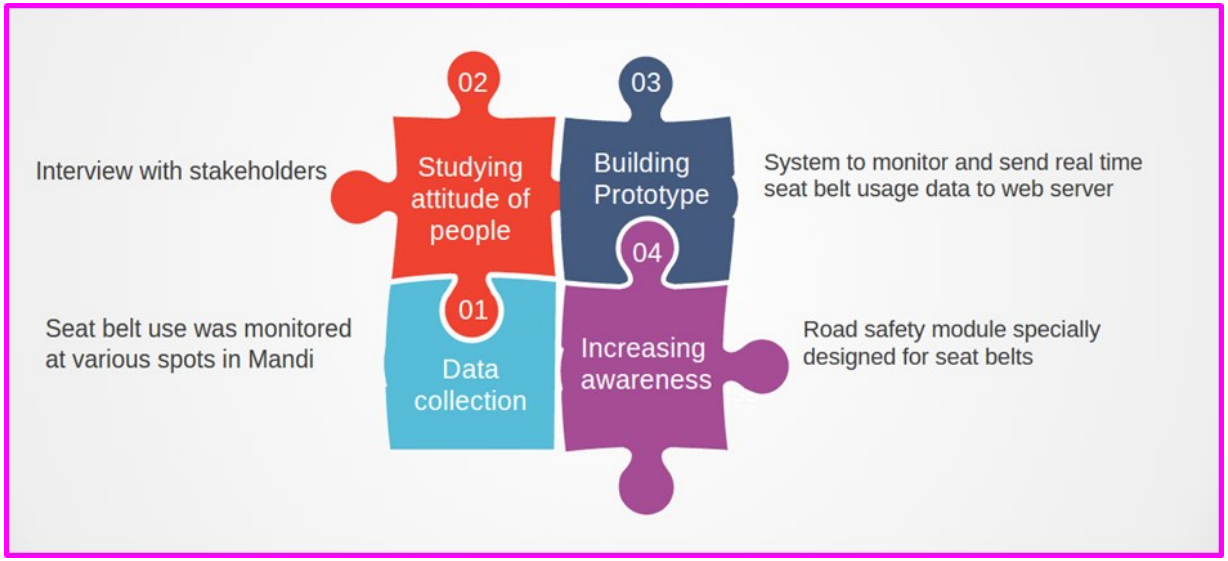



*Figure 5: Objectives to achieve the goals of the project*

## Methodology: Data collection, Interviews and Prototype Development

The goal of our project was to study the basic understanding of effectiveness of seat belts among people in Mandi and to come-up with measures to increase awareness regarding seatbelt use. We developed a real-time monitoring system to report seat belt use among people. Finally we devised a road safety module on seat belts. Figure 5 below, summarizes our objectives to achieve the above goals.

### *Objective 1: Primary data collection of seat belt use in Mandi*

To get a brief idea of seat belt use statistics and usage patterns, we collected data from various road sites in Mandi. The various sites for data collection included roads which were national highways, those which connected local areas in Mandi, and bridges. Bhiuli bridge road seemed an apt choice as it is a national highway and connects to two major cities - Manali and Jogindernagar (Figure 6). Suketi bridge and Gandhi Chowk serve as local roads connecting major local places in Mandi. Victoria bridge roads go to local places in Mandi as well as villages like Kamand.

The number of vehicles with passengers or driver wearing seat belts were counted, for a specific amount of time at each site. The seat belt use at these sites was also recorded for different time of the day.

The data was initially taken in form of tally marks and later stored in excel

sheets. Additional documentation included photographing police cars in which the passengers were not wearing seat belts.

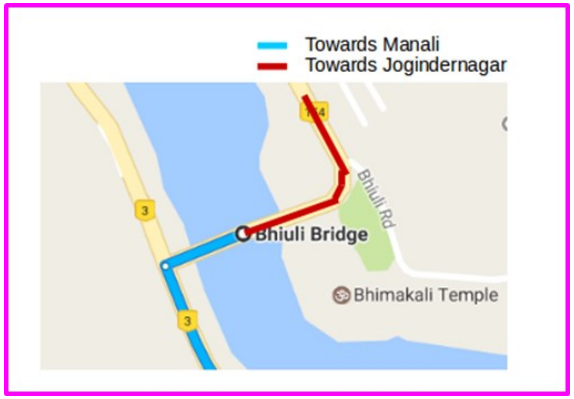



*Figure 6: Bhiuli bridge connecting to Manali and Jogindernagar(Google Maps)*

### *Objective 2: Study attitudes of people regarding seat belt use and its effectiveness*

To understand stakeholders' perception of seat belts our team identified stakeholder groups directly related to our project and interviewed them. The stakeholder groups included - road traffic department officers, local people, professional drivers and driving school instructors (Figure 7). The road traffic department officers included traffic police officers (Police Post, Mandi), traffic clerk (SP Office, Mandi) and RTO officers (RTO office, Mandi) whereas professional drivers included taxi drivers and IIT Mandi bus drivers. Different questionnaires were prepared for different stakeholder groups.

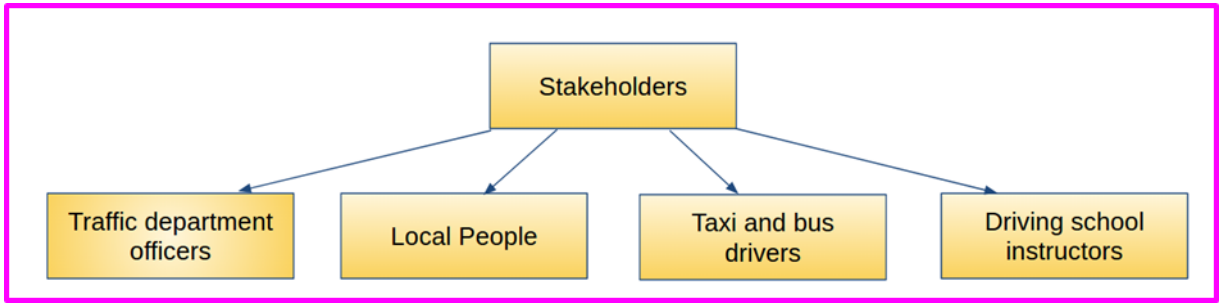



*Figure 7: Interaction with variety of stakeholders to get better understanding*

Open-ended interaction conducted with road traffic department officers focussed on measures taken by the government to increase seat belt awareness, common trends of seat belt use in Mandi, penalty for non-compliance of seat belt law, common reasons for non-compliance of seat belt law and new methods to increase seat belt usage. Interaction with local people focussed on their seat belt usage pattern and common reasons for not wearing seat belts. Professional drivers were interviewed to get a better understanding on their perception of seat belt effectiveness and their seat belt usage pattern in different cities like Mandi, Delhi and Chandigarh. Driving school instructors were interviewed to know about the amount of emphasis they give on wearing seat belts while teaching their students. All the interviews were conducted in Hindi and later translated into English.

The information gathered from the interviews was organized in a database, coded and visualised in form of graphs. The data was studied further by our team to gather insights on perception of seat belt effectiveness among the stakeholders. Additional documentation included

*Figure 8: Interaction with traffic police officers at Mandi (Kumar, 2016)*

The information gathered from the interviews was organized in a database, coded and visualised in form of graphs. The data was studied further by our team to gather insights on perception of seat belt effectiveness among the stakeholders. Additional documentation included photographs with the stakeholders. The insights gathered helped us to devise our road safety module as it gave us a clear idea of the parts to be focussed.

***Objective 3: Build a real time monitoring system which reports seat belt usage.***

Cars these days have seat belt alarms, but these systems can be easily fooled by plugging the belt from behind the seat. The prototype that we made was designed to be a fool proof solution that is also capable of transmitting real time usage statistics to the cloud and at the same time being a cheap independent device which can be fitted in any car without much hassle.

The device uses an Arduino Uno as its CPU, an IR transmitter and receiver couple to detect seat belt usage and an accelerometer to monitor whether the car is in motion or not.

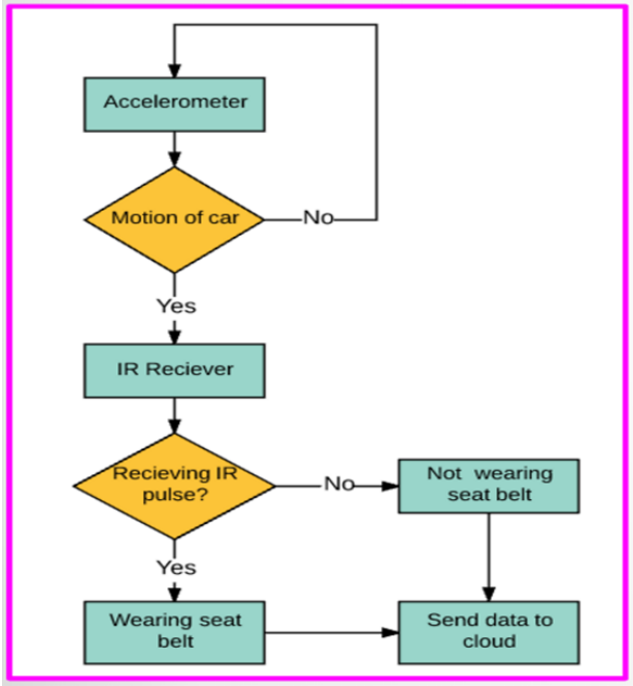



*Chart 1: Basic working of the seat belt monitoring system*

### *Motion Detection*

Accelerometer/Gyroscope sensor (GY-521) is capable of giving accelerations in x, y and z directions, a car moving with constant speed would have zero net acceleration but practically there are certain patterns/disturbances in the acceleration of a moving car (Chart 1). Our algorithm detects these patterns to determine whether the car is moving or not.

### *Seat Belt detection*

IR LED is fitted on the belt and an IR receiver is fitted on the dashboard. IR LED is used to transmit IR rays towards the receiver, this line of sight tells that seat belt is worn. This line of sight may be broken by arm movements, etc. Our algorithm also takes care of this phenomena by analysing the patterns observed in the signal and taking multiple readings at random intervals (Chart 1).

Our system also takes care of the fact that there can be multiple sources of IR in a car, eg: In car remote, sunlight, etc. These sources may fool the system into claiming that seat belt is worn when it is not. We have designed the system to use a specific Morse-code like pulse for IR LED - Receiver which is randomly initialised at boot up, this ensures that the system cannot be confused by other IR sources.

### *Uploading Data*

GSM module (SIM-800A) is used to transmit the data to a cloud database, a website is designed to access the data and visualise insights. GSM module is also capable of sending SMS alerts.

### *Use cases / market*

The device has huge potential both in terms of law enforcement and commercial market. It can be used by parents to monitor their kid's driving habits, it can also be used by fleet services, cab agencies, etc. to monitor their drivers and vehicles.

### *Objective 4: Devise a road safety module specifically focussed on seat belt effectiveness*

The road safety module consists of an educational video, the basic purpose of devising a video was to create a causal link between road safety and seat belts among the people. It also serves the purpose of answering the misconceptions and myths regarding seat belts and increasing awareness among the people. The video concentrates on road traffic accidents around the world and specifically in India and Himachal Pradesh. The video revolves around the idea of 'Unsafe at any speed' and clearly shows the role of seat belts in reducing injuries and deaths in road accidents. The effectiveness of seat belts in different types of collisions is also covered in the video.

The road safety module is to be distributed among driving school instructors so that they can show it to their students during driving sessions and also among RTO officers so that they can show it to the license applicants.

## Results

The results of our primary data collection and baseline assessment interviews confirmed our suspicions about poor seat belt law compliance in Mandi. The results also hint towards serious misconceptions about seat belts among the people in Mandi. The data are presented here by objective.

### *Objective 1: Primary data collection of seat belt use in Mandi*

Our team observed total of 365 vehicles at four different sites in Mandi. The data collection sites included Bhiuli bridge, Suketi bridge, Gandhi Chowk and Victoria bridge. Data was collected on different days and for different time periods. Out of the 365 vehicles observed only 38 vehicles (10.41%) were recorded to use seat belts Figure 9. Only 2 out of 38 (5.26%) vehicles were observed in which the driver as well as the front seat passenger were wearing seat belts. No vehicle out of the 365 had rear seat passengers wearing seat belts.

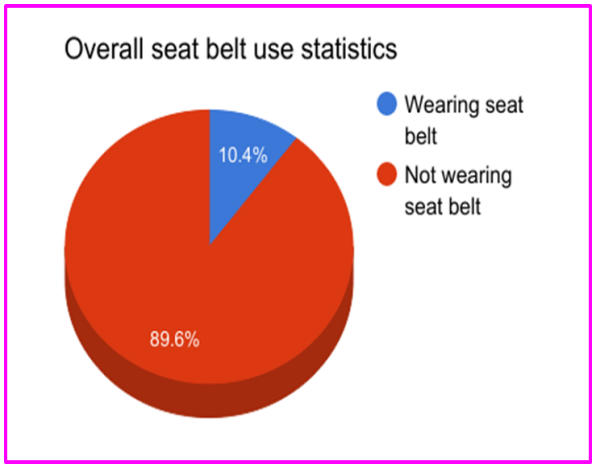



*Figure 9: Overall seat belt use statistics from all sites*

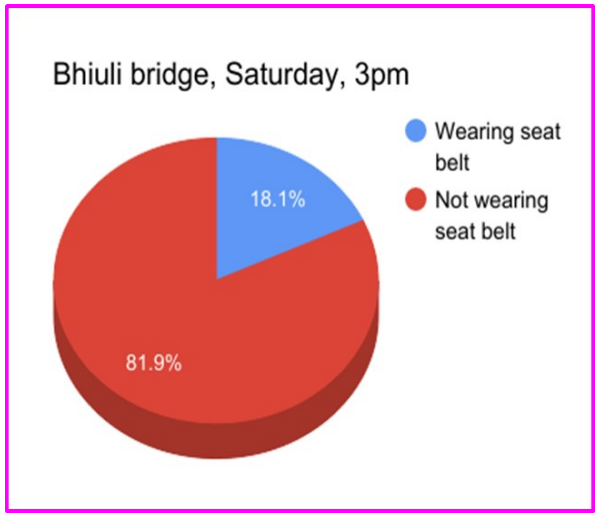



*Figure 10: Bhiuli bridge seat belt use statistics*

As seen in figure 13 lowest seat belt usage was recorded at Gandhi Chowk. Roads at Gandhi Chowk connect to local areas like Indira market, Chauhatta market and Jail road. According to the police officers, people tend to not wear seat belts for short distance journeys. Hence, this explains the low seat belt usage at Gandhi chowk.

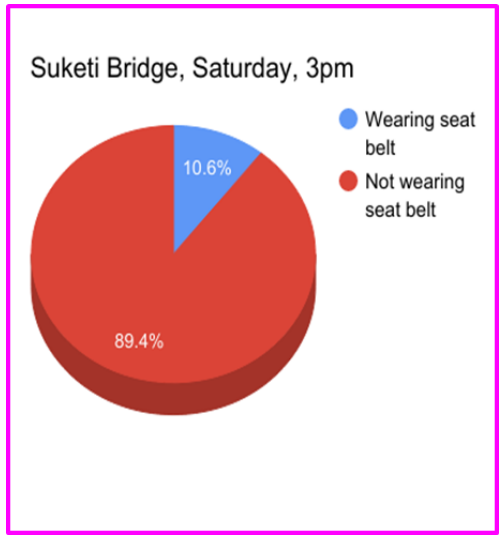



*Figure 11: Suketi bridges eat belt*

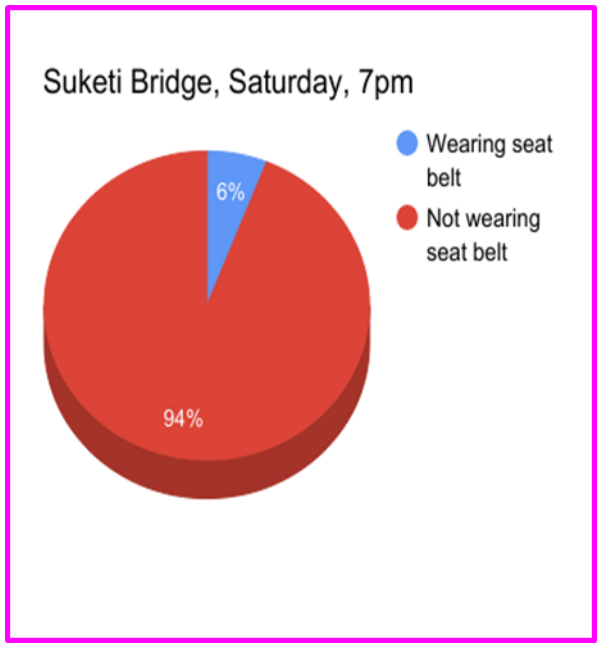



*Figure 12: Suketi bridge seat belt use statistics*

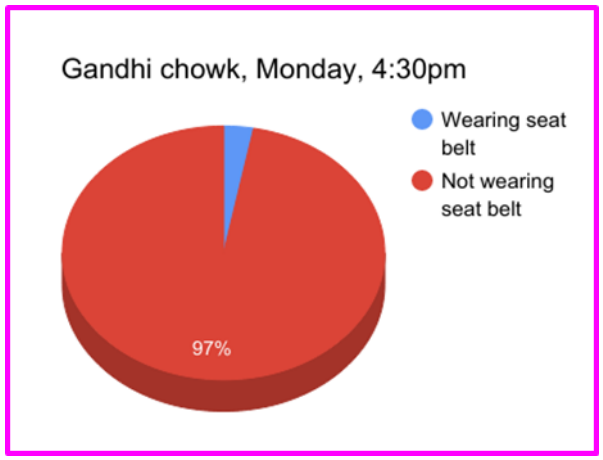



*Figure 13: Gandhi chowk seat belt use statistics.*

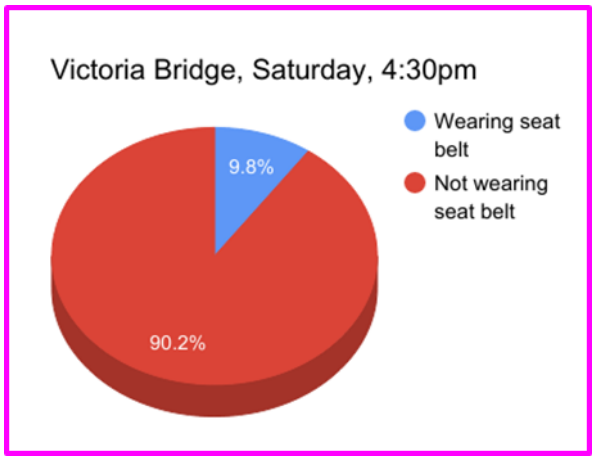



*Figure 14: Gandhi chowk seat belt statistics.*

From figure 11, figure 12 and figure 14 we conclude that seat belt usage percentage was similar at Suketi and Victoria bridge.

### *Objective 2: Study attitudes of people regarding seat belt use and its effectiveness*

To understand stakeholders' perception of seat belts our team identified three stakeholder groups directly related to our project and interviewed them. The three stakeholder groups included - road traffic department officers, local people, professional drivers and driving school instructors.

According to the traffic police, seat belt law compliance is between 10-15% in Mandi. They have observed that the people from other states tend to wear seat belts unlike the local people in Mandi. They also mentioned that government of India is soon going to update the road traffic regulations which will also include a hike in seat belt law penalty from 100 rupees to 1000 rupees. They feel that the hike in penalty is most likely to cause a reform in seat belt law compliance in India. Traffic police officers strongly believe that the penalty for breaking road safety rules are a major motivation for the people to follow rules. They also agreed upon lack of awareness among the people regarding seatbelt use. The traffic police cut ~100 - 150 'chalans' or fine-tickets per month in Mandi town. When asked about a new technology to monitor seat belt use, they were interested in the idea.

Around 83.3% of the taxi drivers in Mandi strongly believe that seat belts should not be compulsory in Himachal Pradesh. When asked about the reason, they said

that seat belts should be used in plain regions and not in mountainous regions. According to the taxi drivers, in hilly terrain there are high chances of a vehicle going down the cliff or overturning. Seat belts restrict movement of the passenger and if the vehicle falls into a river then passengers will die as they cannot get out of the car.

Bus drivers in hilly terrains are not well aware of seat belt usage. We found a few drivers who think that seat belt is not mandatory by the law and its usage restricts their movement on hilly curves. There is a serious need of creating awareness about seat belt effectiveness amongst the bus drivers as not even a single driver was observed wearing a seat belt around Mandi district during our study. After all, a single driver is responsible for safety of fifty people.

90% of the local people in Mandi agreed that seat belts are useful and should be worn irrespective of the terrain but such compliance is not reflected in the primary data collection. 74% of the local people interviewed learned driving cars from their parents and their parents didn't emphasize on wearing seat belts. Most of the people ignored seat belt alarms fitted in their cars.

From the interaction with driving school instructors we found that very less emphasis is given on seat belt usage during driving lessons. We also enquired the officers at Road Transport Office, Mandi (RTO) regarding seat belt monitoring during license tests. The officers said that they do check whether a person is wearing seatbelt during driving license test but he/she isn't declined license for not wearing seat belt.

## Discussion

The results stated above clearly hint towards a major lack of seat belt use awareness among the people of Mandi. During interviews common people agreed that seat belts are effective in road traffic accidents but we cannot see such compliance in the primary seat belt use data collected. This observation hints towards negligence of road safety among the people of Mandi. The taxi drivers hold on to a myth that using seat belts restricts passengers from coming out of the car in case the car falls down the cliff. However the taxi drivers don't know the fact that the best chance of survival rests in remaining conscious and uninjured. The greatest danger lies in the impact that precedes the crash. If a passenger is not using a seat belt, it is very likely that he/she will be knocked unconscious or be severely injured. If he/she is belted, it's very likely that he/she will be able to unbuckle and get out of the car (Michigan State Police, Services Safety Tips, 2017). The traffic police officers never penalise rear seat passengers for not wearing seat belts. Emphasis should be put by the government to increase seat belt use among rear seat passengers. Moreover, license applicants must be refused a driving license for not wearing seat belts during tests. As of now the applicants are granted license regardless of seat belt usage during tests.

Buses and trucks are generally slower than passenger cars. They also have longer deformation distance and greater distance for passengers to move in case of forward impact.

Therefore they don't have seat belts. But considering the scenario of Himachal Pradesh, where buses are prone to overturn and fall down the cliff, seat belts must be enforced in buses for drivers as well as the passengers. Currently, there is no mandatory seat belt law for passengers in buses. The young generation is also most likely not advised to wear seat belts by their parents as the parents themselves are unaware of its advantages.

It is evident that the Government of India needs to go beyond its current initiatives to increase road safety awareness among people. We recommend enforcement of an educational programme on road safety. Advertisements on seat belt advantages can be hosted on television and social media to increase the awareness. In case of an accident, newspapers should include in the report information about whether or not a passenger was wearing a seat belt and was he/she saved or injured less in the accident because of seat belt usage. This will help people link seat belt usage with safety and preservation of human life, and not with a penalty. If people start linking seat belts with safety then major improvement in seat belt usage will be seen.

The real time monitoring system can be useful to increase seat belt usage as people will tend to wear seat belts if they know that the police and concerned authorities are continuously getting reports of their seat belt use. The prototype recommended by our team is an internal monitoring system and so the prototype needs to be installed in cars. An external system, based on image processing, should also be developed to monitor seat belt usage.

## Project Outcomes

The root causes of low seat belt use in Himachal Pradesh were analysed. Several misconceptions and knowledge gaps were observed through our study. Currently there is availability of seat belt alarm systems in new cars but people often tamper them. We developed a non-tamperable real time monitoring system which sends the seat belt usage data to the cloud. This data can be accessed through a website built by our team and can be analysed by experts (link to the website - http://seatbelt.esy.es/) (Figure 15). Such analysis of data can help policy -makers devise appropriate policies. As shown in figure 16, seat belt usage data is visible on the website. The 'Timestamp' field implies time at which the data was recorded, 'Vehicle Id' denotes a particular vehicle and 'Wearing belt' is a boolean value where '1' denotes usage of seat belt and '0' denotes otherwise.

We have also devised a road safety module specifically focussed on seat belt usage. This module basically consists of a video which is to be distributed among driving schools and traffic police officers to increase awareness and importance of seat belt usage among the people.


*Figure 15: Screenshot of the website built by our team*

| Timestamp | Vehicle ID | Wearing belt (boolean) |
|---|---|---|
| 2017-04-23 20:32:38 | 1 | 1 |
| 2017-04-23 20:34:04 | 2 | 1 |
| 2017-04-23 20:36:51 | 3 | 1 |
| 2017-04-23 20:36:57 | 2 | 1 |
| 2017-04-23 20:37:08 | 3 | 1 |
| 2017-04-23 20:37:18 | 4 | 1 |
| 2017-04-23 20:37:29 | 5 | 1 |
| 2017-04-23 20:37:40 | 6 | 1 |

*Figure 16: Screenshot of the seat belt wearing statistics presented on the website*

## Conclusions

Due to the mountainous terrain and narrow roads, Himachal Pradesh has poor road safety and there are very high chances of road accidents. Our study reveals, lack of awareness regarding advantages of seat belt among the people of Mandi. Moreover, the people have held on to myths about seat belts and thus it will be very difficult to change the mindset of people. Carelessness is also seen on the part of traffic police and RTO officers. Government should take steps to demonstrate causal links between seat belt usage and life safety among the people.

The real time monitoring systems will always prove to be helpful to improve seat belt usage.

**Acknowledgements:**

Our team would like to thank the following individuals for their significant contributions to the project:

- Dr. Varun Dutt for letting us use his car for testing of the prototype and also for his guidance throughout the project
- Dr. Fabio Carrera and Dr. Svetlana Nikitina for their invaluable suggestions.
- Traffic police officers at Mandi and the Traffic clerk for their valuable time in our assessments.
- Mr. Manoj Kumar and the bus drivers at IIT Mandi for interacting with us amidst their busy schedule.
- Mr. Nilesh Dixit, Teaching Assistant of the project for guiding us in the interview preparations.

## References:


- WHO Global Road Safety report, 2015. Retrieved from
- http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/
- Road accidents in India, Ministry of Road Transport and Highways, 2015. Retrieved from
- http://pibphoto.nic.in/documents/rlink/2016/jun/p20166905.pdf
- Elvik R, Vaa T, eds. The handbook of road safety measures. Elsevier, 2004. Retrieved from
- https://books.google.co.in/books/about/The_Handbook_of_Road_Safety_Measures.html
- Seat-belts. Texas, United States, American College of Emergency Physicians (ACEP),2002. Retrieved from
- http://www.acep.org/patients.aspx?LinkIdentifier=id&id=26106&fid=1348&Mo=No&acepTi tle=Seat%20Belt%20Fact%20Sheet
- WHO, Safety restraints report, 2004. Retrieved from
- http://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/safety_restraints_en.pdf
- Michigan State Police, Services Safety Tips, 2017. Retrieved from
- http://www.michigan.gov/msp/0,4643,7-123-1878_1711-13689--,00.html
- Causes of death in India in 2001–2003. New Delhi, Registrar General of India, Government of India, 2009. Retrieved from
- http://www.cghr.org/wordpress/wp-content/uploads/Causes_of_death_2001-03.pdf
- Toyota's Regional safety campaign, Indian News and times, 2017. Retrieved from
- http://www.indiannewsandtimes.com/2016/08/29/toyotas-regional-safety-campaign-advocates-importance-wearing-seatbelt/
- Usage of seat belts, NDTV, 2016. Retrieved from
- http://doctor.ndtv.com/storypage/ndtv/id/3706/type/feature/Safety_belts_Why_you_should_use_them.html
- Wear belt even if you are in rear seat, The Hindu, 2016. Retrieved from
- http://www.thehindu.com/news/cities/bangalore/wear-belt-even-if-you-are-in-rear-seat/article6093001.ece

# A New Perspective on Domestic Heating in Mandi


## Abstract

Rural villages in the Mandi District lack effective methods to heat homes during the winter. Throughout this project we evaluated current heating techniques and conducted preliminary tests of a new heating method utilizing packed bed thermal energy storage technology. Through our research, we determined that packed bed technology is not the solution to heating in the Mandi District; however, it could be applicable farther north in India. We recommended investigating alternative heating technology for the Mandi District that reduces the negative environmental and health effects of the region's current methods.



***Team Members:***

Vadluri Vivek, IIT

Shailesh Meena, IIT

Thomas Brown IV, WPI

Karina Larson, WPI

Christopher Salomone, WPI

Nicolette Vere, WPI

***Advisors:***

Dr. Satvasheel Powar, IIT

Dr. Dhiraj Patil, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

## Case for Improved Heating Methods in Mandi District

Determining efficient ways to heat rural homes is a problem for many developing countries due to limited access to modern resources. This leaves minimal options to produce reliable clean heat within rural homes. Worldwide, wood is the main resource used to heat rural homes despite its negative long-term environmental and health impacts (Naeher et al., 2007). Therefore, villages worldwide lack safe and effective methods to heat their homes during the winter months.

The Himachal Pradesh region of Northern India is experiencing these same challenges which are exacerbated by its mountainous environment and varying seasonal temperatures. The Mandi community could benefit from an efficient and environmentally friendly means of heating rural homes. Any future heating method will have to overcome the same challenges, such as a lack of energy sources and minimal finances, in order to be a viable option for the people in the region. Throughout this project we determine if packed bed technology is a viable option for a future heating method that would benefit the region's health and environment.

Rural villages in the Mandi District lack safe and efficient methods to heat their homes during the winter months. Our team worked with the professors at the Indian Institute of Technology (IIT) to research and test the efficacy of packed bed technology as a means for heating homes efficiently and effectively. Our project's mission was to develop recommendations for a domestic heating system utilizing packed bed technology in the Mandi District. The objectives developed to achieve this mission were as follows:

1. Understand current methods and opinions of Mandi homeowners regarding domestic heating.
2. Determine the energy required to heat an average Mandi home.
3. Validate small scale packed bed technology using a physical model.

## Challenges of Rural Heating in the Mandi District

Access to modern heating methods is often limited or nonexistent in communities around the world. About 2.5 billion people worldwide depend on traditional biomass fuels for heating and cooking (Ekouev 2012). Many rural communities in Himachal Pradesh, including villages in the Mandi District, heat their homes with wood, burning fires, or stoves (Jeuland 2015). These fires are inefficient and harmful to the environment. In addition, burning wood in enclosed spaces can cause negative long-term health effects such as decreased lung function (Naeher et al., 2007). The kind of packed bed technology that is currently used in industrial applications has the potential to serve as the major component in an alternative source of sustainable residential heat.

### *Climate in Mandi*

The state of Himachal Pradesh has varying climate conditions across the region due to altitude variations caused by the Himalayan Mountains. There are two distinct seasons in the Mandi District of Himachal Pradesh: winter and summer. These seasons are known for their drastically different weather patterns. Above is a table outlining average low temperatures in Mandi for each season (Figure 1). These conditions make it difficult for a single method of heating to be effective.

in all locations of the region, thus an adaptable method of heating is needed.

| Season | Month | Average Low Temperature (Fahrenheit) | Average Low Temperature (Celsius) |
|---|---|---|---|
| Winter | October | 67.8°F | 20.0°C |
| | November | 56.7°F | 14.0°C |
| | December | 48.4°F | 9.0°C |
| | January | 46.4°F | 8.0°C |
| | February | 50.7°F | 10.0°C |
| Summer | March | 60.6°F | 16.0°C |
| | April | 72.1°F | 22.0°C |
| | May | 79.5°F | 26.0°C |
| | June | 83.3°F | 29.0°C |

*Figure 1. Monthly Low Temperatures in Mandi*

## *Typical Building Materials*

There is a total of 406 villages in the Mandi District with 99.5% of them defined as rural villages (Census of India, 2011). In these remote villages, construction materials for residential dwellings are typically limited to the resources provided by the region, including timber, cement, slate, brick, wood, and mud. These structures are very simple with a majority containing only one or two rooms. Wood and cement are the two main resources utilized for constructing dwellings in the area. Their abundance makes them the fundamental materials for dwelling construction in Northern India.

The villagers take advantage of the materials that surround them in the mountains and local communities. The foundations of their homes are typically cement. The walls are then constructed using stones, as well as cement, and finally the roofs are created using slate rock as shingles. An example of a typical rural home can be seen in Figure 2. These homes allow for the interior to remain cool during the summer months, however, they are not very warm during the winter. Typically, construction of these homes requires only simple tools and techniques (Dave, 2016). Understanding the composition of a typical Mandi home will be necessary to determine the amount of heat these structures require. Our project will attempt to calculate this energy for use in the design of a heating system.

*Figure 2. Rural Home in Mandi*

## *Current Heating Methods*

In order to understand the need for packed bed thermal energy storage systems in the rural regions of the Mandi District, it is necessary to identify the current heating methods used in this area. The simplistic nature of the homes, along with a lack of available resources, presents many challenges regarding heat for the winter. The locals most often turn to firewood and blankets to keep warm. Predominantly, fires are used for cooking in Chulha stoves throughout the day and the radiant heat is used for warmth at night. This cooking and heating technique is a traditional practice among local people and therefore they may resist change.

Wood fired stoves as they are used in Himachal Pradesh are an inefficient heating method that consumes a large amount of resources. In addition, the locals spend approximately 2.7 hours per person per person per trip in rural areas

to collect firewood (Aggarwal & Chandel, 2010). One major concern is that this current heating method could lead to deforestation. The federal government acknowledged this problem with a timber ban in the 1900's (Ministry, 2017) but it was ineffective. It has since been revised because the community disregarded the law and continued to collect firewood as it was their only source of fuel. As this practice continues, the Mandi community will have difficulty collecting firewood as it becomes less available. The end goal of developing a packed bed technology heating system is to reduce the overall consumption of wood in this region through using the cooking stoves that are already in place as an energy source for the system.

## Application of Packed Bed Technology for Heating

A packed bed thermal energy storage system stores heat by pushing a working fluid through a container filled with packed units. The packed bed system is comprised of three components: an energy source, a packed bed, and a distribution method. The heat source warms the working fluid which in turn warms the packed units contained in the packed bed. The packed units retain the heat for an extended period of time until it is dispersed by the distribution method. A simple diagram of a packed bed system can be seen in Figure 3.

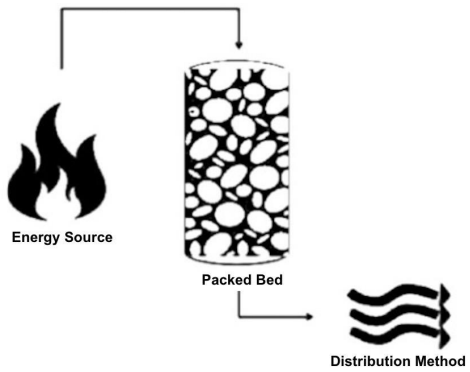



*Figure 3. Packed Bed Technology Diagram*

### *Packed Bed Thermal Energy Storage Technology*

The energy source component in a packed bed system is defined as the method by which the working fluid is heated for the packed bed system. The working fluid in this system can be air, gas or liquid. Once power is provided to the energy source, the working fluid is heated to and pushed through the system to the packed bed component via the distribution method. The distribution method is dependent on the physical state of the working fluid. If the working fluid is in a gaseous state, the distribution method could be a fan. Furthermore, if the working fluid is in a liquid state, the distribution method could be a pump or siphon. Either version of the distribution system would be powered in a similar fashion to the previously described heat source.

The packed bed portion of the system is charged with the energy produced by the heat source. The packed bed component is a collection of equal-sized packed units of the same material in box or cylinder shaped container. A packed unit is a container that holds a substance chosen for its heat retention ability. The heated working fluid is pushed through the packed bed by a distribution system which then heats the packed units. The packed units store this thermal energy to be later released.

The size of the packed units plays a large role in the effectiveness and heat conductivity of the system. If the packed units are larger, then there will be more surface area for heat exchange with the working fluid. Conversely, larger packed units reduce the total pressure of the entire system due to the low number of units. A lower pressure could make movement of working fluid throughout the system more difficult. A balance

between adequate pressure and heat exchange is required for an efficient system ("Segmented" 5).

### *A Latent Heat Thermal Storage System Using Paraffin Waxes*

In 1981, undergraduate students at the University of Delaware investigated the feasibility of paraffin waxes as the phase change material within the packed units of a packed bed thermal storage system. The students developed a system that consisted of thousands of 16 oz. beverage cans containing paraffin and a septic tank that held the cans. In this study, water was used as the working fluid to transfer the heat. The results of the study showed that over an 8-hour time period, the paraffin was an efficient material for storing the thermal energy of water.

thousands of 16 oz. beverage cans containing paraffin and a septic tank that held the cans. In this study, water was used as the working fluid to transfer the heat. The results of the study showed that over an 8-hour time period, the paraffin was an efficient material for storing the thermal energy of water.

The system developed at the University of Delaware is an example of a small scale application of packed bed thermal energy storage technology. Although this technology is used in industry on a much larger scale, this study confirms that it can be scaled down significantly. This study also verifies that these systems can be made out of resources and materials common to the Mandi region (soda cans, cement, and water). We learned of this study through an interview with Professor Guceri of Worcester Polytechnic Institute's mechanical engineering department who was the faculty advisor of this project. This study informed our team of the use of phase change materials in small scale packed bed systems. Ideally, our system would function in a similar manner with comparable results.

## Methodology

In order to understand the current methods and opinions of Mandi homeowners regarding domestic heating, we conducted interviews in four villages in the District. In this region, the most abundant source of energy for a packed bed heater is the wood fires that are already being used for cooking and heating. Due to this fact, we targeted villages that would most likely use wood as their primary source of fuel. After research and a discussion with our Indian teammates we decided to survey the following four villages: Baggi, Kataula, Kahra, and Neri.

A total of 30 interviews across the four villages seen in Figure 4, were completed. We began our interviews with an explanation including that we were students from IIT and that we were performing interviews in surrounding villages regarding heating methods. Then we asked each household a set of standard questions in order to understand the resident's heating methods and opinions.

The first three interview questions were informed us of each homeowner's current heating method and electricity availability. We asked these questions to determine the most common heating methods used and later inform our team's recommendations for using packed bed technology as a heating source in this region.

The second half of the interview consisted of open ended questions that focused on the homeowners' opinions. The first question provided us with the number of people living in the home and whether or not the family lived in their home year-round. This would help us determine if the residents lived in their house during the winter months and if they had an obvious need for a new heating technology. The next question


*Figure 4. Four Villages Surveyed*

concerned the common cooking and heating fuel that the residents used. This question was intended to determine if firewood is commonly used and if there was a need for the technology from an environmental perspective.

The last three questions determined if there was a need for a new technology from the homeowner's perspective. These questions also helped us determine potential characteristics for an improved heating system using packed bed technology. The overall results of these interviews were used to provide recommendations for a heating system design that fulfilled the needs of Mandi homeowners.

In addition to our interviews, we also measured several physical characteristics of the resident's homes to later calculate the heating requirements of each structure. With the permission of the homeowners, we ascertained the volume of the room, the wall thickness, the wall material, the number of windows, and other thermal characteristics. These factors were all inputs to the computerized model that helped our team calculate the energy needed for a heating system.

In order to determine the energy required to heat an average Mandi home, we created a computerized model of a Mandi home. The computerized model required a variety of home characteristics as inputs and output the energy required to heat that home. The purpose of the model was to determine a range of building sizes and features for the development of a heating system using packed bed technology. Based on the resultant energy values, we used this range to provide recommendations for a future heating system design for these homes.

The model itself was programmed using the Engineering Equation Solver software. The model consisted of variables that represent the thermal characteristics of a home such as wall thickness and window count. These values are then used in heat transfer equations to produce the total heat loss due to convection and conduction. This resultant heat loss represents the energy required by a packed bed heating system to keep the room at a specified temperature. In our instance, we used a room temperature of 13°C and an external temperature of 8°C based on average low temperatures in December in

in the Mandi district ("Weather" 1). To produce a target range of building sizes and characteristics, we inserted each individual home into the model and analyzed the results.

In order to validate small scale packed bed technology using a physical model, we designed, built, and tested a proof-of-concept packed bed system. Packed bed technology is currently not being used for residential applications so we designed a smaller example in order to ascertain whether or not this technology functions on such a small scale.

We divided the system into two cycles, a charging and discharging cycle as shown in Figure 5. The charging cycle pumps water using a one eighth horsepower pump. We chose water as our working fluid because it transfers heat easily into the packed bed system. The water is pumped into a plastic container holding the soda lime glass beads which store heat. We chose Glass Beads because they were available in the Thermofluid lab at IIT and materials with a higher heat transfer coefficient would have taken over 4 weeks to deliver to IIT. The discharging cycle also used water that was pumped into a coiled copper tube acting as a radiator for the heat. We chose copper because it has a high coefficient of heat transfer and was readily available in the lab. The entire system was insulated with fire clay bricks to store heat. The system was not designed with cost as a consideration because we were building the proof-of-concept purely for experimental purposes. The system was simply being used to test if the technology could be scaled down and store heat effectively. The system is not intended to be used in homes as it is currently built.

Next, we ran a variety of tests using the packed bed system. First, we tested the discharging cycle without any of the glass beads. This was our control to observe how long water would store heat in the absence of the glass beads. We recorded the amount of time the packed bed took to cool to room temperature. For the second test, we ran the discharging cycle with 5mm glass beads acting as our packed units. The system was designed to

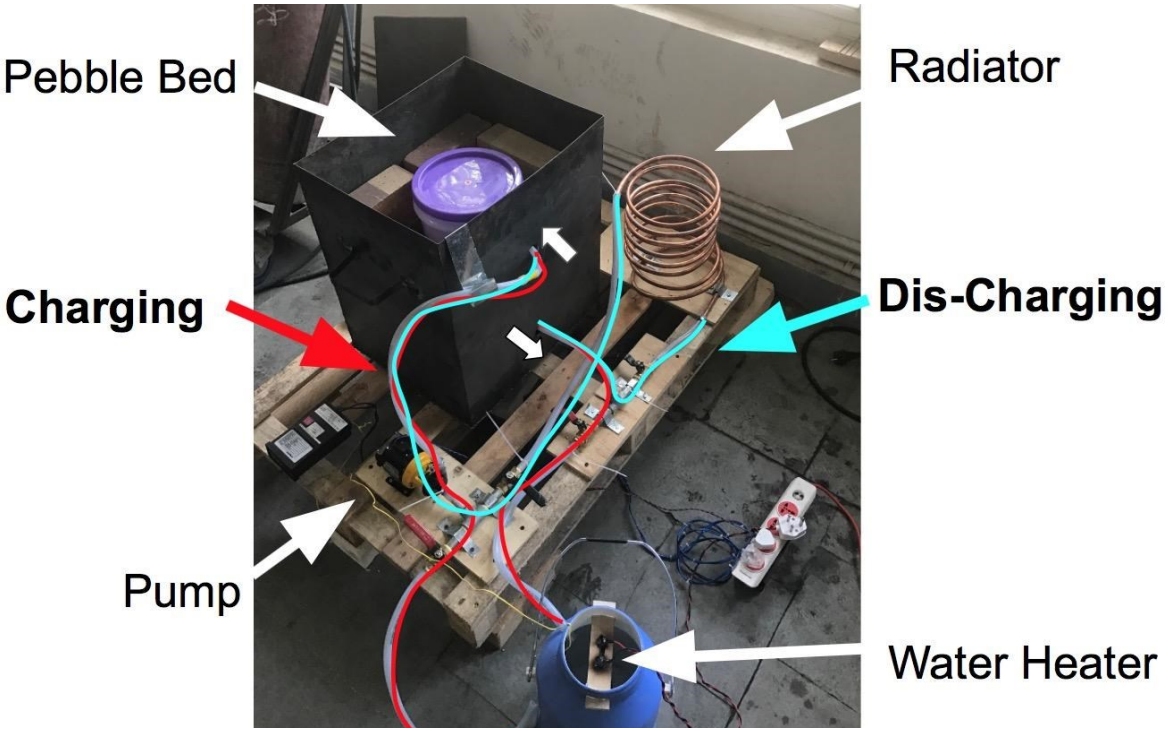



*Figure 5. Physical Model*

to be heated using the charging cycle over a long period but to reduce the amount of time required to prepare each test, we preheated the water to 80°C and then circulated it into the system. The charging cycle ran until the beads reached 80°C. Then we turned each valve to disable the charging cycle and enable the discharging cycle. We recorded the temperature every 5 minutes for the first hour and every 10 minutes for each consecutive hour until the water in the packed bed reached room temperature. We compared system cooling time without beads and with beads to see if the packed bed could effectively store heat for a longer period of time. We conducted two sets of tests using the same procedure.

## Results and Discussion

The following section includes the results and discussion that follow our team's methodology as outlined above.

### *Results of Village Surveys*

Completing interviews in thirty different homes in the Mandi District helped our team determine the current state of domestic heating in the region. Specifically, we gained insight into residents' heating methods, electric availability, fuel usage, and personal perceptions of their own heating methods.

From the homeowners' responses, we found that approximately 45% used blankets as their primary way to stay warm during the winter months. Another 32% used chulhas as their primary heating method, meaning they used their chulhas to cook inside during the day and simultaneously used the radiant heat to temporarily warm their bodies. Other methods such as electric heaters and Angiitis were less common among those interviewed as seen in Figure 6.

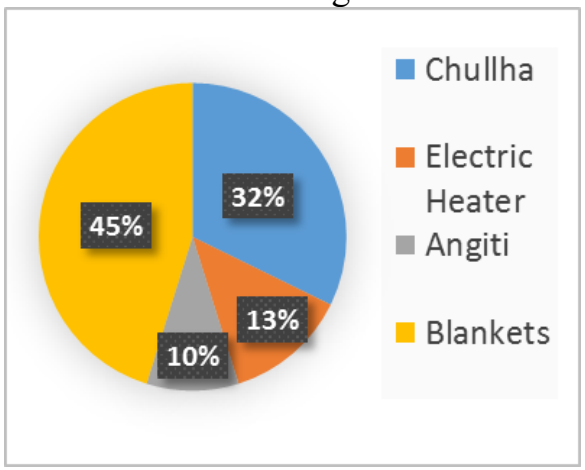



*Figure 6. Primary Heating Method*

Discussions with the homeowners revealed that approximately 84% of them were interested in using improved heating methods in some capacity as shown in Figure 7. Most villagers initially appeared satisfied with their current methods because they had not been exposed to any alternative ways to heat their homes. After further discussing our project, the majority of interviewees expressed interest and seemed open to the idea of an alternative heating system that stores thermal energy. However, among those who expressed interest, nearly all respondents claimed that for them to adopt it, the system would have to be incredibly low cost and function more effectively than their current methods.

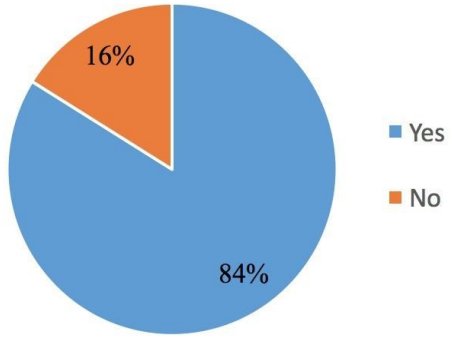



*Figure 7. Interest in an Improved Heating Meth-*

### *Heating Characteristics of a Mandi Home*

Upon reviewing our field measurements, we were able to draw several

conclusions from the collected data. The first conclusion was that the majority of rural houses in the Mandi District used cement as their primary building material. As seen in Figure 8, 90% of the homes we measured used cement as the primary

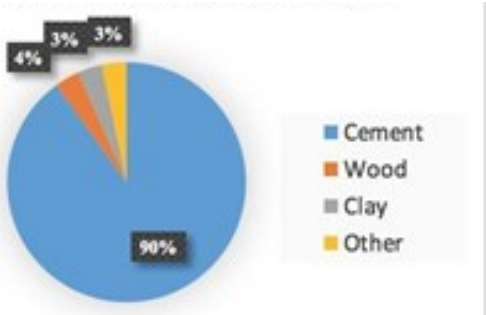
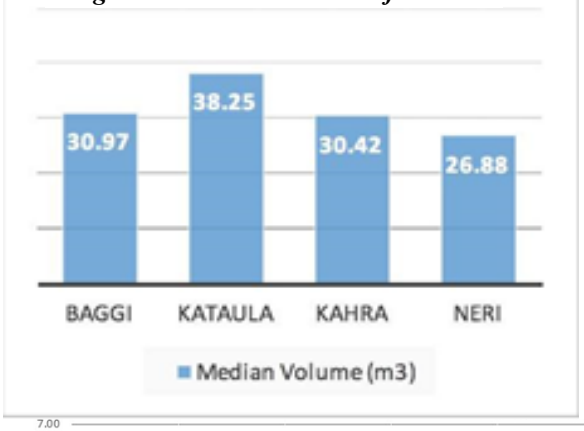



*Figure 8. Primary Building Materials*

material for their structures. This is due to its low cost, availability, and its ease of use. The next conclusion that we observed from our measurements was that the median volume of the rooms requiring heat ranged from approximately 27m3 to 38m3 as seen in Figure 9. This 11m3 gap provided us with vital information regarding how adaptable new heating methods will have to be in this region. Another major heat loss factor for these homes was the size of doors and windows in the room. When combining the areas of all of the windows and doors, we observed that the median open areas ranged from 2.86m2 to 4.39m2 between

*Figure 9. Median Volumes of Rooms*




communities as can be seen in Figure 10. Overall, the home characteristics across the four villages provided us with information regarding the material and size of a room that a packed bed system would have to heat.

In order to determine the amount of energy required to heat a Mandi home, we created the below chart, Figure 11. The X axis represents a home's total

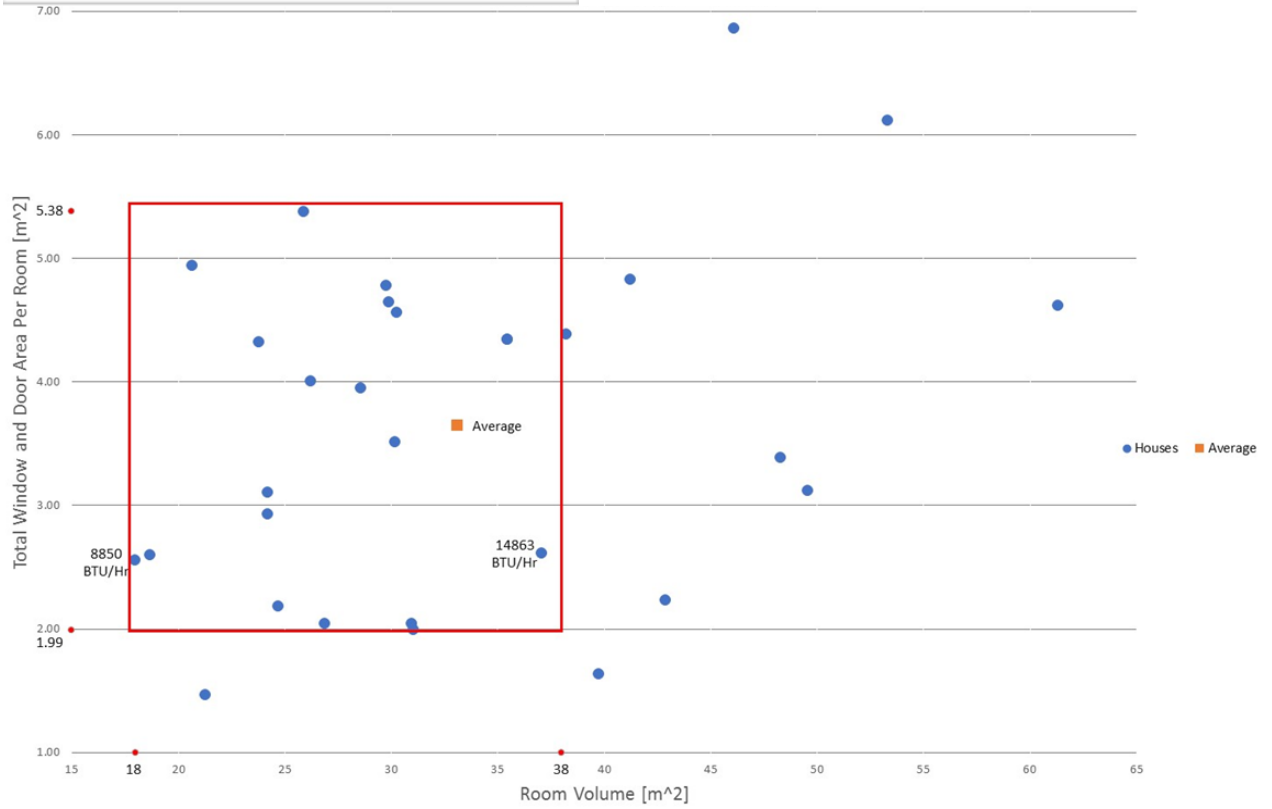



*Figure 11. Home Characteristics*

room volume and the Y axis represents the total area of a home's doors and windows. These are two factors that greatly impact heat loss. We then used our home measurements and our computerized model to calculate the amount of heat that a heating system would have to produce for each of the houses we surveyed. To determine a range of energies for the Mandi District, we focused on room volumes and total window areas that encompassed two thirds of the houses we surveyed as illustrated by the red box. This area represents houses with a total room volume from 18$m^3$ to 38 $m^3$and a total window area from 1.99 $m^2$ to 5.38 $m^2$. Within the four villages, the amount of energy required to heat two thirds of the homes we surveyed ranges from 8850 BTU/Hr to 14,863 BTU/Hr as can be seen in Figure 11. We believe that a heater for this region should be able to operate within this energy target. For perspective, an efficient 2500 Watt electric space heater can produce around 8800 BTU/Hr.

***Results of Testing Proof-of-Concept***

The results of the four tests carried out using the packed bed system can be seen in Figure 12. The blue represents the average values from the two tests that included the discharge cycle without glass beads. the water temperature in the packed bed took approximately 240 minutes to discharge and return to room temperature. The second set of tests, which included the 5 mm soda lime beads, also took approximately 240 minutes to discharge the heat. This can be seen from the orange data points. These

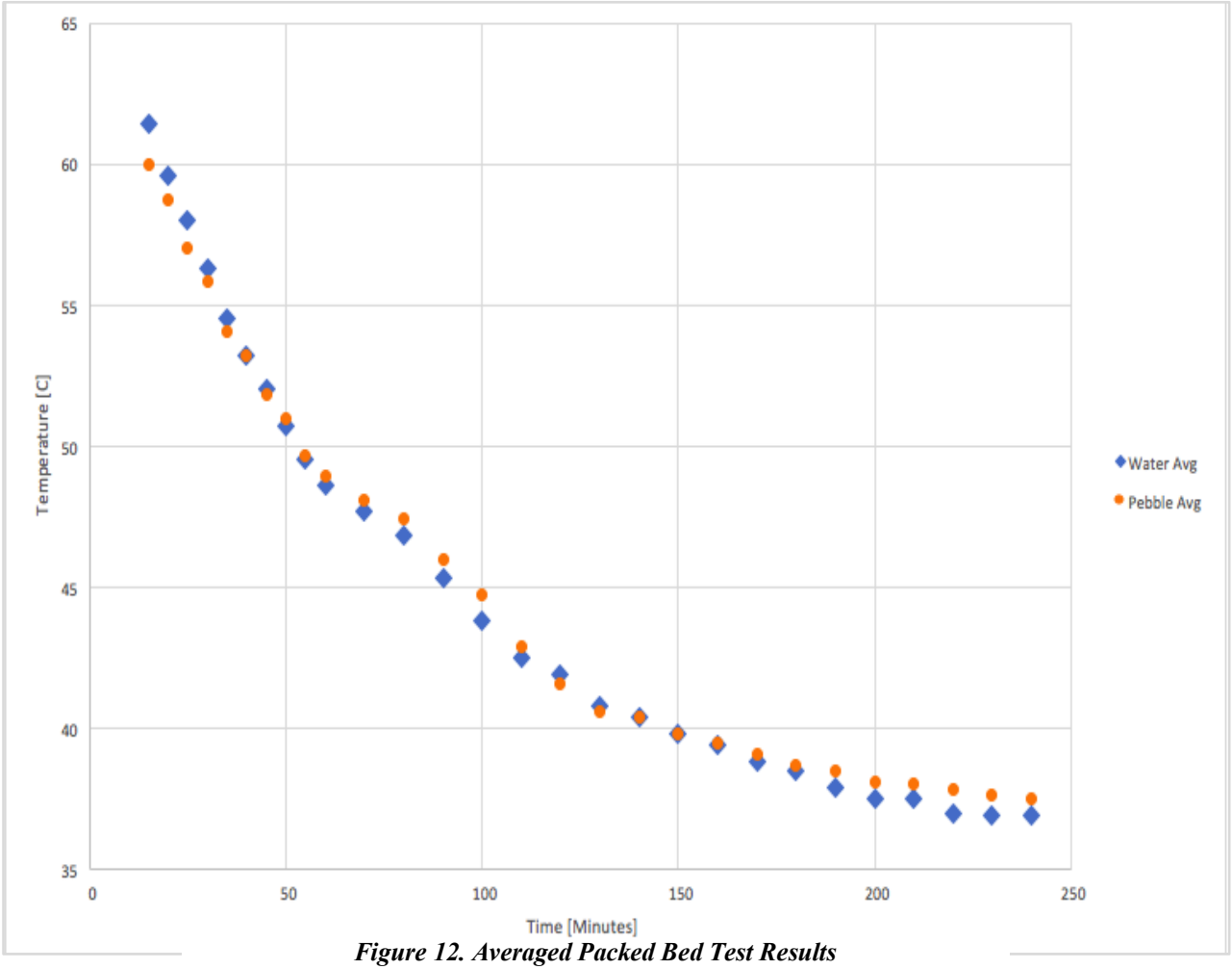



*Figure 12. Averaged Packed Bed Test Results*

tests displayed that the soda lime glass beads could not retain heat more effectively than our control tests. There are several possible reasons for this that are discussed in depth below.

There were several constraints that limited our testing of the proof-of-concept due to the nature of our IQP program. Due to time restrictions, ordering any materials from outside the Mandi area was not an option. Ordering alternate materials would have taken several weeks for delivery. This would have pushed system development and testing beyond a reasonable completion date. Therefore, we were limited to the soda lime glass beads available at IIT. Of those, we chose 5mm glass beads because they were the largest option and had the most surface area. If better heat transfer materials were available for testing, the system may have performed differently in terms of heat retention.

The pump powering our system was also a limiting factor in our design. We had very few options in terms of horsepower. The speed and torque of the pump controlled the flow rate of water through the system. Due to the constraints of our charging and discharging cycles, the system could only operate within a small range of flow rates. For example, if the flow rate was too high, fluid would enter our pebble bed faster than it could drain. The pump available for testing was one eighth horsepower. We determined that this power rating was too high after initial testing. Our solution was to restrict the flow rate using ball joints in the system. This restriction was overheating our pump which required us to design additional equipment to maintain a safe operating temperature for the duration of each test. A smaller pump was not available at IIT or in Mandi. If a smaller pump was available, the cost of the system would decrease and its efficiency would increase due to less restriction.

## Project Outcomes

The completion of building our proof-of-concept packed bed and social interviews revealed a variety of recommendations that are vital for the future of this project. If the development of a packed bed heater continues, the following information must be kept in mind.

### *Social Recommendations*

Upon review of the survey results, we discovered an interesting fact regarding the people who live in the rural villages near the IIT Kamand campus. The majority of families do not use a space heater in their homes during the winter. In fact, the most common method used for warmth was simply putting more clothes on and wrapping themselves in blankets. These responses told us that the people living in this part of Himachal Pradesh do not experience enough cold weather to require space heating in the form of a packed bed heater. Our recommendation for further development is to venture farther north to a region where people require space heating in order to survive the winters.

The current cost of packed bed

Technology, as we designed it, is too high for homeowners in the Mandi district. The survey of the people who live in villages near IIT Kamand revealed that space heating is not required to live throughout the winter in this climate. Despite not necessarily needing this technology, a majority of families did specifically mention that they would be open to considering an improved form of heating in addition to their current use of blankets. The only stipulation would be that the improved technology must cost less than what they currently use. While this might be extreme, in order for a heating technology to be feasible in this region, it should be as cheap as a blanket. Even if our concept was adjusted for realistic use, for example, using a chulha instead of a water heater and a water syphon instead of a pump, the cost of the overall system would decrease but still remain too high for the target homes. Our recommendation for the high cost of the packed bed technology is to adjust the system and to use more common materials while also working to subsidize the cost of the heater by perhaps partnering with the Indian government to help this technology reach locations in need.

### *Technical Recommendations*

The ideal packed bed heating system would run using a chulha and a thermosiphon, eliminating the need for electricity. In our proof-of-concept experiment, we used a hot water heater and a pump to control the water, temperature, and flow. These adaptations were requirements to complete a proof-of-concept of the scaled down packed bed system. However, these additions would make our system too costly for use in small village homes in Himachal Pradesh. The hot water heater and the pump add significant costs to the system that would be too great for our stakeholders. Despite this, we believe our system could be adapted to use a chulha and a thermal siphon to reduce costs of the technology. This recommendation would be valuable to consider in further development of the packed bed technology for use in this region.

The goal of a thermal energy storage device is to hold heat for an extended period of time. Due to lack of availability, our team did not have access to the correct materials which would have been ideal to create the packed units in our system. The 5mm glass beads that we were provided on site, did not have optimal thermal storage capacity for our need. However, past research has shown that phase-change materials are often best for this application. This material is known to have a significantly higher heat capacity than any other materials. Often waxes and paraffin are used in this form. Based on our team's research, we recommend that any future development of our proof-of-concept should use a phase-changing material.

Based on our home measurements and our computerized model results, we recommend that any future heating system for this region is designed keeping an energy output range of around 9,000-15,000 BTUs/Hour in mind. Based on the homes that we measured, to maintain a

temperature differential of 5°C between the outside of the home and the inside of the home, this amount of energy is required

## Conclusion

In conclusion, we determined that packed bed technology is not an appropriate solution for heating homes in the Mandi Region. The results from our local surveys showed that there is a desire for an alternative, low cost, system but our analysis shows that packed bed technology is not the solution due to its technical complexity and high cost. There is still an acute problem in Mandi that could be addressed in order to increase the comfort of those living in rural villages. In addition, while packed bed technology may not be appropriate for these homes, we believe there is still a potential use for this system in northern India due its severe winters.

Upon completion of this project, our team successfully assembled a packed bed thermal energy storage device. Although our proof-of-concept is not designed for home use, we believe that our device can be used in future experiments with other materials inside the packed bed. As a result of this project, we believe there is a future for small scale packed bed heating systems given the right climate and consumers. We also believe that the Mandi District could benefit from an alternative heating system as long as it complies with the specific needs of its residents.

## References


Aggarwal, R., & Chandel, S. (2010). Emerging energy scenario in Western Himalayan state of Himachal Pradesh. Energy Policy, 38(5), 2545-2551. doi:10.1016/j.enpol.2010.01.002

Census of India 2011. (n.d.). List of Villages/Towns. Retrieved February 06, 2017, from http://censusindia.gov.in/2011census/Listofvillagesandtowns.aspx

Dave, B., Thakkar, J., & Shah, M. (n.d.). Prathaa: Kath-khuni Architecture of Himachal Pradesh. Retrieved February 13, 2017,from http://www.academia.edu/3284962/Prathaa_Kath-khuni_Architecture_of_Himachal_Pradesh

EkouevI, Koffi, and Tuntivate, Voravate. Household Energy Access for Cooking and Heating. Herndon, US: World Bank Publications, 2012. ProQuest ebrary. Web. 6 February 2017.

Jeuland, M., Bhojvaid, V., Kar, A., Lewis, J. J., Patange, O. S., Pattanayak, S. K., . . . Ramanathan, V. (2015). Preferences for Improved Cook Stoves: Evidence from North Indian Villages. Energy Economics, 52, 287-289. doi:10.2139/ssrn.2467647

Ministry of Environment & Forests Government of India. (n.d.). Retrieved February 26, 2017, from http://envfor.nic.in/division/introduction-10

Naeher, L. P., Brauer, M., Lipsett, M., Zelikoff, J. T., Simpson, C. D., Koenig, J. Q., & Smith, K. R. (2007). Woodsmoke health effects: A review. Inhalation Toxicology, 19(1), 67-106. doi:10.1080/08958370600985875

Weather statistics for Mandi. (n.d.). Retrieved February 05, 2017, from https://www.yr.no/place/India/Himachal_Pradesh/Mandi/statistics.html

## Acknowledgements

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

The Worcester Polytechnic Institute and the Indian Institute of Technology, Mandi for providing us the opportunity and means to complete this project.

All of the students, faculty and staff at the Indian Institute of Technology, Mandi for their outstanding hospitality and helpfulness during our stay.

Our advisors Dr. Satvasheel Powar and Dr. Dhiraj Patil of the Indian Institute of Technology Mandi, India, and Dr. Fabio Carrera and Dr. Svetlana Nikitina of the Worcester Polytechnic Institute, USA.

All of the local residents that took the time to participate in interviews with us and allowed us inside of their homes.

The staff of the mechanical and thermofluid labs that provided us with assistance in creating our Proof-of-Concept

# Reducing Food Waste at IIT-Mandi


## Abstract

The goal of our project was to research mess hall food waste at IIT-Mandi and provide recommendations to reduce it. To realize this goal, we conducted waste audits on consumer and kitchen waste, and held focus groups with students and staff that eat at IIT's mess halls. The project resulted in the identification of several food waste trends, and the recommendation of assorted methods to reduce food waste, including more food portioning, frequent waste auditing, and greater variety of food options.



***Team Members:***

Ashish Arya, IIT

Harsh Gupta, IIT

Raghav Sethi, IIT

Ryan Cooney, WPI

Katie Merritt, WPI

Colleen O'Shea, WPI

***Advisors:***

Dr. Viswanath Balakrishnan, IIT

Dr. Shyamasree Dasgupta, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

## The Problem of Food Waste

Food waste is a global concern that impacts sustainability and world hunger. Annually, the world wastes 1.3 billion metric tons of edible food, almost one third of the total food produced ("Save Food: Global Initiative on Food Loss and Waste Reduction", 2017). The food wasted could feed 3.48 billion people, easily more than enough for the 795 million hungry individuals in the world ("Hunger Statistics", 2017). As this food decays in landfills it emits greenhouse gases equivalent to 3.3 billion metric tons of carbon dioxide into the earth's atmosphere ("Food Wastage Footprint: Impacts on Natural Resources", 2013).

India produces an annual 105 million metric tons of food waste, which is nearly 40% of its total food production, at a cost of 8.3 billion dollars (Biswas, 2014). That amount of money equates to 4% of India's gross domestic product (GDP). Even though India produces more than enough food to feed its own population, 15%, or 195 million people, are undernourished ("2016 Global Hunger Index", 2016).

The mess halls at the Indian Institute of Technology Mandi (IIT- Mandi) have excessive food waste production. Previous studies at IIT-Mandi have determined that the messes waste on average over 225kg of food each day, which is enough to feed over 180 people. Food waste leads to financial loss, has a negative impact on the local and global environment, and is contrary to the university's mission of educating students about sustainability.

**The mission of this project was to research mess hall food waste at IIT-Mandi and provide recommendations to reduce food waste.** To achieve our overarching goal, we completed a study focusing on **all points of the process of food preparation and consumption** at IIT Mandi. We determined the **magnitude of food wasted** at each point, as well as the systematic and human **causes of food waste**. Based on our data and understanding of food waste at IIT Mandi, we **developed and proposed specific methods to reduce food waste**.

## Background

On the IIT-Mandi campus, students, faculty and staff eat their main meals at one of two mess halls, **Cedar Mess (D1)** or **Maple Mess (D2)**, shown in Figure 1.

*Figure 1: The two messes at IIT Mandi South Campus. D1 at left, D2 at right*

There are also three canteens, which are like food stalls, and one food counter. The counter is in the D1 mess and sells sandwiches, dumplings, and various desserts. D2 Mess has a canteen underneath the main eating area where many students go for omelettes, sandwiches, and late night desserts. There are also two canteens at other locations on campus that serve a variety of foods including fried chicken, noodles, and eggs as well as more traditional Indian cuisine.

Students can also go to the provision store on campus and purchase different packaged snacks and beverages, or they can buy fresh fruit and vegetable from a stand along the main campus road. However, because all students are on a mess meal plan and an overwhelming majority of the campus regularly eats in one of the two messes, this project was aimed at reducing food waste in the messes.

### *The mess halls: Cedar (D1) and Maple (D2)*

The two mess halls are run by two separate contractors who are hired by the university to avoid creating a food monopoly on campus. These contractors have one-year agreements with the university. Each year, their performance is reviewed and the campus allows other contractors to submit bids to replace the current contractors (P. Samuel, personal communication, 31 March, 2017). This system is intended to induce the contractors to produce better food, so they can receive positive feedback from students and staff and thus stay in business.

Students choose what mess they prefer at the end of each month. Most students are assigned to the mess they choose, but each mess is given at least 300 students. Thus, some may not be assigned to their desired mess. However, there is not a regularly enforced attendance system for either mess, so students generally go to whichever mess they prefer.

Both messes provide breakfast, lunch, snack, and dinner at pre-specified times each day. As seen in Figure 2, when consumers enter the mess, they pick up a tray, a cup, and a spoon and then proceed to get their food.

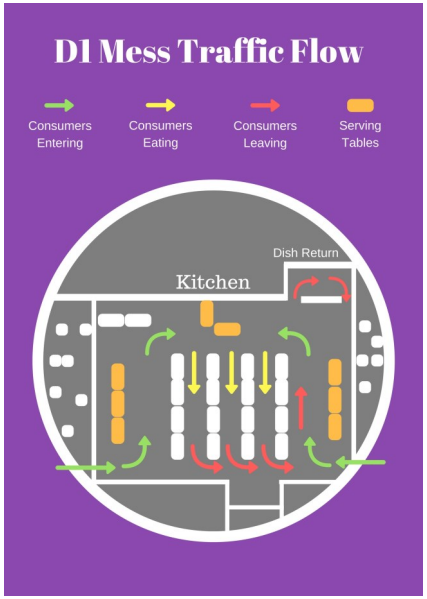



*Figure 2: The traffic flow in the D1 mess hall*

Most of the food, such as rice, dal, salad, and potatoes, are **self-served** and consumers can take as much or as little as they would like. However, there are a few food items that are **portioned** out to consumers by the mess workers. These foods include bananas, paneer dishes, curd, non-vegetarian (non-veg) items like chicken and boiled eggs, and a few other foods. After the consumers eat their food and are ready to dispose of waste, they proceed to a centralized waste area, shown below in Figure 3, where there are two large dust bins designated for food waste as well as sinks to wash up after eating.

*Figure 3: The waste disposal area at D2 mess*

IIT Mandi has instituted a **mess committee** that consists of students from each year. All committee members are elected, and there is one member elected from each hostel on campus. This committee is responsible for managing the menu for the mess halls. They communicate with the mess contractor to choose dishes that taste good and use ingredients that fall within the contractor's budget. The committee members monitor both messes despite being assigned to eat in only one in order to make sure that the mess managers and workers are complying to the mess committee's rules. The mess committee sends out a **monthly survey** to students about food quality and the overall mess experience. Once these surveys have been analyzed, the mess

committee can recommend changes to the managers in both mess halls in an attempt to make the consumers happier. The mess committee is also responsible for creating campaigns to reduce food waste in the mess halls.

Apart from a few exceptions, **all students are required to be on the meal plan** and therefore pay a fee as part of their tuition each semester. The meal plan is currently **Rs 98 per day** and is prepaid with the rest of the students' expenses. Faculty and Ph.D. students have the option to pay for each meal individually as they enter the mess hall, making it more cost effective for them, as they can more easily choose which meals they would like to eat at the mess hall.

### *Previous waste reduction efforts at IIT Mandi*

In IIT-Mandi's 9 year history, only a few waste reduction efforts have been undertaken in the mess. The most obvious effort consists of a series of posters located above the sinks in the D1 mess hall that encourage consumers to waste less food. Using consumer education tools like posters has been proven to work in other universities around the world, so this was an easy and obvious first step to reduce food waste in the mess halls. In fact, at the University of Kansas, using educational posters in their dining halls caused consumer food waste to be reduced by fifteen percent (Whitehair et al., 2013). However, the posters being used in the D1 mess appeared to reduce food waste for only about two weeks, before food waste returned to baseline levels (A. Singh, personal communication, 24 March, 2017). Despite this, the posters have been left in place for over one and a half years. Both messes also have a chalkboard installed where a daily estimate of the total food waste produced is written.

## Methodology

The mission of this project was to research mess hall food waste at IIT-Mandi and provide long-term recommendations to reduce food waste. To complete our mission, at each point of the process of food preparation and consumption at IIT-Mandi, we:

1. Determined the magnitude of food wasted
2. Explored why food is wasted
3. Developed methods to reduce food waste

### Determining the magnitude of food wasted at IIT-Mandi

Our first step was to **audit kitchen** and **consumer** waste in the D1 and D2 messes. To categorize consumer waste, we required consumers in the messes to segregate their food waste into different waste bins based on food type, as seen in Figure 4.


*Figure 4: Buckets for post-consumer food waste segregation*

We conducted **'monitored segregation'** surveys at D1 (4 days) and D2 (7 days) where we observed behavior at each meal, counted the number of trays (i.e. meal takers) and weighed the waste produced for each of the foods on the menu.

During these 'monitored' waste audits, we observed that consumer waste was less than in former weeks because of our presence and the mere act of segregating waste. To isolate the impact of the act of

without being present at the mess in order to remove the impact of our presence (‘**unmonitored segregation**’).

To automate the waste segregation measurements, our team created an electronic sensor to count the number of trays deposited in the mess. The device uses an ultrasonic sensor to count the number of trays passed through the disposal slot. An Arduino microprocessor is used to process input from the sensor, and to update an LCD display to show the number of trays detected which is shown in Figures 5 and 6. This device represents both a tool for data collection as well as a deliverable for our project.

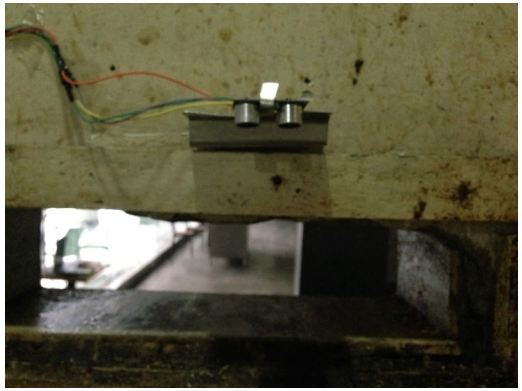


*Figure 5: Sensor mechanism over tray disposal slot at D1*

*Figure 6: Additional electronics and LCD screen for tray counter*

To test the impact of our presence on waste disposal, we also audited several meals in D2 mess where we did not enforce segregation but remained present at the meal, and counted the number of consumers as they returned their trays (**‘monitoring without segregation’**).

During our initial survey with monitored segregation we also measured the waste created by the kitchens. This included **leftover food** and **kitchen trimmings**. Additionally, in the D1 mess we measured the **weight of food that was served**.

Our final task for this objective was to measure the **waste created by each individual consumer**. This was achieved with an electronic device that stored data about the weight of a mess dustbin each time food was thrown into it, shown in Figure 7. This device was placed below a dustbin used for food disposal, and weighed the change in weight from each consumer’s contribution of waste.

Part 1 (labeled in Figure 7) is a wooden and metal base to support the dustbin. Below Part 1 is a load cell, which is part of a Wheatstone bridge (Part 2). An operational amplifier is used to enlarge the voltage change from the Wheatstone bridge. An Arduino (Part 3) processes the signal and stores the weight of each individual’s waste. The device then uses a cellular GSM connection to store data in the cloud, through Google Sheets. During normal operation, the electronics are housed inside Part 4.

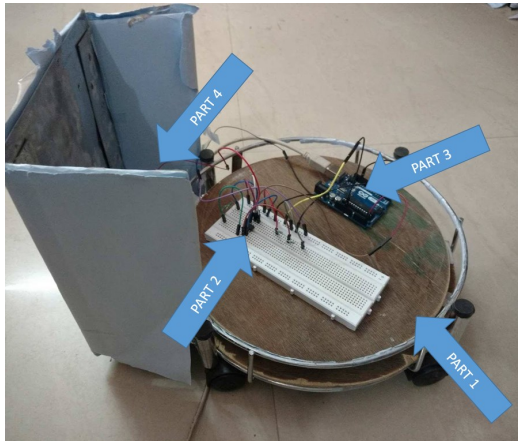



*Figure 7: The prototype that measures the weight of an individual’s food waste*

### Exploring why food is wasted

To determine why food is wasted, we conducted **focus groups** with mess consumers and **interviews** with a variety of stakeholders. Our focus groups were used to determine consumer attitudes about why food is wasted.

**Seven** separate focus groups were conducted with students in each class year, as well as campus guards and faculty that eat in the messes. Groups were selected from attendees at snack time. Typically, all group members were chosen from the same table of friends to ensure that all members were of the same school year. Focus groups allow participants to express original ideas about the causes of waste and about potential reduction methods and thus they allowed us to observe trends and common food waste perceptions. We were also able to use individual responses and group dynamics to develop an understanding of the cultural significance of food waste at IIT.

We conducted total of **eight interviews in D1** mess and **five interviews in D2** mess. In each mess, we interviewed mess workers, mess managers, and chefs. We also received additional information from the managers and chefs throughout our auditing process through informal conversation. Outside of the mess, we conducted interviews with various campus managers and members of the student Mess Committee. Due to a need for language translation, our interviews with mess workers, chefs, and managers were fully structured. Our other interviews with university administrators were semi-structured, allowing interviewees to express their personal experiences and new ideas about food waste that we had not encountered or considered.

### Developing methods to reduce food waste

To analyze food waste reduction methods, we first synthesized our data and observations to identify trends and points of further inquiry. Based on this information, we performed a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the dining services at IIT Mandi. This analysis was used to identify specific qualities of IIT's dining services that effective food waste reduction methods would take advantage of, as well as any weaknesses or threats to possible reduction methods. After conducting the SWOT analysis and analyzing data, possible recommendations were generated.

## Results and Discussion

This chapter discusses the results of our data collection and observations, and our corresponding analysis. The possible recommendations that follow from our data are found in the following chapter.

### Consumer, leftover, and trimming waste amounts are about equal

Our data collection for four days in D1 mess shows the approximate contribution of consumer, overproduction, and trimming waste to total waste, seen in Figure 8.

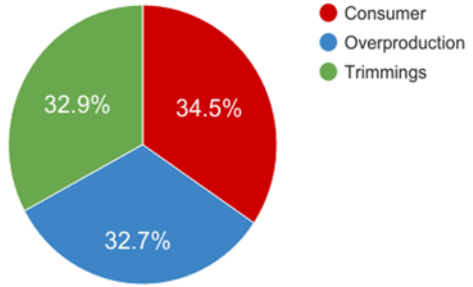



*Figure 8: Contribution of different waste types to total waste*

It is notable that most trimming waste is unavoidable. Thus, most avoidable waste comes from overproduction and consumer waste. That said, we did find that the trimming practices in the messes, and especially D1 mess, lead to some easily avoidable waste. For example, Figure 9 below shows avoidable carrot and

Our interviews with mess managers and mess workers indicated that in both messes, neither the head chef nor the staff cooks have formal training on waste reduction, which may be a cause of the presence of easily avoidable trimming waste.

*Figure 9: Cucumber and carrot trimmings from D1 mess, including some relatively large chunks of avoidable waste*

Our interviews and data collection have shown that the likely main cause of overproduction waste is that mess managers have no reliable way of knowing how many students to expect at each meal.

Some meal attendance trends are consistent and apply to both messes. For example, Saturday lunch and dinner have lower attendance. Students in our focus groups have expressed that they frequently miss Saturday dinner and sometimes lunch because they travel off campus to eat (see Figure 10). Despite these common trends, both mess managers have expressed that they do not know exactly how much food to prepare because students do not always eat at their assigned messes, and because special events on campus may draw students away from the messes.

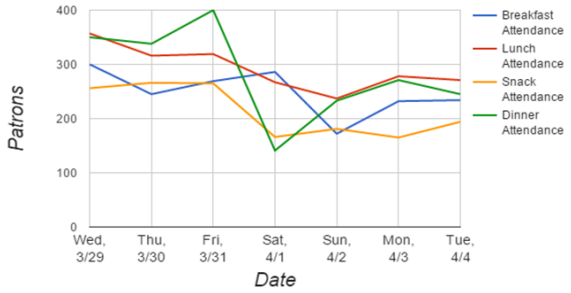



*Figure 10: Attendance over one week in D2 mess*

While consumer waste is undoubtedly a significant portion of total waste, not all consumer waste can be avoided. Upon first examination of the initial food waste data collected before the project began, it was determined that Wednesday, Friday, and Sunday breakfast produced some of the largest amounts of waste. Figure 11 illustrates the total breakfast waste data that we collected in our week at D2, which closely resembles the trends in breakfast waste that were found previously.

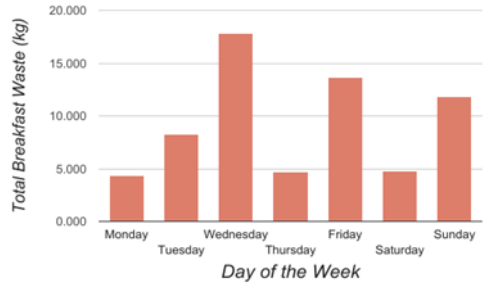



*Figure 11: Breakfast waste data collected prior to separating avoidable and unavoidable waste*

From this graph, it was assumed that these meals were the most wasted because students liked them the least. When the waste audit was conducted, the data that was collected directly contradicted this assumption. The high amount of waste on Wednesday and Sunday was actually mostly due to unavoidable waste from banana peels and eggshells, which are only served on these mornings. When this unavoidable waste was factored out of the total waste weight for the meal, the avoidable waste was shown to be reasonably low. The graph that corrects for unavoidable waste is shown below in Figure 12.

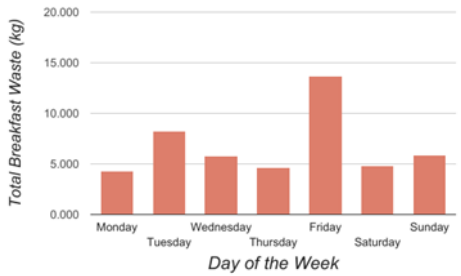



*Figure 12: Avoidable breakfast waste in D2 mess*

## D1 and D2 have similar waste patterns

As indicated by Figure 13, located below, both mess halls have very similar waste patterns. D1, indicated by the blue bars, has slightly less food waste than D2, indicated by the red bars, despite having more consumers assigned to it. This means poor food quality due to high attendance should not be the main cause of food waste.

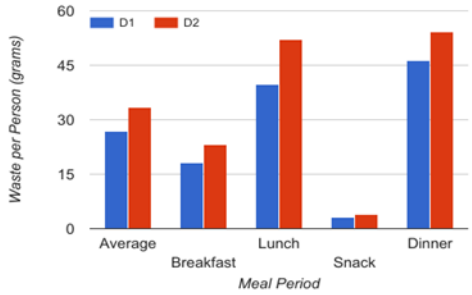



Figure 13: Comparison of waste in D1 and D2 messes

In order to compare an important staple food at the two messes, we compared the roti waste per person at lunch and dinner. This comparison was motivated by focus group and mess survey feedback indicating that the roti in D1 mess is incorrectly cooked and uses inferior ingredients when compared to D2. As seen in Figure 14, located below, the average roti waste is almost identical for the two messes (D1 is represented by the blue bar while D2 is represented by the red bar).

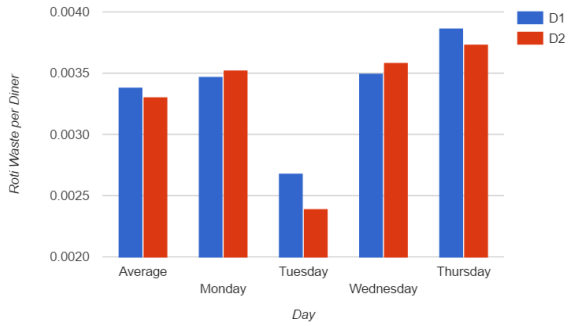



*Figure 14: Roti waste at lunch per person in D1 and D2 mess*

This may mean that food quality between the two messes is relatively similar. Most focus group participants seem to believe that one mess has better quality food, but that is not evident based on the data. It may also mean that food quality is not the main cause of waste, if low and high quality roti are wasted in similar quantities. This data gives more reason to believe that mess systems and consumer attitudes are the driving cause of food waste.

## Dips and vegetarian main courses are wasted most

One trend that we identified was the amount of waste produced for each food type. As seen by Figure 15 below, dips and vegetarian main courses are wasted by consumers the most. This is largely due to the repetitive nature of the menu, as well as the excess amount of gravy and dips that students serve themselves in relationship to the solid foods that accompany them.

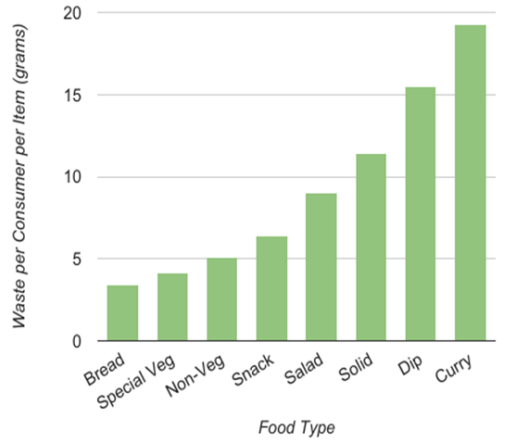



*Figure 15: Avoidable and potentially avoidable waste of different food groups, per consumer, per item*

## Monitored segregation reduces food waste

Based on our monitored and segregated waste audits in the D2 mess, it was apparent that having consumers segregate their food waste while we monitor them greatly reduced the total amount of waste produced. This is evidenced by comparing data that we had previously collected data for the first three weeks of March in the D2 mess with our monitored and segregated waste audit performed in the last week of March. This relationship is shown in Figure 16 where the grey bars show a consistently lower amount of waste during segregated monitoring.

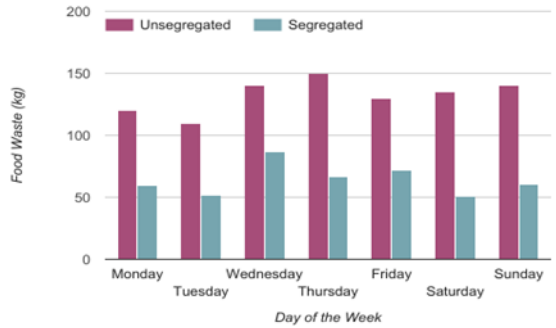



*Figure 16: Segregated and unsegregated waste in D2 mess over the course of one week*

Consumer feedback from focus groups and informal communication indicates that these audits may have reduced waste for three reasons. First, segregation is inconvenient, leading people to waste less food in order to avoid sorting waste. Second, it's embarrassing to be watched while disposing of large amounts of waste. Third, people were scared that we may punish them for wasting food, because they did not know exactly why we were watching them dispose of waste.

## Portioned foods are wasted less

As previously mentioned, most foods served in the mess are self-served by the consumers themselves. However special and/or expensive foods are often portioned by a mess worker. These portioned foods include non-veg items, sweet items, paneer, and bananas. Our waste audits have shown that at all mealtimes in D2 mess, self-serve menu items are wasted more than portioned menu items. This is true for both consumer waste and overproduction waste (see Figures 17 and 18 below).

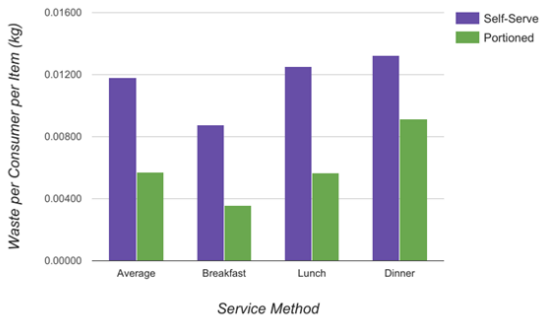



*Figure 17: Avoidable consumer waste in D2 mess for self serve and portioned items*

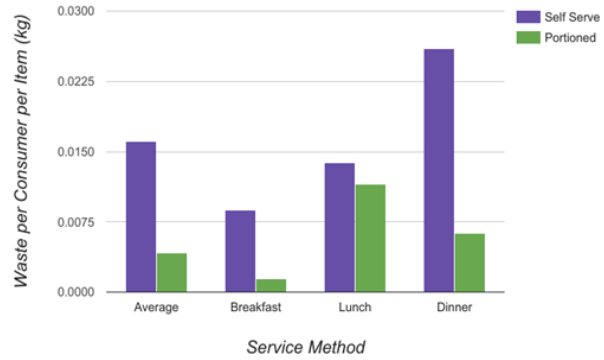



*Figure 18: Avoidable leftover waste in D2 mess for self serve and portioned items*

We hypothesize that this difference is in part a function of the appeal of portioned foods. We also believe that because portioning prevents students from taking very large quantities of food at once, they are less likely to dispose of portioned foods. This also may be due in

part to the length of lines for food. Focus group participants indicated that when lines are long, as shown below in Figure 19, consumers do not want to stand in the long line more than once. Thus, they take too much food, and cannot finish it if they become full or do not like the taste.

*Figure 19: Picture of the line in D1 during snack time on Monday, April 11.*

### South Indian breakfast items are wasted more

Three days a week, both messes serve breakfast dishes native to South India. Many students in our focus groups commented that "these dishes are not cooked properly and do not have a good taste". Through the waste audits that we have conducted in both mess halls, we have found that South Indian food is wasted more than North Indian food during breakfast, which is the only meal where South Indian food is prepared, as illustrated in Figure 20.

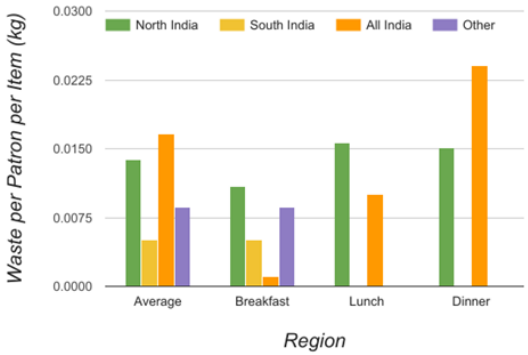



*Figure 20: Waste based on food region at D2 mess*

### SWOT Analysis

After gathering both quantitative and qualitative data, we conducted a SWOT analysis on IIT Mandi's mess system (see Figure 21).


*Figure 21: A SWOT analysis of the Mess systems on the IIT-Mandi campus*

Our analysis indicates that the campus food and food waste systems are generally strong in using campus-wide feedback, as evidenced by surveys sent out to all students asking for mess feedback. Additionally, the student mess committee and campus administrators have strong control over the mess contractors. However, the mess system is especially weak because of its limited and repetitive menu as well as the very low budget that the mess contractors are given.

There is great possibility for change using competition between the messes and by increasing the contractor's budget. However, any methods that are implemented must be dynamic enough to

avoid the plight of former food waste reduction methods that failed after several weeks.

## Recommendations

As previously mentioned, the key deliverable from this project is a set of recommendations that can be implemented to reduce food waste at IIT Mandi. These will be provided to the Mess Committee, Green Panel, and mess managers, and all three stakeholders will need to collaborate to implement the recommendations.

### Mess systems must be adjusted

From our focus groups, it is apparent that many consumers take too much food in order to avoid having to wait in the long queue more than once. As seen before in Figure 19, the queues to get food can become quite lengthy. To combat this, we propose that each mess hall add a third counter specifically designated for refilling trays. This would allow consumers to be able to take less food their first time through the line without fear of waiting in a long queue for a second serving.

The cost of a meal plan at IIT Mandi breaks down to Rs 98 per day: Rs 20 for breakfast, Rs 8 for snacks and Rs 35 for each of lunch and dinner. Focus group participants and a member of the mess committee identified that at this cost, there is relatively little expectation of better food or greater variety. Thus, the Mess Committee has indicated that it would like to raise the cost of a meal plan to Rs 100 or Rs 105. However, based on feedback from the head chef at D1 mess, Rs 110 is the necessary minimum cost to adequately increase taste and menu diversity. The university should undertake significant research into the ability of all students and their families to cover this cost before raising prices.

Currently, the mess managers at D1 and D2 mess can roughly estimate from experience how many students will attend a meal and how much food they will eat. However, nearly half of the food waste produced comes from overproduction of food in the kitchen. This is in part because of this unreliable system for predicting attendance. We recommend that both messes begin to use quantitative methods, such as the sensor we created, to understand exactly how many diners attend each meal. This will allow the managers to cook based on an exact average attendance for a given menu or meal period.

### Students and mess staff must be educated about food waste

As seen in our waste audits, especially at D1 mess, large chunks of edible vegetables are often disposed of with other trimmings. As other colleges like WPI often have training for their cooks on reducing trimming waste, we believe that this would be an appropriate step for IIT's messes to undertake. A potential further step could be to implement a program where the waste that each mess worker creates is monitored. This would allow chefs and managers to identify those that need further training or reassignment based on high waste production.

We believe that our existing waste weighing prototype can be improved upon to give personal feedback to users. One possibility is a "gamified" system that uses smartphone or web-based updates to privately alert users of their waste generation. With this system, students could track trends in their waste, see where they fall in the distribution of waste generators, and gain insight on the importance of their behavior. Gamification has been shown to have potential for positive changes in attitude and behavior, including in sustainability related contexts (Fijnheer, van Oostendorp, 2016).

### Food quality must be improved and food must be varied

As identified by focus group participants and our observations, the gravy or curry from liquid-based dishes is heavily wasted. In order to improve the quality of curry dishes and correspondingly reduce waste, we recommend that the mess chefs cook thicker curries and lower the ratio of liquid to solid components in curry dishes. This should prevent the wastage of liquid components of curry dishes.

Based on popular responses in both the focus groups we conducted and the mess survey answers, many students are not happy with the taste of food and repetition of the menu being served. To make consumers at the mess halls happier, we recommend that chefs change the menu more frequently and add more variety to it. This will allow consumers to enjoy a more varied menu and not waste as much food. This will be possible if, as mentioned previously, the mess budget is increased to Rs 110 per day.

### Communication with mess managers must be improved

As we saw during our week of auditing at D2 mess, the manager was not aware of special events happening on campus that decreased mess attendance and in turn raised overproduction waste. Thus, we recommend that one duty of the mess committee is to alert the mess managers of special events on and off campus that may draw students away from the messes. This will allow the mess managers to produce less food to account for fewer consumers.

## Conclusion

After analyzing food waste at IIT-Mandi's two mess halls, our team was able to determine several recommendations for the university based on our data collection. We conducted waste audits in both mess halls, ran focus groups with mess consumers, interviewed mess and campus administrators, and determined a set of recommendations for the university to implement in the future. Some of these recommendations regarded systematic changes, like increasing the price of the meal plan and tracking attendance in each mess hall. Other recommendations involved more training for the mess staff about portion sizes and food waste reduction, as well as introducing more variety to the menu. We will present these recommendations to members of the Mess Committee, Green Panel, and mess managers, in hopes that they will take further action to reduce mess hall food waste.

## Acknowledgements

There are many people that were essential to the success of this project. First, we would like to thank our advisors, Professors Balakrishnan, Carrera, Dasgupta, and Nikitina. They provided insights to the project that may otherwise have gone unnoticed and helped guide us towards success. We would also especially like to thank the mess workers who went out of their way to help us audit waste and test our prototype. Finally, we would like to thank Kent Fong, Virginia Massa, and Daniel Salisbury for helping our team with our waste audits.

## References

*2016 global hunger index: India.* (2016).

Biswas, A. K. (2014). India must tackle food waste. Retrieved from https://www.weforum.org/agenda/2014/08/india-perishable-food-waste-population-growth/

FAO. (2013). *Food wastage footprint : Impacts on natural resources* FAO.

Fijnheer, J. D., & Van Oostendorp, H. (2016). Steps to design a household energy game. *International Journal of Serious Games, 3*(3) doi:10.17083/ijsg.v3i3.131

Hunger statistics. (2017). Retrieved from https://www.wfp.org/hunger/stats

*SAVE FOOD: Global initiative on food loss and waste reduction* (2017).

Whitehair, K., Shanklin, C., & Brannon, L. (2013). Written messages improve edible food waste behaviors in a university dining facility. *Journal of the Academy of Nutrition and Dietetics, 113*(1), 63-69.

# Knowledge, Awareness, and Disaster Management Techniques Against Earthquakes in Mandi and Kullu Districts of Himachal


## Abstract

The Himachal zone experiences tremors and minor earthquakes frequently. There are also precedence of some major earthquakes in the past. Our goal in this project was to assess public knowledge and awareness regarding earthquakes and related emergency measures and to propose technical solutions to pre- and post-disaster problems. The assessment revealed that there is a major lack of awareness in the general public of Himachal Pradesh regarding disaster management. Based on our analysis, we designed a pair mobile applications for spreading awareness and a mechatronic model to aid in rescue post-occurrence.



***Team Members:***

Shikhar Shukla, IIT

Lovedeep Singh, IIT

Kunal Gour, IIT

Nitesh Bansiwal, IIT

***Advisors:***

Dr. Varun Dutt, IIT

Dr. Kala Venkata Uday, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

WPI

Indian Institute of Technology Mandi

# Earthquake - Awareness and Aftermath

## Introduction

By definition, a 'Natural Disaster' is defined as an event that is brought about by natural forces, resulting in possible loss of life and economic resources (Wikipedia). The cause of the event may or may not be influenced by human activity like construction, drilling, mining, etc. The local geography and terrain constitution plays a major role in the type of natural disaster that could probably occur in the area, its propagation and also the preventive and mitigation aspects to avoid or reduce the loses.

Our project research location is the hills of Himachal Pradesh with primary focus on Mandi and Kullu districts. The local terrain is hilly and abundant with seasonal streams and major rivers like Beas, Ravi, Sutlej and their tributaries. Himachal Pradesh includes the Himalayan foothills as well as high-rise new fold mountains, with some seismic activity still ongoing in the region. There is a huge variation in the climatic conditions of Himachal Pradesh due to variation in altitude (450–6500 meters). The climate varies from hot and sub-humid tropical (450–900 meters) in the southern low tracts, warm and temperate (900–1800 meters), cool and temperate (1900–2400 meters) and cold glacial and alpine (2400 –4800 meters) in the northern and eastern high elevated mountain ranges.

The high risk of major loss in earthquake can be interpreted from Table 1. We can see that proper awareness among people can reduce this loss up to 90%.

Our project is focused on 'Mitigation Techniques for Earthquakes'. Earthquakes are one of the most prevalent and unpredictable natural disasters in Himachal. As of now, there are no affordable and practical mechanism available for either the prevention or prediction of an earthquake. Earthquakes in hilly regions like Himachal are more disastrous as they can be a prelude to several other natural disasters like landslides, flash floods or mudflows.

### *Stakeholders and Goals*

There are two primary stakeholders in our project: the general public and the Government. While in case of the general public , we were interested in finding out how much awareness they possess about different aspects of earthquakes knowledge, in case of the Government, we were more interested in the enforcement of rules and regulations for the construction of public buildings.

The goal of our project is to find the most appropriate mitigation techniques for the Himachal region. Also to modify and evolve them, so as to let stakeholders adapt easily to them and spread awareness regarding not just the causes and effects of earthquakes and their mitigation, but also the possible aftershocks and other disasters as an aftermath of the earthquake itself. Furthermore we will be proposing technical applications and gadgets to facilitate disaster management.

| Sr No. | Scenario if all buildings are not earthquake resistant | | Scenario if all buildings are earthquake resistant | |
|---|---|---|---|---|
| | **Physical** | **Cost(in million)** | **Physical** | **Cost(in million)** |
| Loss of Lives | 65000 | 6500 | 12000 | 1200 |
| Loss of Buildings | 1,36,339 | 9540 | 8298 | 580 |
| **Totals** | | 16040 | | 1780 |

*Table 1- Losses in magnitude 8.0 hypothetical earthquake if occurred again in Kangra*

Source: "HPSDMA", Earthquake Hazard Profile of the State(1991)

Currently, there are government bodies like the Natural Disaster Management Authority, which undertake the relief fund maintenance and aftermath management for earthquakes and other disasters. But there is still a need for research in the area of mitigation techniques as aftermath management measures are a step to be taken at a later stage. There is also a need to educate and spread awareness regarding aftershocks and disasters following an earthquake that might hit the populace after a certain period of the main shock, and thus catch them unprepared.

Our long-term goal is to prevent as much loss of life and property as possible, specially that which occurs due to lack of awareness, inappropriate construction plans formulated without proper scientific and architectural knowledge, and accidents after the major shock due to after-effects of it. Technical applications developed by us can help in detection of earthquakes minutes before it happens, giving ample time to prepare for it and thus saving a number of lives.

## Objectives

In order to achieve our goals, we thoroughly researched the most appropriate mitigation techniques for the region. In order to do so, we first gathered data regarding the kind of mitigation techniques acceptable by the stakeholders and their preferences for the mode and method of awareness.

Our first objective was to collect data from all aspects of society and study their acceptance of modern mitigation techniques and scientific information. This gave us information regarding the receptivity of stakeholders.

The second objective was to research the best and most suitable disaster management techniques and evolve them, if needed, to fit the stakeholders' needs and practices. We also developed awareness models, like Smartphone game applications for awareness and communication systems for emergencies, based on the data and behavioural patterns of the respondents. This was done to educate them about the need for a long term preventive measure and use of better planning and techniques in construction and natural resource extraction.

The last objective of our project was to detect earthquakes prior to their occurrence, and therefore to help government and rescue teams in post-disaster operations.

## Background

Seismically speaking, Himachal Pradesh lies in one of the most earthquake prone areas of the country. According to the Amateur Seismic Center, Pune, districts like Kangra, Kullu, Mandi, Hamirpur, Una, Bilaspur and Chamba lies in zone V, while the remaining districts like Spiti, Kinnaur, Shimla and Solan lies in the zone IV. [4] The terrain is hilly all through Himalayas and is traversed by major rivers like Sutlej, Beas, Ravi and other tributaries. According to Himachal Pradesh State Disaster Management Authority, "The state has not only been shaken by earthquake occurring in its territory but also in the neighboring areas of J&K in the North, Tibet in the East and UP hills in the South East." [3]

According to Himachal Pradesh State Disaster Management Authority, mMost of the stakeholders of this state are rural people with the house consisting mainly of walls of clay mud, unburnt bricks or random rubble masonry without any earthquake resisting features and are at risk of total collapse if intensity IX or more actually occurs in future and might have severe damage with very large cracks and partial collapses even in Intensity VIII areas. Also in the urban areas with burnt-brick houses do not have the earthquake resisting features, namely good cement mortar seismic bands and roof typing etc. and so they are also at a risk of severe damage under intensity IX as well as in VIII whenever such an earthquake would occur. [3]

Some of the mitigation techniques adopted by various earthquake prone areas all over

*Figure 1.1- A house in Rural area*

the world are discussed to gather the information of the present scenario and to implement them wherever possible. According to Varun Joshi, MS Rawat, AK Sharma, K Kumar & AK Panda (2011, 201-202), people of Himachal live in houses made up of stones, soil and wood, and one of the features is that no window or door or any part of the house is joined with nails. These types of houses are known as 'chaukat' and are made from locally available building material along with long and thick wooden logs, slate and clay. Sometimes even the whole tree is used in the house. One such house is depicted in Figure 1.1

Stone used are hard rocks, preferably quartzite, if available nearby, as shown in Figure 1.2. "The houses being constructed specially in the village area in Sikkim are fully earthquake resistant. The houses are generally constructed on a sound ground where base is made up of wall filled with locally available hard stones, later plastered by cement. A wood beam is used to make a frame fabrication on the strong stone wall. The partition inside the house is also done by the wood beams. The wall of the houses is made up of locally available bamboo fabricated sheets which are very light in weight. After fabrication of sheets, these sheets are raised along the wood beams and fixed with the help of nails." [1]

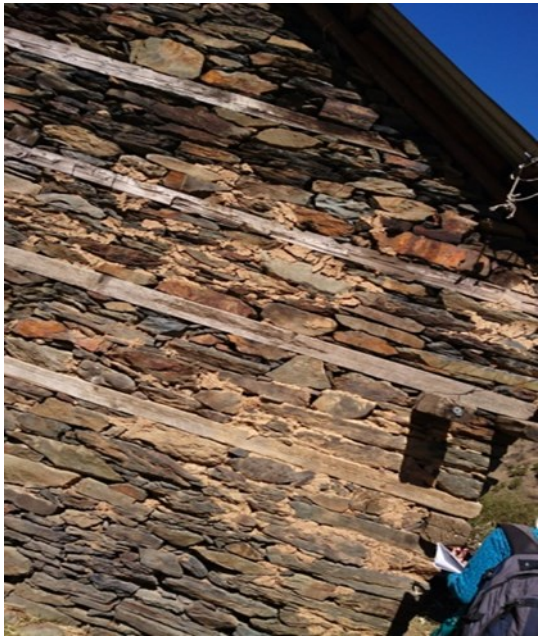


*Figure 1.2- Traditional Earthquake Resistant house*

According to Liu, Zhang and Zou (2012), aerated concrete is used in building houses in earthquake prone areas as it is light-weight, porous, thermal insulated fire-proof material with good seismic capacity. Using this material, the whole building can be made of 40% less weight than the one made from burnt brick. The reduction in the building weight reduces earthquake damage, greatly improving the seismic capacity of building. Carbon Fiber Composites are also used in making earthquake resistant houses because of its high tensile strength, low density, durability and corrosion resistance, which serve as seismic reinforcement. [2]

As shown in figure 1.3, there are some mitigation techniques such as use of bamboo retrofitting, as well as use of clay, wood and stone. If people in rural Himachal are made aware of these techniques, this will help them in reducing the damage caused by earthquakes.

*Figure 1.3-House built using Bamboo Retrofitting*

## Methodology: Investigating Public Knowledge

To gauge general public awareness and knowledge regarding earthquakes, and to help in cases of such an emergency, we set three objectives for ourselves as shown in Table 2.

| Objectives | Methods |
|---|---|
| Assess the existing conditions | Interviews with Local Peoples |
| Develop appropriate strategies for spreading awareness among peoples | Awareness based Android Snake & Ladder game app.<br>Pamphlets, Posters and awareness website. |
| Pre-disaster detection and helping in rescuing program. | Development of P wave detection app.<br>13x13 $cm^2$ rescue robot for detecting human body in piles. |

*Table 2*

Our first objective was to assess the current conditions and knowledge of people regarding earthquakes and their response to such emergency conditions. We also obtained information regarding their preferences for the methods of warning and awareness programs.

To assess the existing conditions, we first analyzed the scope and nature of our focus groups and respondents needed. The location was decided so as to include urban as well as rural populace, in all age groups, educational backgrounds and economical standing. The location for interviews was decided as Mandi town, Katindi region, Kullu town area and surrounding villages. To get a more detailed and systematic idea of the stakeholders' perceptions regarding earthquake measures and aftermath, we conducted interviews of two broad stakeholder groups: residents and government officials directly or indirectly related to earthquake measures and aftermath activities.

The interviews conducted were mostly one-on-one interviews (Figure 2.1) which were semi-structured in style, with both qualitative and quantitative aspects. The data recorded was roughly sectioned into two parts. The first section inquired about the current knowledge and response of people when facing such an emergency. It also gauged the preparedness of the general populace and the possible precautions taken for such emergencies. The preparedness level was based on whether the resident's house followed all the norms and guidelines advised by the government of India for houses built in the seismic zone-V as well as the awareness of the resident regarding the Dos and Don'ts in case of an earthquake. The precautions considered included having knowledge of evacuation plans in case of an earthquake, having decided upon a family meeting place, preparation of a safety kit, water and food reserves for emergency situations.

*Figure 2.1-One on One interviews*

The second section of the interview questionnaire concentrated on the expectations and acceptance of the residents towards dif-

different warning mechanisms and awareness models. We also obtained information regarding current awareness programs experienced by the respondents, if any, and improvements that could aid the process. In this section we inquired about the warning mechanisms most suitable for them such as television prompts, smartphone alarm systems or public sirens, etc. We also gauged the most acceptable method that could impact public awareness and their adaptability to it.

Additionally, we interviewed Mr. Nand Lal, Senior Architect, H.P.P.W.D., Mandi, and the employees in the office regarding the norms and guidelines passed down by the Government of India for public buildings as well as private houses. We inquired about the department's role in disaster management and the implementation of various norms in both public and private properties. We also asked about their opinions and suggestions to improve the current condition and problems faced during the implementation of the norms.

Our second objective was to develop appropriate strategies and technical solutions based on the data recorded from the respondents. The data recorded was analyzed to obtain the most acceptable method for warning systems and awareness models such that it could have a greater impact on the overall situation and have a long term impact on disaster management, precautions, planning and aftermath. The information gathered was organized in a database and analyzed to produce graphical models to display key findings among the multiple parameters and model our strategies accordingly. A Snakes & Ladder game was developed to spread awareness about Earthquakes. The detailed survey questionnaire for officials can be found in Appendix 2

In our third objective, we focused attention on the technical part of the project. We discussed with our mentors and decided to make a mobile app based on Fast Fourier Transformations of accelerometer signals to pre-detect earthquakes from P waves. In addition, realizing the importance of post-disaster measures, we came up with idea of rescue robot with dimension 10cm x 10 cm which can search for human bodies under debris. The bot is based on heat signature detection using IR cameras .

## Results

Below, we present our results from our interviews corresponding to our objectives. In total, 49 people were interviewed from the Mandi town, Katindi village, Kullu town and surrounding villages. Additionally, Mr. Nand Lal, Senior Architect from H.P.P.W.D. Mandi Head Office and other employees from the Office were also interviewed.

### *Objective 1: Assess the existing conditions*

Our open-ended interview with the Senior Architect of H.P.P.W.D. Mandi Head Office, revealed valuable information regarding implementation of the norms passed by the government of India regarding construction of residential, public and private commercial buildings as well as infrastructure. He told us about the policies and strategies currently in place for Disaster Management and the improving condition of risk and Disaster Management in Mandi Region and Himachal in general.

The interview with the Senior Architect revealed that current there are no warning or predictive systems for earthquakes at the district level. Rather, only effort for disaster aftermath are made and there is a government body consisting of officials from various departments to oversee the Disaster Management and aftermath issues. It was also revealed that there are no set evacuation plans for the populace and the infrastructure is often planned without taking into consideration any mass or ordered evacuation plans.

He stated that though the public buildings and constructions under P.W.D. follow all norms and guidelines passed by the government, it is often not so with the private constructions due to poor implementation and enforcement system. These construc-

constructions are often built by semi or unskilled construction workers due to their cost effectivity and mostly don't follow any set plan or blueprint. These constructions are non-resistant to earthquakes and in turn cause large scale destruction of property and life.

From our interviews with common people, we concluded that there is a huge difference in awareness and preparedness level in rural and urban areas. At one end, awareness level is more in urban areas. At the other end, rural area are following traditional methods of house building making their houses more resistant and prepared for earthquakes situations.

The areas in which interview were conducted were Mandi town, Kullu town, Baaghi and Katindi. Peoples of some villages around Kullu were also interviewed. The main focus was to interview people linked with different economies, geographical area and cultural backgrounds. While the people were more disconnected from the urban developments, people in Mandi and Kullu were aware of the drills conducted by Government. People in Katindi though connected to Main road were not much aware of the government guidelines and policies.

Figure 3.1 represents the data interpreted about Earthquake resistant building. Most of the house are less or not at all prepared for earthquake. Roughly 83% of houses falls under this category. The figures are quite haunting considering the seismic zone V conditions in Mandi District.

Figure 3.2 indicates the prepared levels of people for earthquake situation. Different aspect like safety kit, Emergency contact no., immediate reaction to earthquake situation were considered in determining the preparedness level. Again, mMost of the people were not at all prepared for such situation. 43% of the peoples didn't have any preparedness while 47% of the people were having some basic ointments and safety measures. Sadly and quite expectedly , only 10% peoples were fully prepared for earthquake situations.

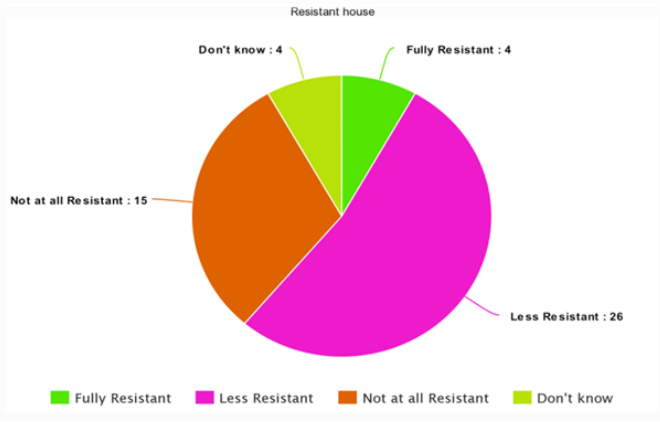



*Figure 3.1- Earthquake Resistant Houses*

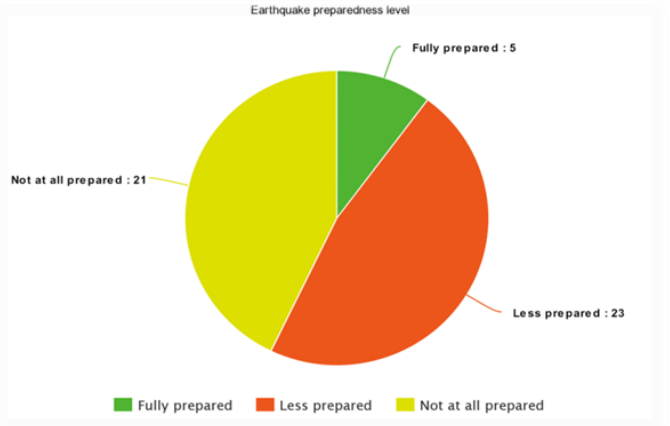



*Figure 3.2- Preparedness in General Public*

### *Objective 2: Develop Appropriate Strategies to Spread Awareness*

After gathering all the data from the residents, we organized the data in a database and analyzed it. The data was represented in the form of pie-chart and histograms to draw out the key findings and distinguish public perceptions and their preferences.

The data obtained from the interviews [Figure 3.3] indicated that only 19.51% of the general populace had ever met any of the awareness programs run by any government or non-government agency. While the 80.49% had never been educated about earthquake precautions, construction norms or disaster aftermath management. This, when correlated with the data for preparedness [Figure 3.2] which shows that only about 10.20% of the population is prepared for emergency situations like earthquakes

clearly depicts the acute lack of awareness among the residents. Thus, the root cause for negligence and unpreparedness is majorly the lack of awareness.

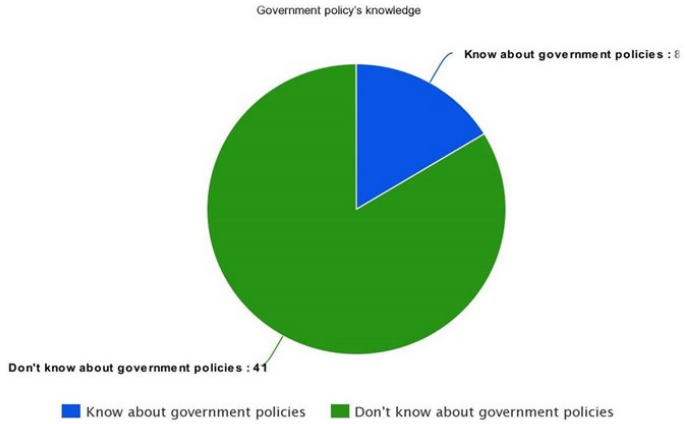



*Figure 3.3- Knowledge of Government Policies*

In response to being asked about the basic procedures and actions to be taken during an earthquake, most of the respondents only described the instinctual action of running to an open space which may not always be a good choice, and may even be a fatal mistake in certain situations. While a minority of the respondents did know about the basic Do's and Don'ts of the actions to be taken during an earthquake, courtesy of their school curriculum, but they too mentioned that the lesson were not too much stressed on and were just mentioned once.

On being asked about the mode of spreading awareness, the most common response was to make it simpler yet less cumbersome than the traditional awareness camps and posters. Though the traditional methods are effective, they often lead to loss of interest of the attendees. They suggested to make more interesting such that it is easily accepted and understood, without being too tiresome. Also, they suggested that the process should be a recurring one, so that the information is refreshed in their memories and not easily forgotten over time.

***Objective 3: Pre-disaster detection and helping in rescuing program.***

This objective dealt with the technical part of the project. In depth research was done on possible solutions for detection of earthquakes and to make a gadget which can help with rescue operations in post hazard situations. These can be summarized in Table 2 as follows:

In the context of Earthquake detection, it was determined that innovation and easy use of solution is first priority. The solution proposing detecting the radon gas activity was rejected on basis of the cost and time involved in carrying out solution.

Pressure(P) waves and Shock(S) waves are two major type of waves involved in an earthquake with P wave being faster, less destructive and S waves are slow and more destructive. The frequency of P waves is in between 1-10 Hz and they be simulated in lab easily. Detection of P wave is possible in two methods, first one being use of Reverse Pendulum method and second being making use of Smartphones accelerometers for detection. Second one is lesser accurate in general but more accessible and more affordable.

In context of Gadget for helping rescue operations, the solution of debris remover was rejected on the ground of the cost involved

| Problem | Possible Solutions | Selected Solution |
|---|---|---|
| Earthquake detection | Radon gas activity detection<br>P-wave detection using Reverse Pendulum<br>P-wave Detection using Smartphone Accelerometer | P wave detection using Smartphone Accelerometer |
| Rescue Operations Helping Gadget | Debris remover<br>Human detection system using heat signatures and Motion sensors<br>Human detection using $CO_2$ detector | Human Detector using Heat signatures and Motion sensors. |

*Table 3—Pre-disaster problems and solutions*

and inefficiency of the solution. The solution involving CO2 deemed unrealistic as in case of earthquake there may be fire hazards leading to false detection. Henceforth, the solution of using heat signatures was finalized along with use of PIR sensors for detecting motion sensitivity.

## Discussion

Various ideas were discussed throughout the project. The ideas discussed can be categorized in two major sections.

***Pre-Disaster Preparedness and Awareness***

Awareness is one of the most important and risk determining part of any disaster preparedness program. Our team proposed many ideas for spreading awareness, including commonly used idea like Posters, Pamphlets and websites. The one idea that interested the team was developing an android game involving the awareness aspect.

Dr. Varun Dutt suggested the idea of making a basic Snakes and Ladders game [Figure 4.1] with an innovative touch. In this game, the user will be rolling a dice giving a random number; Aif the user reaches a ladder, he will be shown a video showing some general awareness module. Similarly , if user falls on a snake, he will be given a chance to bypass it by giving correct answer to 3 basic questions related to earthquake preparedness. The game is focused on gaining attention of young generation who use Smartphone frequently.

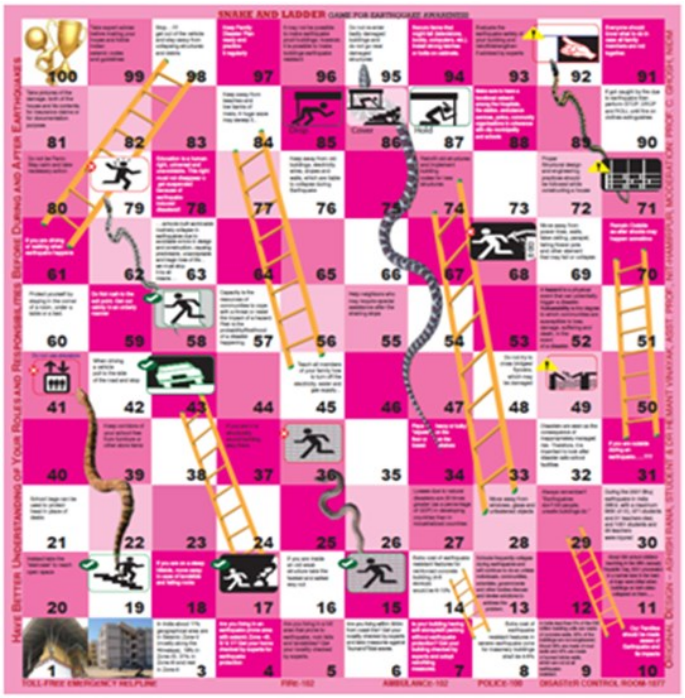


*Figure 4.1- Snake and Ladder Game*

In addition to the game, the team made a website www.eqaware.weebly.com and a video to spread awareness about the disaster.

***Pre-disaster prediction***

In the context of pre-detection prediction, the team focused on detection of earthquake on basis of detection of Pressure waves (P) waves using Smartphone accelerometer. One such application is MyShake by UC Berkeley Seismological Laboratory. Our application will be using accelerometer sensor of smartphones. Smartphones are sensitive enough to detect P waves and alarm us a few seconds earlier. To verify whether the reading of accelerometer is from P waves or is it normal shaking, we will do Fast Fourier Transformation (FFT) of the accelerometer's reading and match it with the readings of quake alarms' (manufactured by jds products and well known for its proper functioning) readings to check whether the accelerometer's peaks are equal to that of quake alarm's in range of 1-10 Hz. The prototype version will be limited to use on single smartphone. However, as an extension to the app , the data from various devices can be analyzed to confirm the occurrence of earthquake. A basic SWOT analysis of the app is presented in Table 4

***Post-Disaster Rescue operations robot***

The third objective of the team was to make a technical gadget to help rescue teams in carrying out their operation. After discussing various available solutions, the team decided to work on a Human Detection Robot. The main aim of the bot will be to detect any human activity in debris and then to signal the same to a rescue team. The robot will be autonomous and information will be conveyed through a Bluetooth module fitted on the robot. The size

| Basic SWOT analysis of Earthquake prediction app | |
|---|---|
| Strengths | Low cost method<br>Accessible and easily usable |
| Weakness | Accuracy is limited<br>Noise can result in false prediction |
| Opportunities | Data from many smartphones can be analyzed to increase accuracy<br>Accuracy can be increased by using more complex algorithm |
| Threats | Better methods are available, for eg. Reverse Pendulum |

*Figure 5.1- Snake and Ladder Game*

of the robot will be 13x13 cm2 making it small enough to find its way through debris.

The main limitation of the robot is the cost of the bot. A fully functional robot will cost around ₹11000 (calculated att MRP) which is affordable for government funded teams but not to non-profit organizations and other volunteers teams. Apart from that, the robot will not be 100% accurate and may give false signals.

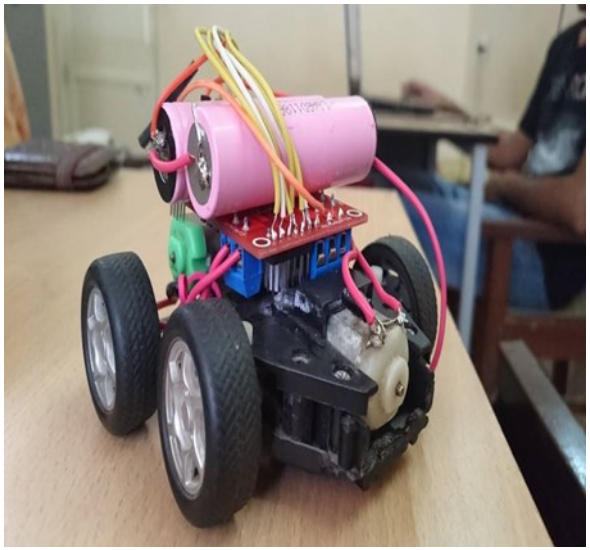


*Figure 6.1- Prototype of Rescue Robot*

## Project Outcomes

From the analysis of our results, we identified three main problems with current conditions: lack of education regarding earthquakes, shortcomings with implementation of norms for construction, and lack of any warning and rescue system. To address these shortcomings, we have a recommendation and two prototypes that can be implemented to improve the current condition.

***Recommendation to ensure earthquake resistant constructions***

To ensure that private construction follow proper norms and guidelines passed down by the Government of India, we recommend setting up of an authoritative body that supervises and enforces construction projects such that only the approved plans are followed. Additionally, it can issue and regulate work licenses for construction workers (such as masons) who have a say in the structure's basic design and planning. This would promote skill acquisition among construction workers.

We recommend that training centers should be set up for masons to educate them about the basics of construction foundations and norms to be followed. In this way, not only the enforcement of plans will be implemented easily, but the long term effects will ensure an overall emergence of planned and risk proof infrastructure. This can ensure

that even those landowners who are unable to afford the services of an architect or engineer would at least have a qualified and informed mason who can still advise them and follow all the norms required for the concerned region.

***Awareness amongst stakeholders about earthquake preparedness***

In our surveys we found that stakeholders are not aware of earthquake preparedness practices. We have made an app for a Snakes and Ladders game which will have videos and questions which one has to answer in order to proceed. So it is expected that users will have a virtual image of how destructive an earthquake can be. Knowing a few facts and protection techniques will help to save a lot of lives.

***Prior warning to a coming earthquake***

Earthquake detection app which uses accelerometer sensor of a smart phone will detect P waves which travel faster than the destructive shock [s] waves. The app can alarm us about a coming earthquake from miles away, which will give us a few precious seconds to hide in some safe place and save our lives. Using IOT, sensors can be put on trains, which will let the trains know about the upcoming earthquake so that they will have proper time to minimize their speed.

Government will have data as to where an earthquake has struck, and with what magnitude, so that they can approach that place to rescue people.

A general siren in public places or television broadcasts or radio or smartphone notifications will make people aware of upcoming threat so that can be prepared and at least save their lives.

***Rescuing people underneath rubble***

An autonomous robot has been designed which can go into the depths of rubble and detect signs of some living thing being stuck underneath; it can then send a signal to the receiving end. It will help to rescue people since sometimes we don't have any idea if there is someone under the rubble or not and while removing rubble we may also harm the person underneath. This robot is able to tell the precise location of the person.

## ACKNOWLEDGEMENTS

Our team would like to acknowledge the following individuals and institutions for their contributions to the completion and success of this Interactive Socio-Technical Project:

- The Indian Institute of Technology– Mandi for giving the opportunity to participate in this project.
- Our mentors Dr. Varun Dutt, Dr. Venkata Uday Kala, Dr. Svetlana Nikitina and Dr. Fabio Carrera for their guidance and support throughout the project.
- Mr. Nand Lal, Senior Architect from the Mandi Public Works Department for his valuable time and information.
- Dr. Devika Sethi for her support and guidance throughout the course work of this project.
- Mr. Nilesh Dixit, Teaching Assistant for the project for his regular feedback and assessments.
- Mr. Sudhakar Kumar, Project Associate, ACS Lab, for his help on Earthquake detection algorithm and alarming application development.

## References

"Berkley University", http://news.berkeley.edu/2016/02/12/new-app-turns-smartphones-into-worldwide-seismic-network/

"Track Earthquakes ", http://earthquaketrack.com/p/india/himachal-pradesh/recent

"Quake alarm", http://www.quakealarm.com/

"National Institute of Disaster Management (NIDM) ", http://nidm.gov.in/PDF/IEC/ludo.pdf

V Joshi, MS Rawat, AK Sharma, K Kumar & AK Panda. 2011, "Traditional knowledge of natural disaster mitigation and ethno medicine practices in Himalaya with special reference to Sikkim", Indian Journal of Traditional Knowledge Vol. 10 (1), January 2011, pp. 198-206.

Wei Liu, Xiaolong Zhang and Pan Zou. 2012, "The mitigation measures of frequent earthquake in the construction of new rural area", Advanced Materials Research Vols 594-597, 2012, pp. 1629-1633.

"Himachal Pradesh State Disaster Management Authority", Earthquake Hazard Profile of State, http://hpsdma.nic.in/ProfileOfState/EarthquakeHazardProfile.pdf

"Amateur Seismic Centre, Pune, 2017", http://asc-india.org/seismi/seis-himachal-pradesh.htm

# Developing a Proposal for a Landrace Seed Bank in the Mandi District


## Abstract

The goal of this project was to determine the need for a local landrace seed bank in the Mandi district. If this need was found the follow up goal was to propose model for a seed bank. To achieve this goal our team completed thorough surveys focusing on local perception and usage of landrace and hybrid seeds, local seed storage techniques, and farmer interest in a seed bank. Nutritional analysis was also done to compare both types. These tests and surveys resulted in evidence for a local landrace seed bank and a proposal for



**Team Members:**

Rohit Chauhan, IIT
Yogendra Dhiwar, IIT
Rishabh Meena, IIT
Reese Petersen, WPI
Christopher Rockwell, WPI
Rachel Scaer, WPI

**Advisors:**

Dr. Shyam Kumar Masakapalli, IIT

Dr. Puran Singh, IIT

Professor Fabio Carrera, WPI

Professor Svetlana Nikitina, WPI



An Interactive Qualifying Project/Interdisciplinary Sociotechnical Project submitted to:

## Investigating the Current Condition of Agriculture in the Mandi District

The farmers of the Mandi district are a deeply religious group of people who proudly operate independently. With very little documented information about agriculture, the crop varieties and practices being used are unknown to outsiders. This has allowed many of the farmer's' problems to go unnoticed and prevented the exchange of valuable agricultural knowledge, warnings of possible threats and new opportunities.

The current gap in farmers' agricultural knowledge is more of concern now than ever, as they face the increasing effects of climate change. A changing climate will make things even more difficult for the farmers of the Mandi district who rely predominantly on rain for irrigation. It is estimated that between the year 2010 and 2039 crop yields across the globe will decline between 4.5 and 9% (Guiteras, 2007). With rising temperatures, unpredictable rainfall, and more natural disasters, the threat of crop failure and seed extinctions becomes ever more prevalent.

With this in mind, we first determined that agriculture in the Mandi district had to be investigated and documented. We focused specifically on the enigmatic use of landrace and hybrid seeds. Landrace varieties are indigenous seeds that are commonly adapted to the specific agro-climatic conditions of their region. To learn more about these seeds, we explored seed usage, seed storage and farmer perception of seeds.

Soon after beginning our investigation of landrace and hybrid seed usage we identified that the farmers were poorly educated and therefore, were unaware of the best agricultural practices.

Some of the most common malpractices we discerned were poor storage of seeds, misuse of fertilizers, improper choice of seeds, and a lack of awareness of disappearing landrace seed varieties.

## Creating a Seed Bank in the Mandi District

After gaining a better understanding of agriculture in the Mandi district and gauging farmers' interest, we concluded that establishing a landrace seed bank would be beneficial to both individual farmers and the farming community as a whole. The goal of this project is to create a proposal for a landrace seed bank by learning about seed usage and storage techniques in the Mandi district. This seed bank would allow farmers to exchange and store seeds for little to no cost. It would also provide educational services to the farmers in an attempt to expand their knowledge about the seeds they are using and how to store them properly.

## Methodology

In order to accomplish our goal, we created 5 different objectives to guide us:

1. Explore the extent of usage of landrace and hybrid seeds
2. Identify local seed storage techniques used by small scale farmers
3. Study farmers' awareness and perception of landrace and hybrid seeds
4. Investigate pros and cons of landrace and hybrid seeds
5. Develop a proposal for a local landrace seed bank

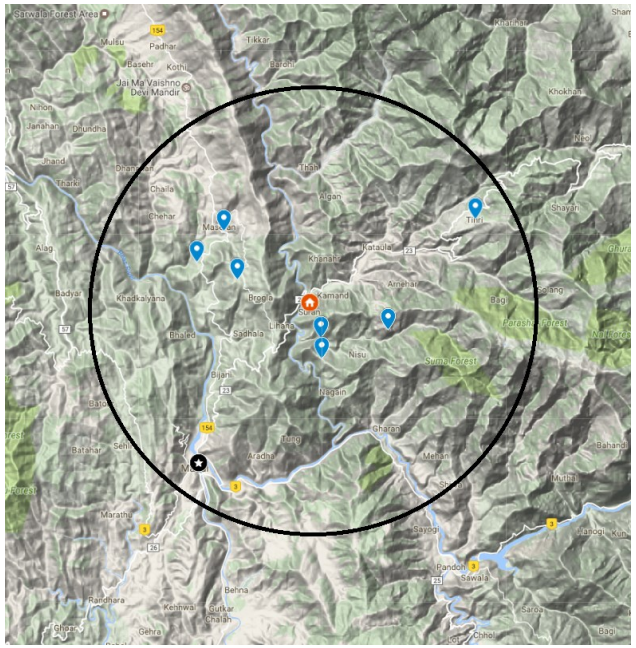


*Figure 1 Map Showing Survey Locations*

To accomplish these objectives, we conducted interviews with farmers from 7 villages (Dwardu, Taryambali, Neri, Tihiri, Doohaki, Drang, Namlay) in the Mandi district. These villages (blue markers in Figure 1) were chosen within a 10 km distance from IIT (orange home icon) since, we determined farmers would not be interested if they had to travel further than the nearest seed distributors in Mandi. We then chose villages at low, middle, and high altitudes to account for different climates and crops. Along with these villages, we interviewed officials at the Agricultural Department in Mandi (black star marker).

In these interviews, we focused on crop production, usage and opinions of hybrid and landrace seeds, expenditures, storage techniques, and farmers' interest in a landrace seed bank. To record this data, interviews were conducted by our IIT group members and translated for us to record. Over the course of this project we created three different iterations of our surveys to make them more concise and relevant.

Our surveys were unable to clearly identify the pros and cons of landrace and hybrid seeds, so, we conducted a preliminary nutrient test. In this test we looked at the nutrient content of different landrace and hybrid seeds. We conducted this test in order to learn whether or not one of the varieties was nutritionally dominant over the other.

## Results

The following sections focus on the most relevant and conclusive data found from the local farmer interviews. Each section focuses on how we accomplished an objective, as well as the concluding data.

## Evenly Split Usage of Landrace and Hybrid Seeds

To come to a better understanding of agriculture in the Mandi district we surveyed the farmer's' extent and usage of landrace and hybrid seeds to better understand why they were using each variety. The data below offers a preliminary understanding of this information.

The table below shows the overall split between landrace and hybrid seeds used by the farmers. As you can see, there is a fairly even split between landrace and hybrid seeds in the Mandi District. In figure 2, the slice labeled "Mix" indicates percentage of farmers who use a combination of landrace and hybrid seeds: most commonly half landrace and half hybrid in one plot. Using this the new split would be 50% landrace and 42% hybrid.

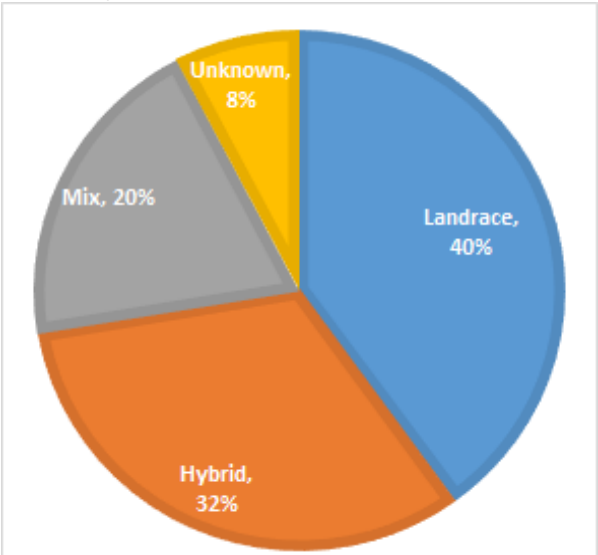


*Figure 2: Seed Split by Type*

This data only accounts for the reported type of seed grown. It does not display the amount of each seed that a farmer uses or the area the crop is grown in.

Figure 3 shows all crops that were commonly grown in the Mandi district (Not including arbi, kodra, lady finger, matar, pea, and radish due to small sample size). Crops that were found in the same number of farms were grouped together.

Less common crops are usually landrace, with a 66.7% landrace to 33.3% hybrid split, for crops with five or fewer instances of use. These crops are also commonly grown in smaller areas, averaging at 1.6 bighas (one bigha equals one quarter of an acre) compared to the overall average of 3.7 bighas.

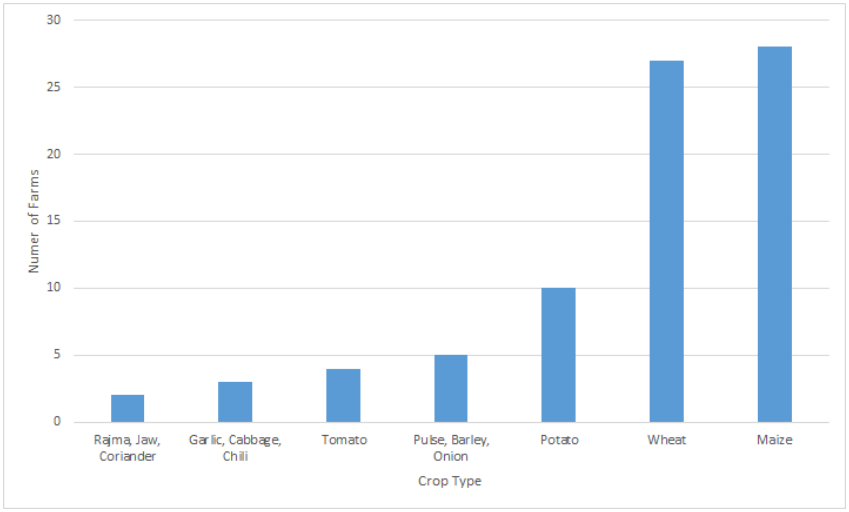



*Figure 3 Popularity of Crops by Appearance*

As you can see in figure 3, maize and wheat are the most commonly grown, found in almost 100% of farms. They also account for the most seeds and largest areas. As major crops of the area, landrace crops were used solely for home consumption. It is important to note that farms that sold crops are significantly larger. The median size of a farm that sold crops is 9.9 bighas, while the median size of a farm that doesn't sell crop is 5.1 bighas. Compare this to the 1.3 Bigha average of less common landrace varieties, and it becomes obvious that many landrace varieties are being given fewer resources, while land and money is instead being invested into growing larger amounts of hybrid seeds, as the farmer hopes to sell them for profit.

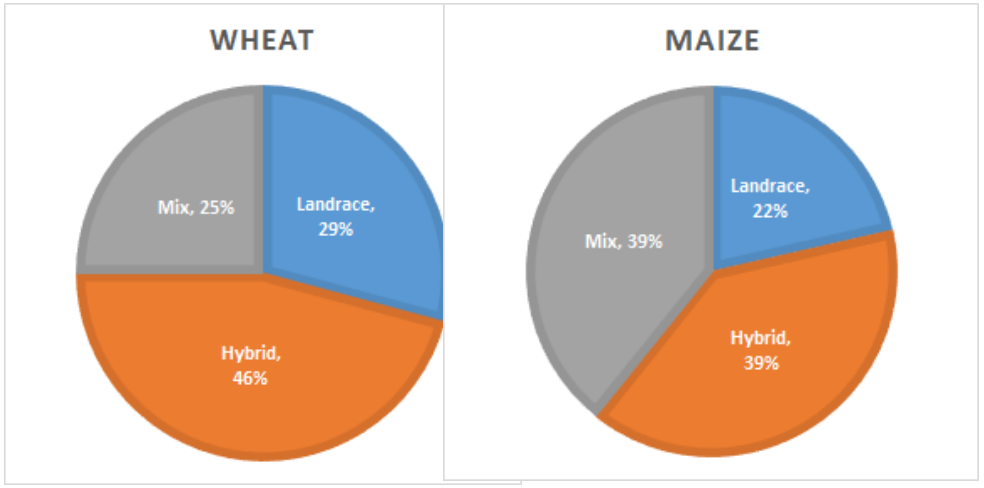



*Figure 4: Landrace Versus Hybrid Split for Maize and Wheat*

These hybrid seeds can be expensive. Maize seeds cost an average of 59 rupees per kilogram and wheat seeds cost an average of 20 rupees per kilogram. Farmers used an average of 16.7 kilograms of maize seeds and 41.3 kilograms of wheat seeds. This represents a cost of 985 rupees and 830 rupees respectively. Landrace seeds are free as 93.3% of landrace seeds came from the farmer, while 100% of hybrid seeds were bought from a supplier. It's difficult to see whether the profits brought in by hybrid seeds is more or less beneficial than the low cost of the landrace seeds. Either way, to compete with the growing interest in hybrid seeds, it is important that landrace seeds stay free and readily available.

## Majority of Farmers' Using Improper Storage Methods

One part of our survey focused on identifying seed storage techniques used by local farmers. We focused on techniques that would be useful for storing seeds in the prospective seed bank. As we delved deeper into the issue we realized many farmers are using incorrect storage techniques, further throwing landrace seeds in danger.

A quick breakdown of the storage methods shown in figure 5 shows a pattern of improper seed storage. Drums were the most commonly used, with 71% of interviewed farmers using them as their main storage method. Drums are an ineffective storage method; due to the lack of airflow and sunlight in a drum, seeds can easily become infected by insects or rot. 65% of these farmers used medicinal herbs or pills in these drums to deter insects, disease and rot, compared to 50% of farmers using leaves in other storage devices.

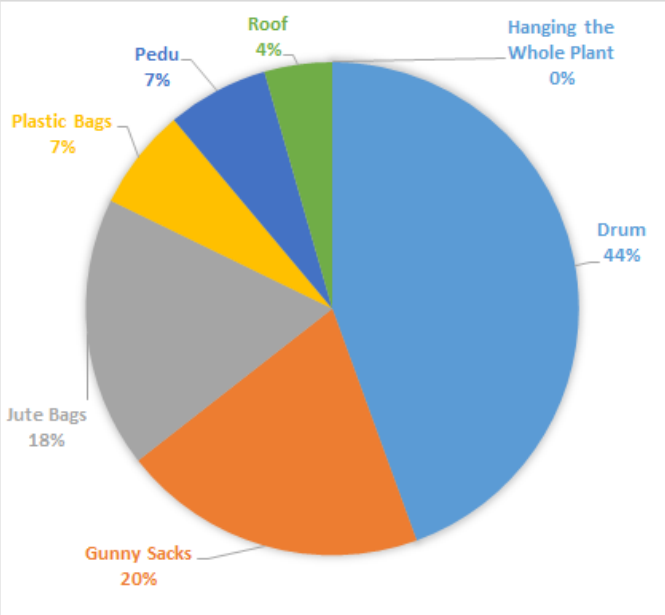



*Figure 5: Farmer Use of Seed Storage Methods*

This data shows that the majority of farmers are facing issues with rot, as they use the medicinal herbs to deter it. Farmers who use drums as their primary storage method, face issues with rot at an even higher rate. 65% of farmers using drums as their primary storage method reported insect infestations while 50% of farmers overall reported insect infestations. There is a parallel between reporting insect infestations and using medicinal plants to deter them, as seen above, the numbers are the exact same. These numbers together suggest that the major issues of seed rot are caused by lack of farmer knowledge in proper storage techniques.

After establishing the existence of the storage problem, it is important to know how it is affecting the community as well as their seeds. 64% of farmers reported that landrace seeds are their preferred seed source if available. If unavailable, the same farmers are forced to buy hybrid seeds. In some cases, insect infestations during storage make landrace seeds unfit for planting, causing farmers to switch to hybrid seeds. Currently, if farmers lose seeds to an insect infestation, it can permanently diminish their ability to grow that crop variety in the future, as replacing landrace seeds is extremely difficult due to them being impossible to buy. This can cause extra expense to the farmer as he is forced to buy hybrid seeds. Even worse, it could cause the loss of an endangered crop variety. If a species is reduced to a small amount of seeds and infected by insects, it could be impossible for it to grow again. Luckily there is a solution. Some of the farmers that we spoke to claimed that if seeds are stored hygienically, there will be no problems with pests. The reportedly hygienic methods were as follows:

- Storing seeds in containers with airflow, such as:
  - Jute bags
  - Gunny sacks
- Exposing seeds to regular sunlight, especially infected seeds
- Storing maize in the husk, hanging

As you can see in Figure 5, no farmers claimed to use hanging the whole plant as a primary storage method, but occasionally farmers would show they were using the method for a small amount of seeds and vouch for its effectiveness.

## Farmers Unaware of Landrace and Hybrid Seed Qualities

To better understand why farmers are choosing either landrace, hybrid, or both types of seeds we included questions on our survey to gauge their perception of the seeds. From our preliminary interviews, we compiled a list of pros and cons for both types of seeds. We put this list into a multiple-choice format on our survey so that farmers could easily pick what they thought the pros and cons were. There were two pros that stood out clearly. We found that 77% of farmers felt landrace crops were more nutritious than hybrid. While landrace was perceived by farmers to be more nutritious, nearly 73% of farmers said that hybrid seeds produced a higher crop yield.

One of the major reasons for creating a landrace seed bank in the Mandi district would be to preserve genetic diversity. Part of preserving genetic diversity is protecting landrace seeds that are in danger of going extinct. 57% of farmers were aware of landrace seeds going extinct but did not necessarily know why or which varieties. Of the varieties mentioned, the two most common were kodra and red rice.

## Nutritional Testing to Find the Difference between Landrace and Hybrid

Thermogravimetric analysis was done on landrace and hybrid maize seed samples to determine if there was a difference in nutritional content, as previously reported by farmers. Thermogravimetric analysis is a method of thermal analysis where chemical and physical properties of a sample are measured as a function of increasing temperature (Coats & Redfern, 1963).

In our tests, samples were heated up to 800 degrees Celsius at a constant rate, during which a continuous measurement of the samples mass was taken. Major nutritional blocks such as protein and carbohydrates will burn at set temperatures, leading to a mass loss. The percent of total mass lost at these temperatures thresholds will show its nutritional content.

This method was used on one sample of landrace maize and one sample of hybrid maize. A comparison of their mass over time and temperature showed no major differences.

## Discussion

As we studied the results of our surveys it became clear that a landrace seed bank is needed in the area. The need can be broken up into 4 different areas: lack of farmer education, protection of endangered landrace varieties, farmer access to landrace seeds, and climate change adaptations.

First let's focus on the importance of preserving farmer access to landrace seeds.

As mentioned in results, larger farms are choosing to supplement their income by growing an excess of high yield hybrid seeds to be sold at market. As farmers become more interested in these profits they are likely to continue to move away from landrace varieties towards hybrids (Himachal Pradesh Agriculture Department). This shift could constitute a threat against the genetic diversity provided by landrace varieties.

There are already a large number of landrace seed varieties reported in very few farms and raised in small areas.

These varieties are more vulnerable purely due to being less common and grown on smaller areas. A landrace seed bank would protect these landrace varieties from endangerment or extinction if their use continues to decrease and allow farmers to continue to use landrace seed varieties that are adapted to the local condition and climate.

According to our survey, the majority of farmers spend money on hybrid seeds annually, while making no profit. This is because two thirds of farmers use all of their crop for home consumption. Easier access to free landrace seed varieties through the seed bank would reduce this cost. The average total cost for maize and wheat crops is 1815 rupees. Average farmer income in Himachal Pradesh in 2013 was 6426 rupees per month or 70,686 rupees a year (National Sample Survey Office, 2013), so buying seeds represents a significant expense for farmers, with no return of income from the farm. A reduction in this expense could have positive impact on a farmer's production, potentially allowing them to sell crops. A seed bank could potentially eliminate this cost, as it would provide free access to landrace seed varieties.

As mentioned in the results, it's very important that landrace seeds are properly stored in order to maintain a high degree of farmer accessibility as well as preserve endangered varieties.

The majority of farmers are using drums as a storage methods and this is putting many of their landrace seeds at risk. Due to the lack of airflow and sunlight in a drum, seeds can easily become infected by insects or rot. These seeds are often unusable when it comes time to plant. With 71% of interviewed farmers using this storage method, we can assess that the majority of farmers are using improper storage methods. This means a couple different things. First, that endangered landrace species could easily be lost or damaged by farmers using such techniques. Second, an increase in storage method education would most likely improve these seeds' germination rates. Better storage methods would mean that farmers could potentially spend less money on hybrid seeds, use more of the seeds they prefer, have higher yields, and store viable endangered seeds for a longer time.

The issues with landrace seed storage are strong evidence for a seed bank. The seed bank would be able to properly store and protect endangered landrace seeds that are in danger of being lost to an insect infestation. Currently, if farmers lose seeds to an insect infestation, it can permanently diminish their ability to grow that crop variety in the future, as replacing landrace seeds is extremely difficult. The seed bank would act as a permanent supply of these landrace varieties, allowing farmers to replace any lost seeds. This would greatly increase their ability to grow their preferred varieties of seeds, as well as protect endangered varieties. The bank would also be able to facilitate education in storage methods for the farmers, so they could properly store their own seeds. Access to free seeds and education from the bank would also reduce costs for farmers, as they would no longer need to invest as much money into hybrid seeds. A seed bank would also greatly increased accessibility to landrace seeds.

Our surveys show that landrace seeds were thought by farmers to be more nutritious, while hybrid seeds were said to be higher yielding. Both seed types are important to the farmers' success and therefore both must be preserved. Hybrid seeds are readily available according to farmers, but landraces are typically stored by individual farmers and have no large supply. A seed bank would provide these farmers a central location to store their seeds and allow them access to previously unavailable landrace seeds.

With more than 50% of farmers being aware that landrace seeds are going extinct it is clear that there is a need to protect these seeds before they completely disappear. The seed bank we are proposing will properly store and grow these endangered landrace seeds. It is important to create this seed bank as soon as possible in case these endangered seeds need to be reintroduced. This could happen if a blight or change in climatic conditions wiped out another popular crop. An example of this was the corn blight of 1970 in the United States where 5% of the crops were wiped out (Muir, 2011). If this were to happen to an agriculturally based economy like India the results could be catastrophic. As climates change, these landrace varieties could also be crossed with other varieties to make crops that are adaptable to a region as well as produce higher yields. Having this access to genetic diversity could be imperative for protecting the world's food supply.

Many farmers claimed that landrace seeds were more nutritious than their hybrid counterparts. We tested this theory in the lab to see if there was any truth to the claim.

Thermogravimetric analysis showed that in the case of maize there was no difference in terms of nutrition between landrace and hybrid seeds, but our results are still inconclusive. With only one sample tested, our sample size is not large enough to inspire any confidence or rule out any error. Testing was also only done on maize, one of the two major crops. An increased sample size is needed, as well as testing using wheat, before any substantial conclusions can be drawn.

Testing should also include details about vitamin content, but our current method of thermogravimetric analysis is not accurate enough detect them due to their miniscule mass. Vitamins are a major part of nutrition and could account for the discrepancy between our results and farmer perception. Atomic absorption and flame emission spectrophotometry testing could be used to test for Vitamins C and A, calcium, and potassium in a future study (Asghari, Palizban, & Bakhshaei, 2015).

## Seed Bank Proposal

Based on the information gathered from our farmer surveys, there is a need for a seed bank. This bank will protect endangered landrace species, give better, low cost, access to seeds for farmers, and educate farmers in sound agricultural practices. The proposal below contains the details of the seed bank, detailing the costs and resources necessary to run it, and the processes required to make it successful.

## Storage Methods

It is important that the seeds are stored using an effective and proven method. Improper storage methods can cause a large loss of seeds. 71% farmers we interviewed faced problems from incorrect storage, impacting their ability to sustain a useable number of landrace seeds. Common threats to seeds are insect infestations, seed rot, and a decrease in germination rates. The seed storage methods we are recommending for the seed bank have been recommended as effective by local farmers as well as supported by research.

Maize is one of the most vulnerable crops to improper storage. 50% of farmers complained it would become infested with a bug called cun, ruining the seeds. Other farmers assured us that if the seeds were stored hygienically they would be free of bugs and store well. The most effective storage method is to harvest the cobs whole with the husks still intact. Two corn husks are then tied

together and hung in an area with plenty of airflow. Placing the cobs in the sun monthly eliminates any threat of infection (Vernooy).

*Figure 6: Maize Hung in the Husk*

The other most commonly grown crop is wheat. Although it doesn't face as many issues as maize, its proper storage is still very important. One of the most effective methods is storing the wheat in gunny or jute bags. It is extremely low cost, and easily accessible. The nature of the bag allows for airflow keeping the seeds dry and fresh. These seeds should also be placed in the sun every month or so to prevent insects and keep the seeds dry. Barley will also be stored the same way.

Other commonly grown seeds such as the pulse Rajma can be stored in a pedu. Many local farmers have stopped using this practice due to the time and effort required, but it is still one of the most effective methods available (Vernooy).

## Structure and Location

The seed bank must be placed at a central location from all the villages, with easy access. It must also have access to staff, transportation, and open area for the seed bank. Considering all of these factors, we have decided the best place for a seed bank would be IIT.

The seed bank should be a simple concrete room. There should be a few windows for proper air ventilation to prevent seed rot. There should be hooks inside and outside to properly hang jute and gunny bags, as well as maize for drying. There should also be simple shelves to keep containers off the floor to prevent insect infestations.

The botanical gardens will serve as areas for seed proliferation, allowing the seed bank to sustain and improve its seed supply. The already existing seed bio labs will be used for occasional germination testing, to assure a batch of seeds is still viable.

*Figure 7: Jute Bag*

## Management

An important part of a seed bank is who will run it. Local Krishi-Kendras are run by governmentally trained agriculture staff. Our seed bank would at first be run by a member of this staff, possibly a few interested grad students, and a few interested local farmers. The staff member and grad students would work in collaboration to train the local farmers. Once the local farmers were well trained they would take over running the seed bank.

Regular education programs would be held for other farmers by the seed bank staff in collaboration with IIT professors and grad students. These programs would focus on the costs and benefits of seed varieties, proper seed storage methods, and preventing depletion of land.

Other seed bank management duties would include:

- Monitoring outtake and input of seeds
- Seed processing/occasional drying
- General maintenance
- Germination testing
- Desk work

## Seed in and out

An extremely important aspect of the seed bank's operations is where the seeds come from, how they are distributed, and how they are replenished.

Startup funding will first be procured from IIT or a Non-Governmental Organization (NGO). This funding will allow for the seed bank to be built. This funding will also be used to purchase some difficult to access landrace seeds. Other landrace seeds will be deposited by local farmers with the understanding that during the next season they will have access to an equal amount of free seeds for their farms. Seeds that exist in small amounts will be grown in the botanical gardens, so a large supply is available.

Farmers donating seeds and removing seeds each year will continue to be the standard practice of the seed bank. Farmers who needs seeds but are unable to donate will be able to purchase seeds at a small cost or donate their labor to the farm instead.

Germination testing must be done to all stored seeds on a regular basis. The first test should be done as soon as seeds arrive at the seedbank to determine if their quality is high enough to warrant preservation. Regular seed germination testing will then be conducted minimally bi-annually.

| Collection size* | Test size* | Number of tests** |
|---|---|---|
| ≥ 1000 | 25 - 50 | 4 - 10 |
| ≥ 500 | 25 | 2 - 4 |
| ≥ 250 | 10 | 2 - 4 |
| < 250 | No test | 0 |

*Figure 8: Seed Germination Testing Sizes*

Figure 8, created by the Millennium Seed Bank Partnership, and shows the appropriate size of each test depending on how many seeds you have available. The sample size must be no smaller than 10, as it is the smallest number that allows for still meaningful data.

There is a simple homemade way of testing seeds by simply placing them on wet paper towel in a plastic bag, but the seed bank will most likely be using the seed lab's more elaborate setup. Each test ends when all seeds have germinated or a designated period of time has passed. If fewer than 70% of the seeds germinate, the quality is too low to justify continuing storage. The percentage germinated should be recorded in the database with the corresponding seed.

After some time, a pattern will be established and it will be easy to predict at what point a batch of seeds will have significantly decreased in quality. Knowing this data will allow for the caretaker to predict when new seeds will be needed. This means new seeds will be grown in the botanical gardens to replace seeds that have just gone bad.

As previously stated, seeds will be planted in the botanical gardens to allow for old seeds to be replenished. In order to tend the plants correctly, the farming practices of local farmers must be documented. Important aspects include: how the ground is tilled for the seed, how they should be planted, if they need to be watered, what amounts of fertilizer are most effective, when the plant is ready for harvest, and how to harvest the seeds. Other information that must be discovered is the size of plot needed to regularly replenish the seeds, and any necessary farming supplies.

After the seeds are harvested they must be properly processed for storage. The processing techniques of the local farmers will be documented and put into practice much like the farming techniques. Common home processing techniques are well known and are listed below to be used as an initial technique

There are two distinct categories of seeds, dry seed pods and wet fleshy seeds. Processing dry seeds is fairly simple.

Once the seed pods or heads have dried and turned brown, they are removed from the plant and put in a paper bag. The bag is stored in a well circulated, dry, warm area for two weeks until the pods dry out and shed their seeds. The seeds are then removed from the other plant matter or "chaff". One method used to remove the seeds is thrashing. The pods are manually opened, rubbed between hands, until the seeds separate. Another method is winnowing. A set of containers is set on the ground in front of a fan as shown below.

*Figure 9: Example of Winnowing*

Seed pods are poured from standing height in front of the fan. This separates the seeds by density: the denser seeds land closer to the fan and the chaff is blown away.

Processing fleshy seeds is a slightly more involved process. The plant's fruit is cut open and the seeds are scooped out. The seeds are added to a container which is filled with water and stored in a warm area to ferment. The seeds are stirred daily to separate the pulp. After a few days, the seed/water mixture become frothy from the fermentation. The water, pulp, and any floating seeds are poured off the mixture. More water is added to the seeds and poured off until the seeds are clean. The seeds are dried in hanging mesh bags that are shaken daily or spread out on a paper towel. It is very important the seeds are not dried in direct sunlight or excessive heat, as it can prevent the seeds from germinating.

Dry seeds of both varieties are stored in a labeled container such as a jar or an envelope in a cool dry location with constant humidity and temperature. This method gives most seeds a shelf life of one to five years depending on their variety (Hutton, 2010).

## Application and Website

Digital accessibility is imperative for keeping a spread out community connected to the seed bank. As many farmers' only access to the internet is an Android phone, an app and mobile website will be very important to reaching out to them. The main focus of the app will be a database showing the amount of each variety of seeds available in the seed bank, as well as information about the seed and proper storage techniques. Seeds will be tracked in the database using Passport data. This information is very valuable as it will allow for genetic information of the seeds to be recorded and tracked. (GBIF)


*Figure 12: Android Application*

The following information will be tracked in the passport:

- The name of the village where the seeds were retrieved from
- A mark of the village on a map
- The elevation of the village
- Genus and Species
- Amount stored
- Picture of seeds and crop if possible
- Serial number assigned to batch
- Storage method
- Percent in germination testing
- Data of last germination test

The second aspect of the app will be a calendar of events showing available education programs taking place.

Another aspect of the database will be to track the farmers interacting with the seed bank. It will include the following information

- Name of Farmer
- Name of Village
- Map marker of Village
- Amount/Variety of seeds donated
- Corresponding serial numbers of seeds
- Amount/Varieties of requested seeds for next season
- Lesson Interests
- Interested in Volunteering?
- Contact Information

Such a database will allow for the correct amount of seeds to be given to the correct farmers each year. Tracking farmers' educational interests will allow for lessons that target the farmers' interests and needs effectively. Volunteering interest will allow for easy contact to any interested farmers when additional work at the seed bank is available.

## Financials

As previously stated, the seed bank will need startup funding. The most straightforward way to procure funding will be by applying for a grant through IIT.

If we are unable to procure funding through IIT then requests can be made to other government agencies for assistance such as DBT, DST, and NASF.

## Conclusion

Initially, we were unaware of the current agricultural practices being used in the Mandi district because of the lack of documented information. From our surveys in villages near IIT we discovered that there were several areas of possible improvement. Much of these problems like improper storage of seeds, unawareness of endangered seeds, and poor seed selection originate from a lack of knowledge. In an effort to help mitigate these problems we determined that a landrace seed bank would be advantageous to the farmers of the Mandi district.

We have developed a detailed plan for a landrace seed bank located on IIT's campus. The proposed seed bank will offer a source of education for farmers while also lowering their seed expenditures and preserving the genetic diversity of the area. To help facilitate farmer involvement and begin a baseline source of documentation, we created an Android app and website. These tools will allow for better management of the seed bank and act as an easy source of knowledge for the farmers. We hope that this plan and app will serve as a model and inspiration for future seed banks in rural districts like Mandi.

## Acknowledgments

We would like to thank the following individuals who made this project possible:

Dr. Fabio Carrera, for his guidance and support throughout the project

Dr. Svetlana Nikitina, for her advice and help throughout the project

Dr. Shyam Kumar Masakapalli, for his help with the testing and his help understanding local agriculture

Dr. Puran Singh, for his help creating and updating the surveys

The farmers of Mandi, for their patience and hospitality throughout the interviews

## References

Asghari, G., Palizban, A., & Bakhshaei, B. (2015). Quantitative analysis of the nutritional components in leaves and seeds of the persian moringa peregrina (forssk.) fiori. Pharmacognosy Research, 7(3), 242-248. doi:10.4103/0974-8490.157968

Coats, A. W., & Redfern, J. P. (1963). Thermogravimetric analysis. A review. Analyst, 88(1053), 906-924. AN9638800906

Community seed banks (2015). Taylor and Francis

Guiteras, R. (2007). The impact of climate change on indian agriculture.

Muir, P. (2011). Diminished crop diversity.

National Sample Survey Office. (2013). Income, expenditure, productive assets and indebtedness of agricultural house-