NEED ASSESSMENT SURVEY REPORT-2012

RICE MILL CLUSTER,

BIRBHUM, WEST BENGAL

DCS MSME SCHEME

DESIGNER : KAUSTAV RAY MANDAL
CONTENTS:

1. Acknowledgement
2. Introduction
3. General information
4. Documentation overview
5. Cluster level
   5.1. Cluster level information
   5.2. Cluster product and by products
   5.3. Raw material
   5.4. Existing machineries and equipments
   5.5. Manufacturing process
   5.6. Packaging exhibition
   5.7. Problems faced at cluster level
      5.7.1. Heterogeneity
      5.7.2. Technical
   5.8. Proposals
      5.8.1. Assumptions
      5.8.2. Model characteristics
      5.8.3. Performance characteristics
6. Design audit unit base
   6.1. List of units
   6.2. Individual unit audit report
   6.3. Problems faced as unit basis
      6.3.1. Poor quality of paddy
      6.3.2. Rice brand testing lab
      6.3.3. Environmental problems
   6.4. Opportunities areas for design interventions
   6.5. Technical problems
7. Analysis and recommendation
   7.1. Technical analysis
      7.1.1. Parboiling
         7.1.1.1. Performance analysis of boiler
         7.1.1.2. Par-boiling system
      7.1.2. Pre-cleaning
7.1.3. Removing the husk
7.1.4. Paddy separator
7.1.5. Polisher/whitener
7.1.6. Separation of white rice

7.2. Rice husk technology
7.2.1. Rice quality an overview
    7.2.1.1. Quality characteristics of paddy
    7.2.1.2. Quality characteristics of milled rice
    7.2.1.3. Paddy quality determination
    7.2.1.4. Procedures for measuring quality of paddy grain
    7.2.1.5. Procedures for measuring quality of milled rice
    7.2.1.6. Standards and grades of milled rice
    7.2.1.7. Comparison of rice mill output
    7.2.1.8. Testing of a rice mill performance and quality

7.2.2. Insects and rodents
7.2.3. Husk problem
    7.2.3.1. Green technology
    7.2.3.2. Feedstock
    7.2.3.3. Preparation of feed stock
    7.2.3.4. Rice husk processing plant
    7.2.3.5. Combustion and power generation unit
    7.2.3.6. Liquid sodium silicate and activated carbon production
    7.2.3.7. Precipitated silica production
    7.2.3.8. Main applications of products

7.3. Water re-utilisation
    7.3.1. Boilers/boiler-house
    7.3.2. Cooling towers
    7.3.3. Drinking water
    7.3.4. Water recycling
    7.3.5. Water treatment in rice mill

8. Optimal design of a rice mill utility system with rice husk logistic network
8.1. Introduction
8.2. Problem statement
8.3. Problem formulation
8.4. Model formulation
8.5. Conclusion
9. Conclusion
1. ACKNOWLEDGEMENT

I would like to thank Birbhum Rice Mill Association and entire team for organizing the Design Clinic Scheme Program and showing me their work also letting me be part of their work-life to accomplish the program.

I would also thank “Design Clinic Scheme; National Institute of Design”, who has given me an opportunity to accumulate an intensive report after realizing my strength, potential and past experiences.

My special thanks to each individual unit member of Birbhum Rice Mill Association and Mr. Dipak Pramanik, the chairman of Birbhum Rice Mill Association, who have given me their great support during the design audit. Without their kind involvement and assistance I would have not been able to accomplish the Need Assessment Survey on rice mill cluster in Birbhum district.
2. Introduction:

India is the second biggest rice producing country in the world after China. It contributes about 20 percent of the world output of rice. Paddy being the major cereal crop of India covers an area of more than 42.8 million hectares, the largest under any single crop. West Bengal is the highest rice producing state in India and Birbhum district plays a vital role in rice producing. Being a designer as well as an engineer I always like to observe and analyze objects or system with economical benefits. Birbhum Rice Mill Cluster is running under several problems. During my Need Assessment Survey in this cluster as well as unit basis audit I have tried to figure out the flaws in an interactive way with mill-owners and workers and to provide them some spot solutions. And most importantly I have tried to spot out certain innovation and design area that would help for better growth of product and running a unit well.
3. **General Information** :

Birbhum is situated in the west part of West Bengal. Its neighbor districts are Murshidabad, covering its east and partially north border, and Burdwan, covering its south border. West and rest part of north border is in touch with Bihar.

The zilla sadar of Birbhum is Suri. Another towns are Sainthia, Sukhna, Bolpur, Dubrajpur, Nolhati, Bakreswar etc. Suri is well communicated with state capital Kolkata by railway and highways. Here is present Shantiniketan at Bolpur. Soil nature is red in color. The famous Baulgaan continues its tradition over the years.

The rice mills are situated at different parts of the district. Murakshi river flows across the middle of the district dividing it into two parts. The main towns are powered by Bakreswar Thermal Power Plant, though northern region is powered by Farakka Power Plant. At Bakreswar India’s largest rice mill presents.
4. Documentation Over View:

Interviewee:
1. Dipak Pramanik
2. Goutam Chhajer
3. Surendra Coher
4. Prem Chhajer
5. Falguni Laha
6. Jagadish Ch. Jash
8. Lalit Kr. Agarwala
9. Rahul Khaitan
10. Dip Chand Khaitan
11. Chandra Nath Mondal
12. Dilip Pal
13. Bijoy Choudhury
14. Mukesh Kr. Choudhury
15. Purushottam Choudhury
16. Vivek Choudhury
17. Karan Choudhury
18. Biswa Bijoy Ghosh

The field work of the Need Assessment Survey was conducted from June 4, 2012 to June 8, 2012 in nineteen rice mills which are selected by Birbhum Rice Mill Association at different part of Birbhum.

The purpose of the survey was to collect detailed information by observing the process of manufacture, by meeting and interviewing different people involved in this profession and to identify the problem areas. All the findings were recorded using notes and photographs.

Views of various parties were taken into account to get a better understanding of the scenario. I was provided with a co-ordinator from the association to help me to visit different unit during the survey. I was welcomed with different type of reactions. Few of the people were very friendly and over enthusiastic to share their view and information of the material and process and some welcome me with susceptible eye (I was asked questions like “Are you from income tax department?”). But over all I got a friendly environment and immense cooperation from the owners of the rice mills.
5. Cluster Level:

5.1. Cluster Information:

Rice mill cluster in Birbhum has near about ninety three units in different part of the district. The owners of all the rice mills have formed Birbhum Rice Mill Association. The chairman and vice-chairman of the association are Mr. Dipak Pramanik and Mr. Narottam Kr. Sarda respectively. The President of this association is Mr. Biswa Bijoy Ghosh. The association has certain norms which have been decided by the mill owners collectively and all the rice mills have to follow the norms. The relationship between the mill owners is very friendly. India’s largest rice mill belongs to this cluster.
5.2. Cluster product and by products:

Rice is the product and husk and ash are obtained as byproducts.
5.3. **Raw Materials**:

Paddy is the only raw material in this cluster.
5.4. **Existing machineries and equipments:**

The units under the cluster use more or less same type of technical machineries and equipments. Some units, though few in number, have machineries and equipments of higher degree of technical facility and production rate. And the rests have mediocre technical equipments.
5.5. **Manufacturing Process:**

The manufacturing process employed in the clusters is continuous and fully automated or semi automated, consisting of Paddy Cleaning, Par Boiling, Drying, Milling, Sorting and Packing. The Cleaning section consists of raw paddy cleaners, de stoner and dust blowers, where the dust, mud, stones and immature paddy are removed to make it completely free from the foreign materials. The next stage is a pre-milling process called Parboiling, which is the partial cooking of the grain with husk, done to impart the required hardness to paddy grains so as to withstand the pressure exerted during the Milling process. The parboiled paddy is taken to the Drying section which consists of the Drying plant, Heat exchanger and Blower.

The steam produced by the boiler is used for drying the paddy in the drier. The drying time can be altered by adjusting the temperature of the drier. When the paddy is sufficiently dry, it is taken to the Milling section. Milling is the process of removing husk from paddy by application of force through a rubber roller. Milling section consists of a Rubber Sheller, Cone Polishers, Bran Blower and Separator, De-stoner and a Vibrator machine.

The paddy is collected in a separate room and is used as the fuel for firing the boiler, or sold for making cattle feed, manure, etc. The shelled paddy is then directed to the Paddy Separator, which will separate the unshelled paddy and the rice. The unshelled paddy will again go back to the Rubber Sheller and the shelled paddy is taken to the first Cone Polisher, where the rice bran is also removed from rice. This will then go to the Bran Blower and Separator, which will completely remove the bran from the product. The bran will be collected in a separate room and will be sold to the consumers directly. The hulled paddy is again taken to the second and third Cone Polishers for polishing the rice. After polishing, the rice will move to the de-stoner and vibrator, where stones and broken rice are completely removed from the product to make it superior in quality. The rice collected at the end of the milling section then moves to the Color Sorter for removing the black and immature rice completely. The product is then moved to the Packing Section for packing in different sizes of polythene and gunny bags, weighed, stitched and taken to the store room for dispatch.
The flow-chart of the manufacturing process can be shown as follow:

![Flow Chart]

The milling machines are controlled by a central control panel. A huller, a whitener, a colour sorter, and a packer can be also controlled locally. All the machines are sequentially operated, while the machines are conversely stopped if an overload is detected. The main silos such as paddy silo, brown rice silo and polished rice silo are very large, compared with the auxiliary hoppers for each machine which can be used as buffer hoppers. Their levels can be detected by proximity sensors (switches) attached to the main silos and auxiliary hoppers. So, the exit gates of silos or hoppers are automatically controlled by the signals from the proximity sensors. The amount of materials in the main silos is automatically measured by the load cells installed at the bottom of the main silo legs.

The manufacturing process can also be divided in two stages for better understanding. These are

1. RAW RICE / PARBOILED RICE PROCESSING FLOW CHART
2. PROCESS FLOW CHART FOR SUPER POLISHING / REFINING FOR CUSTOMIZED OR EXPORT MARKET
1. RAW RICE / PARBOILED RICE PROCESSING FLOW CHART

Raw Rice Processing:

- Paddy
  - For parboiling Process
  - Sun Drying
  - Drying by either process

- Shelling Unit

Cleaning

Dehusking

Husk Separator

- Paddy Separator
  - Unshelled Paddy
  - Brown Rice & Unshelled paddy

Polishing Unit

- Bran Separator
  - For Bran Removing from Rice
- Rice Grader
  - Broken Rice Full full Rice & Impurities

- Weightment & Packing

Brown Rice
2. PROCESS FLOW CHART FOR SUPER POLISHING/REFINING FOR CUSTOMIZED OR EXPORT MARKET

Rice Making Unit

Silky Unit

De-stoning Unit

Colour Sorting Machine

Grading

Packing
5.6. Packaging Exhibition:

The final product is now packaged and exhibited.
5.7. Problems faced by the cluster:

5.7.1. Heterogeneity: The major problem faced by the cluster is heterogeneity in the composition of rice milling industry. Large variations are found in type, capacity, location, services rendered as well as in ownership of different processing units. Consequently investment requirement, cost and return also vary over a wide range. Heterogeneity in rice mill cluster arises mainly from the widely varying economic activities made available to private rice mill in different areas and sectors of the district.

5.7.2. Technical: Another common feature of rice milling industry is considered that its technical potential capacity is not fully utilized and this is because of the seasonal concentration and spatial spread of paddy production coupled with the existence of a number of diverse processing units competing with one another in supplying facilities. As these small mills generally do not purchase and store paddy on their own, their operations tend to be restricted to the paddy season, and their installed capacity remained unutilized/underutilized during the rest of the period of the year.

5.8. Proposal:

A simulation model for system evaluation of a rice mill plant is developed with SLAM (simulation language for alternative modelling).

5.8.1. Assumptions: The assumptions used in the model were the following:

a. The intake period of materials is $T_1$ h in the morning and $T_2$ h in the afternoon with $T_3$ h for lunch break, but the milling operation was carried out continuously.

b. The weight of an entity in the simulation is assumed to be M kg.

c. The conveying time for chutes is included in the conveying time of the bucket elevator.

d. No machine breakdown is occurred.
e. The duration time of each process is determined on the basis of actual data with a normal distribution and a standard deviation of 5%.
f. The materials separated from each machine does not include other foreign materials.
g. The capacity of the processes is taken as intake X t/h, hulling Y t/h, milling Z t/h, and packing P t/h.
The unit of simulation time in the model is minute.

5.8.2. Model characteristics:

The model is consisted of a network model and an user insert model. The main milling process controlled by a programmable logic controller is expressed with the network model, while the duration time of each process and the control on the materials intake process are expressed with the user insert model.
The automatic operation of each machine and the hopper exit gates are considered as nodes of SLAM. The network model consists of the main network for the automated basic milling process, sub-network for the creation of entities according to time, and control network. The automated basic milling process is modelled in the main network, and the creation of entities according to time is modelled in the sub-network. The intake time of materials is modelled with GATE, OPEN and CLOSE nodes. The signals for the control of each machine and exit gates of hoppers is described in the control network. The levels inside the hoppers are described with a DETECT node, and exit gates of hoppers are automatically operated with OPEN and CLOSE nodes and ALTER node according to the signals of DETECT nodes. The duration time of each process is modelled in the user insert model. Also, the amount of intake materials is controlled in the user insert model using SUBROUTINE EVENT.

5.8.3. Performance characteristics:

The main performance characteristics of the model to be analysed are

i. Hulling efficiency, milling efficiency and milled rice recovery
ii. The amount of foreign materials discharged from each machines
iii. Flow restriction in process
iv. Stopping the individual machines
v. Capacity of individual machines.
6. Design Audit Unit Wise:

6.1. The units which have been audited during Need Assessment Survey are:
## LIST OF RICE MILLS WITH TELEPHONE NUMBERS & ADDRESS

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Name of Rice Mill</th>
<th>ADDRESS</th>
<th>Mobile No.</th>
<th>Contact Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R.K. Rice Mill</td>
<td>Sukhna</td>
<td>9434001447</td>
<td>Dipak Pramanik</td>
</tr>
<tr>
<td>2</td>
<td>Birbhum Agro Product (P)Ltd.</td>
<td>Sainthia</td>
<td>9434004537</td>
<td>Goutam Chhajer</td>
</tr>
<tr>
<td>3</td>
<td>Sree Kocher Rice Mill</td>
<td>&quot;</td>
<td>9434021119</td>
<td>Surendra Kocher</td>
</tr>
<tr>
<td>4</td>
<td>Chhajer Rice Mill (P)Ltd.</td>
<td>&quot;</td>
<td>9434017971</td>
<td>Prem Chhajer</td>
</tr>
<tr>
<td>5</td>
<td>Kushal Rice Mill</td>
<td>&quot;</td>
<td>9434021119</td>
<td>Surendra Kocher</td>
</tr>
<tr>
<td>6</td>
<td>Swastidipa Rice Mill</td>
<td>Angargoria</td>
<td>9434007835</td>
<td>Falguni Laha</td>
</tr>
<tr>
<td>7</td>
<td>Bharat tirth Rice Mill</td>
<td>Deocha</td>
<td>9434032518</td>
<td>Jagadish Ch. Jash</td>
</tr>
<tr>
<td>8</td>
<td>Ma Shanti Agro Food (P)Ltd.,</td>
<td>Mollarpur</td>
<td>9434003588</td>
<td>Dilip Kr. Agarwala</td>
</tr>
<tr>
<td>9</td>
<td>Jay Baba Bakerswar Rice Mill (P)Ltd.</td>
<td>&quot;</td>
<td>9732009854</td>
<td>Rahul Khaitan</td>
</tr>
<tr>
<td>10</td>
<td>Khaitan Rice Mill</td>
<td>&quot;</td>
<td>9434001484</td>
<td>Dip Chand Khaitan</td>
</tr>
<tr>
<td>11</td>
<td>Suri Rice Mill</td>
<td>Suri</td>
<td>9434004059</td>
<td>Chandra Nath Mondal</td>
</tr>
<tr>
<td>12</td>
<td>Amarduty Agro Tech (P) ltd</td>
<td>&quot;</td>
<td>9434006048</td>
<td>Dilip Pal</td>
</tr>
<tr>
<td>13</td>
<td>Jai Balaji Rice Mill</td>
<td>&quot;</td>
<td>9434000097</td>
<td>Bijoy Choudhury</td>
</tr>
<tr>
<td>14</td>
<td>Daulat Ram Industries</td>
<td>Dubrajpur</td>
<td>9434032880</td>
<td>Mukesh Kr. Choudhury</td>
</tr>
<tr>
<td>15</td>
<td>Bharat Mata Rice Mill</td>
<td>&quot;</td>
<td>9434007592</td>
<td>Purushottam Choudhury</td>
</tr>
<tr>
<td>16</td>
<td>Birbhum Rice &amp; Gl. Mills</td>
<td>&quot;</td>
<td>9434014664</td>
<td>Karan Choudhury</td>
</tr>
<tr>
<td>17</td>
<td>Satyanarayan Rice Mill</td>
<td>Boipur</td>
<td>9434019171</td>
<td>Biswa Bijoy Ghosh</td>
</tr>
<tr>
<td>18</td>
<td>Sarbottam Rice Mill</td>
<td>Ahmodpu r</td>
<td>9434013800</td>
<td>Narottam Kumar Sarda</td>
</tr>
</tbody>
</table>
6.2. Individual Unit Audit Report:


<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical</td>
<td>No serious machinery problem</td>
<td>Highly equipped, software oriented and has its own technician. Regular monitoring is done.</td>
</tr>
<tr>
<td>2.</td>
<td>Labour</td>
<td>Available</td>
<td>Lack of skilled workers.</td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>Sudden break down and low quality of power.</td>
<td>Needs steady, uniform and continuous power supply.</td>
</tr>
<tr>
<td>4.</td>
<td>Water</td>
<td>Available</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>10.</td>
<td>Supply chain</td>
<td>Almost regular.</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>No such problem.</td>
<td>Good.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Ok.</td>
</tr>
<tr>
<td>16.</td>
<td>Govt. Policy</td>
<td>Power subsidy</td>
<td></td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Training and skill upgradation
2. Environmental factors

Strength:

Highly equipped machineries, Good packaging and branding, organized unite.

Expected Yearly Turn Over: Satisfactory.
### 6.2.2. Bhirbhum Agro Product (P) Ltd., Sainthia.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical</td>
<td>Frequently happens.</td>
<td>Lack of good technicians, electricians.</td>
</tr>
<tr>
<td>2.</td>
<td>Labour</td>
<td>Non-availability</td>
<td>Lack of skilled workers. Unit is run by semi-skilled workers.</td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>Sudden break down and low quality of power.</td>
<td>Needs steady, uniform and continuous power supply.</td>
</tr>
<tr>
<td>4.</td>
<td>Water</td>
<td>Available</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technology, modernization
2. Training and skill upgradation
3. Ergonomic and environmental factors

Strength:

Family business, market demand.

Expected Yearly Turn Over: Under-achievement.
### 6.2.3. Sree Kocher Rice Mill, Sainthia.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Labour</td>
<td>Non-availability.</td>
<td>Lack of skilled and fresh workers. Unit is run by semi-skilled workers.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted. Help of corporate house is needed.</td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technology modernization
2. Training and skill upgradation
3. Packaging and branding
4. Ergonomic and environmental factors

**Strength**: Eager interest, family business, market demand.

**Expected Yearly Turn Over**: Fluctuation occurs due to seasonal effect.
### 6.2.4. Chhajer Rice Mill (P) Ltd., Sainthia.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Power</td>
<td>Low quality of power.</td>
<td>Supply is continuous, but fluctuations beyond range.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted. Help of corporate house is needed.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
</tbody>
</table>
Oppportunities area for design and development:

1. Technology, modernization
2. Training and skill upgradation
3. Packaging and branding
4. Marketing

Strength: family business, local consumer.

Expected Yearly Turn Over: Under achievement.
6.2.5. Swastidipa Rice Mill, Angargoria.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Power</td>
<td>Low quality of power.</td>
<td>Supply is continuous, but fluctuations beyond range.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant. Chimney blockage often occurs.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted. Help of corporate house is needed.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technology, modernization
2. Training and skill upgradation
3. Packaging and branding
4. Ergonomic and environmental factors

Strength: Worker, labour, management.

Expected Yearly Turn Over: under achievement.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Power</td>
<td>Low quality of power.</td>
<td>Supply is continuous, but fluctuations beyond range.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No such problem.</td>
<td>It is situated in a remote area.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>No such problem.</td>
<td>Good.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>14.</td>
<td>Banking</td>
<td>High interest.</td>
<td></td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Training and skill upgradetion
2. Ergonomic

**Strength:** Management.

**Expected Yearly Turn Over:** Fluctuating.
### 6.2.7. Ma Shanti Agro Product (P) Ltd., Mollarpur.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Power</td>
<td>Low quality of power.</td>
<td>Supply is continuous, but fluctuations beyond range.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted. Help of corporate house is needed.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technical, modernization
2. Packaging and branding
3. Marketing
4. Ergonomic and environmental factors

Strength: Local consumers, quality of product.

Expected Yearly Turn Over: Under achievement.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical</td>
<td>Highly sophisticated.</td>
<td>Has its own Technicians.</td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>No such Problem.</td>
<td>Continuous and Quality power supply.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>6.</td>
<td>Drainage problem</td>
<td>No such Problem.</td>
<td>Good.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>No such problem.</td>
<td>Has its own packaging and branding unit.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>13.</td>
<td>Marketing</td>
<td>No such problems.</td>
<td>But needs corporate houses as their regular customers.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Good.</td>
</tr>
<tr>
<td>16.</td>
<td>Market and competition study</td>
<td>No such problem.</td>
<td>Has its own marketing dept.</td>
</tr>
</tbody>
</table>

Opportunities area for design and development:

1. Environmental factors

**Strength**: Highly equipped, marketing strategy, quality of product.

**Expected Yearly Turn Over**: More or less achieved.
### 6.2.9. Suri Rice Mill, Suri.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Labour</td>
<td>Not available.</td>
<td>Lack of skilled and fresh workers.</td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>No such problem.</td>
<td>Continuous, steady and uniform power supply.</td>
</tr>
<tr>
<td>4.</td>
<td>Water</td>
<td>Crysis</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted. Help of corporate house is needed.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
</tbody>
</table>
Oppportunities area for design and development:

1. Technical, modernisation
2. Training and skill upgradation
3. Packaging and branding
4. Marketing
5. Ergonomic and environmental factors

Strength: Local consumers and local suppliers.

Expected Yearly Turn Over: Fluctuates.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Labour</td>
<td>Not available.</td>
<td>Lack of skilled and fresh workers.</td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>Average.</td>
<td>Steady and uniform, but discontinuous power supply.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted. Help of corporate house is needed.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Ok.</td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technical, modernisation
2. Training and skill upgradation
3. Packaging and branding
4. Marketing

**Strength**: Quality of product.

**Expected Yearly Turn Over**: New unit, running three months only.
### 6.2.11. Amarduty Agro Tech. (P) Ltd., Suri.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Labour</td>
<td>Not available.</td>
<td>Lack of skilled and fresh workers.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit.</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Not so sophisticated.</td>
<td>Some amount of product is damaged and wasted. Help of corporate house is needed.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Ok.</td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technical, modernisation
2. Training and skill upgradation
3. Packaging and branding
4. Marketing

Strength: Local consumers and suppliers.

Expected Yearly Turn Over: Under achieved.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical</td>
<td>No serious machinery problem.</td>
<td>Has own technicians</td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>Sudden break down and low quality of power.</td>
<td>Needs steady, uniform and continuous power supply.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Own.</td>
<td>Some % of product is wasted.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>14.</td>
<td>Banking</td>
<td>Comparing it with other industry.</td>
<td>Bank should consider this industry at a different angle at it deals with agricultural product.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Ok.</td>
</tr>
<tr>
<td>16.</td>
<td>Govt. Policy</td>
<td>Power subsidy</td>
<td></td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technical, modernisation
2. Training and skill upgradation
3. Packaging and branding
4. Marketing

Strength: Local consumers.

Expected Yearly Turn Over: Under achieved.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical</td>
<td>No serious machinery problem.</td>
<td>Has own technicians</td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>Sudden break down and low quality of power.</td>
<td>Needs steady, uniform and continuous power supply.</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Own.</td>
<td>Some % of product is wasted.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>14.</td>
<td>Banking</td>
<td>Comparing it with other industry.</td>
<td>Bank should consider this industry at a different angle at it deals with agricultural product.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Ok.</td>
</tr>
<tr>
<td>16.</td>
<td>Govt. Policy</td>
<td>Power subsidy</td>
<td></td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Technical, modernisation
2. Training and skill upgradation
3. Packaging and branding
4. Marketing

Strength: Local consumers.

Expected Yearly Turn Over: Under achieved.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical</td>
<td>No serious machinery problem.</td>
<td>Has own technicians</td>
</tr>
<tr>
<td>2.</td>
<td>Labour</td>
<td>Non-availability of skilled and fresh labour.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Power</td>
<td>Sudden break down and low quality of power.</td>
<td>Needs steady, uniform and continuous power supply.</td>
</tr>
<tr>
<td>4.</td>
<td>Water</td>
<td>Not available through out the year.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Water re- utilisation</td>
<td>Govt. permissible limit</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>10.</td>
<td>Supply chain</td>
<td>In-adequate supply.</td>
<td>Seasonally affected.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Own.</td>
<td>Some % of product is wasted.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>14.</td>
<td>Banking</td>
<td>Comparing it with other industry.</td>
<td>Bank should consider this industry at a different angle at it deals with agricultural product.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Ok.</td>
</tr>
<tr>
<td>16.</td>
<td>Govt. Policy</td>
<td>Power subsidy</td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>Ownership</td>
<td>Fragmentation.</td>
<td></td>
</tr>
</tbody>
</table>
Oppertunities area for design and development:

1. Training and skill upgradation
2. Environmental factors

**Strength**: Organised planning, technical knowledge, huge experience, quality of product.

**Expected Yearly Turn Over**: Fluctuating.
### 6.2.15. Satyanarayan Rice Mill, Bolpur.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Problems</th>
<th>Type of problem</th>
<th>Remarks/Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Technical</td>
<td>No serious machinery problem.</td>
<td>Has own technicians</td>
</tr>
<tr>
<td>5.</td>
<td>Water re-utilisation</td>
<td>Govt. permissible limit</td>
<td>Compromise between permissible limit and owner’s profit without polluting nature.</td>
</tr>
<tr>
<td>7.</td>
<td>Rice brand testing</td>
<td>Does not know what degree of quality of rice they are producing.</td>
<td>Needs a Rice Brand Test Lab in the district.</td>
</tr>
<tr>
<td>9.</td>
<td>Ash disposal</td>
<td>No place to dispose ash as it is highly pollutant.</td>
<td>If an ash handling plant, such as fertilizer plant, can be set up in any remote area in the district, ash will be used as a raw material in that plant.</td>
</tr>
<tr>
<td>11.</td>
<td>Packaging and branding</td>
<td>Own.</td>
<td>Some % of product is wasted.</td>
</tr>
<tr>
<td>12.</td>
<td>Inspection</td>
<td>Regular basis.</td>
<td>Good.</td>
</tr>
<tr>
<td>14.</td>
<td>Banking</td>
<td>Comparing it with other industry.</td>
<td>Bank should consider this industry at a different angle at it deals with agricultural product.</td>
</tr>
<tr>
<td>15.</td>
<td>Ergonomic</td>
<td>No such problem.</td>
<td>Ok.</td>
</tr>
<tr>
<td>16.</td>
<td>Govt. Policy</td>
<td>Power subsidy</td>
<td></td>
</tr>
</tbody>
</table>
Opportunities area for design and development:

1. Training and skill upgradation
2. Environmental factors

**Strength**: Bank independency, family business.

**Expected Yearly Turn Over**: Under achieved.
6.3. Problems faced as unit basis:

The problems in the units of Rice Mill Cluster, Birbhum, West Bengal are almost homogeneous in nature. The main three problems in this cluster are

1. Poor quality of paddy
2. No Rice Brand Testing Lab
3. Environmental problems such as ash disposal, water re-utilisation.

4. 6.3.1. Poor quality of paddy:

The impurity in paddy here is 10-12% whereas in Panjab and Hariyana it is merely 1-2%.

It is estimated about 10 percent of paddy/rice is damaged and/or lost in processing, storage and transport with the present methods and machinery. Sixty to eighty percent head yield is obtained with 10-25 broken and admixture of bran and husk whereas with modern techniques, 68-72 percent head rice with 5-7 percent broken and better utilizable by-products. Since paddy is the staple food of practically all paddy growers and also it is seasonal with one harvest per year, there should be some facility in storage which can be protected from various hazards like damage caused due to spontaneous heating, damage by birds, rodents and insects.
6.3.2. **Rice Brand Testing Lab**:

There is no Rice Brand Testing Lab in the district. They have to go Burdwan to test the rice brand. If such lab be set up with the help of Govt. this problem can be solved permanently.

6.3.3. **Environmental Problems**:

Bran obtained in milling is a part of the rice kernel and as such is quite rich in fat. Polished rice contains 0.3 percent fat whereas brown rice contains about 2.2 percent fat on a moisture free basis. Rice bran contains 20 percent extractible but the bran produced in commercial mills usually contains 13-18 percent extractible. The quantity of bran if totally extracted for the oil in it, is capable of producing 7.17 lacs tones of edible rice bran oil. Thus, if this total potential is exploited, enough oil would be available to curtail a major portion of the import of edible oils required to fill up the ever widening gap between the demand and supply of edible oils in the country.

Rice husk is the largest by-product of rice milling industry which amounts to 22-24 percent of the total paddy. The heating value of husk has been reported to be 3000-3500 Kcal/kg. Thus, husk can be used for generating steam for parboiling paddy and as heat source mechanical dryers. Twenty kg of husk can generate 60,000-70,000 Kcal which would be enough to reduce the moisture content of one tones of paddy from 20 to 14 percent. It can be used as fuel in domestic stoves and as a soil conditioner or a diluents component in commercial mixed fertilizers. It can also be used as an abrasive material because of its high silica content. Husk ash is used in glass industry for polishing. Rice husk can be directly used as a loose insulating material in building and cold storage facilities. Success has been achieved in the use of husk ash for manufacturing cement. Pure silicon which is used for making semiconductors is a very costly material that can be obtained from rice husk. Boards and briquettes can also be produced from rice husk.
6.4. Opportunities areas for design interventions:

The areas where interventions are required are listed below:
1) Technology,
2) Marketing
3) Entrepreneurship & Management
4) Human Resource & Training
5) Finance
6) Infrastructural facilities
7) Govt. Policy

6.5. Technical Problems:

Parboiling of paddy, a process of partial boiling or cooking prior to milling which imparts an extra strength to the rice kernel so that it could withstand the milling stress and result in higher head yield. This significant increase in the hardness of the kernel results due to gelatinization of the starch during parboiling and the disrupted protein which expanded and occupied all the air spaces in the endosperm.

Research on food value of rice has shown that parboiled rice has more nutritive value than the raw rice because of the migration of vitamins from outer layers of the rice kernel into the inner starchy endosperm due to moisture heat treatment. Moreover, due to better milling quality, the losses of broken and fines into the bran are reduced considerably in the milling process of parboiled rice, and hence, total rice outturn of 72-73 percent (2-8 percent more than the raw rice) and whole rice outturn of 60-65 percent (20-30 percent more than raw rice) are obtained. This is perhaps the easiest and cheapest method of attaining the self-sufficiency in meeting the growing demand for rice.
Loss of rice due to inefficient drying method is also not insignificant. Sun drying is the most popular and traditional method of drying. This method is completely dependent upon weather and it needs specially constructed large floor area that restricts the capacity of a mill to a certain extent. Excessive losses will occur due to scattering, birds, rodents etc. This can be improved by drying paddy in a mechanical dryer using husk as burning fuel.
7. **Analysis and Recommendation**:

One whole at the present scenario, the cluster has no homogeneity up to the mark; design intervention is required in training and skill upgradation of workers, packaging and branding, marketing, technology. It has a high income discrepancy between the worker and the unit owner.

7.1. **Technical Analysis**:

A schematic diagram of a milling system is as follow:

![Schematic diagram of a milling system](image)

1. Rice tank;
2. Paddy sort-out sieve;
3. Tank;
4. Husking machine with cylindered rubber;
5. Tank;
6. Rice sort-out sieve;
7. Grit collector;
8. Tank;
9. Whitening machine;
10. Polishing machine;
11. Whitened rice classifying drum.

E1, E2, E3, E4, E5, E6, and E7: convey buckets.
X1, X2: Cyclones for collecting bran.
F1, F2, F3: separation fans.
In the previous diagram the convey buckets can be replaced by ducts which are used with forced draft fans or blowers. The separating fans are powered by individual servo motors that its speed can be controlled individually according to will.

7.1.1. **Parboiling** :

Parboiling of paddy is a hydrothermal process that may be defined as gelatinization of starch within the rice grain. During the parboiling process the starch and protein expand and fill the internal air space which creates strong cohesion between them. Both fissures and cracks present in the endosperm are sealed and tough enough to withstand milling stresses which increases the total yield of edible rice and minimizes the broken rice quantity.
The fuel used in the boiler is generally a bio-mass. Among the Asian countries India has the highest total use of biomass mainly as wood whereas, Bangladesh has the high proportional use of non-wood biomass. This biomass is derived from rice husk, cow-dung rice straw and lesser amounts of jute stick, fire wood, twigs, leaves and other waste materials.

A schematic diagram of existing par-boiling system is shown below:
The energy flow through the existing furnace can be shown as

![Energy Flow Diagram]

7.1.1.1. Performance analysis of boiler:

7.1.1.1.1. Determination of inside volume of boiler:

The length, diameter and wall thickness of steam vessel are measured. The presence of steam generator safety measures like safety valve, pressure-gauge, temperature meter, chimney etc are observed and are recorded. The volume of cylindrical steam generator is calculated using the equation (1).

\[ V = 1000 \times (\pi D^2/4) \times L \]  
---------(1)

Where, 
- \( V \) = Volume of steam generator, litre
- \( D \) = Diameter of steam generator, m
- \( L \) = Length of steam generator, m

The semi-cylindrical was in irregular shape. Therefore, the cross-sectional area was divided into a number of trapezoids i.e., the boundaries between the extremities of the ordinates are assumed to be straight lines. The following equation (2) of trapezoidal rule is generally used to calculate the cross-sectional area.

\[ A = \frac{d}{2} (O_0 + 2O_1 + 2O_2 + \ldots \ldots \ldots + 2O_{n-1} + O_n) \]  
-------------------- (2)

Where, 
- \( A \) = X-sectional area of steam generator, \( m^2 \)
- \( d \) = common distance between ordinates, m
- \( O \) = ordinates at each point of division, m
The cross-section was multiplied by the length of steam generator to calculate the volume of steam generator (equation 3).

\[ V = 1000 \times A \times L \quad \text{(3)} \]

Where, \( V \) = Volume of steam generator, litre
\( A \) = X-sectional area of steam generator, m\(^2\)
\( L \) = Length of steam generator, m

7.1.1.1.2. Determination of Initial, final and evaporated water (steam) volume for different boiler:

a. Horizontal:

**CASE I:** both the initial and final level more than half full:

Initial Volume, \( V_i = \left[ \pi R^2 - R^2(\theta - \sin\theta)/2 \right]xL \quad \text{(4)} \)

Final volume, \( V_f = \left[ \pi R^2 - R^2(\Phi - \sin\Phi)/2 \right]xL \quad \text{(5)} \)

Where, \( V_i \) = Initial water volume, m\(^3\)
\( V_f \) = Final water volume, m\(^3\)
\( R \) = Radius of steam generator, m
\( \theta = 2 \cos^{-1}(a/R) \quad \text{(6)} \)
\( a = H_i - R \)
\( H_i \) = Initial water level, m
\( \Phi = 2 \cos^{-1}(b/R) \quad \text{(7)} \)
\( b = H_f - R \)
\( H_f \) = Final water level, m
\( L \) = Length of steam generator
CASE II: initial level more than half full and final level less than half full

Initial Volume, \( V_i = \left[ \pi R^2 - R^2(\theta - \sin \theta)/2 \right] \times L \) \( \ldots (8) \)

Final volume, \( V_f = \left[ R^2(\phi - \sin \phi)/2 \right] \times L \) \( \ldots (9) \)

Where, \( V_i = \text{Initial water volume, m}^3 \)

\( V_f = \text{Final water volume, m}^3 \)

\( R = \text{Radius of steam generator, m} \)

\( \theta = 2 \cos^{-1}(a/R) \) \( \ldots (10) \)

\( a = H_i - R \)

\( H_i = \text{Initial water level, m} \)

\( \phi = 2 \cos^{-1}(b/R) \) \( \ldots (11) \)

\( b = R - H_f \)

\( H_f = \text{Final water level, m} \)

\( L = \text{Length of steam generator} \)

CASE III: initial and final level less than half full:
Initial Volume, $V_i = \left[ R^2(\theta - \sin\theta)/2\right] \times L$ \hspace{1cm} (12)

Final volume, $V_f = \left[ R^2(\Phi - \sin\Phi)/2\right] \times L$ \hspace{1cm} (13)

Where, $V_i$: Initial water volume, $m^3$

$V_f$: Final water volume, $m^3$

$R$: Radius of steam generator, $m$

$\theta = 2 \cos^{-1}(a/R)$ \hspace{1cm} (14)

$a = H_i - R$

$H_i$: Initial water level, $m$

$\Phi = 2 \cos^{-1}(b/R)$ \hspace{1cm} (15)

$b = R - H_f$

$H_f$: Final water level, $m$

$L$: Length of steam generator

b. Semi-cylindrical:

Initial volume of water

$V_i = \text{Initial wetted X-sectional area} \times \text{Length of steam generator}$ \hspace{1cm} (16)

Final volume of water

$V_f = \text{Final wetted X-sectional area} \times \text{Length of steam generator}$ \hspace{1cm} (17)

Weight of feed water, kg

$W_{\text{feed}} = \text{Volume of feed water} \ (m^3) \times \text{specific weight of water} \ (kg/m^3) \times \text{Sp. gravity}$ \hspace{1cm} (18)

Weight of final water, kg

$W_{\text{final}} = \text{Volume of final water} \ (m^3) \times \text{specific weight of water} \ (kg/m^3) \times \text{Sp. gravity}$ \hspace{1cm} (19)

Weight of evaporated water (kg), $W_{\text{steam}} = W_{\text{feed}} - W_{\text{final}}$ \hspace{1cm} (20)
7.1.1.1.3. **Efficiency of boiler:**

Sensible heat in feed water, kJ/kg

\[ h_{feed} = W_{feed} \times C_{pw} \times t_{feed} \]  

(21)

where,

- \( h_{feed} \) = heat content in feed water, kJ/kg
- \( W_{feed} \) = weight of feed water, kg
- \( C_{pw} \) = 4.1868 kJ/kg-K
- \( t_{feed} \) = temperature of water, °C

Heat addition to steam, kJ/kg

\[ q_1 = h_f + xh_{fg} - h_{feed} \]  

(22)

where,

- \( q_1 \) = heat addition to steam, kJ/kg
- \( h_f \) = sensible heat in hot water, kJ/kg
- \( x = 0.95 \), quality of steam
- \( h_{fg} \) = latent heat of vaporization, kJ/kg
- \( h_{feed} \) = sensible heat in feed water, kJ/kg

Heat addition to remaining hot water in the steam vessel, kJ/kg

\[ h_{rw} = h_f - h_{feed} \]  

(23)

Total heat addition into vessel/boiler, kJ

\[ E_{out} = q_1 \times W_{steam} + h_{rw} \times (W_{feed} - W_{steam}) \]  

(24)

Total energy supplied, kJ

\[ E_{in} = W_{husk} \times C_{husk} \]  

(25)

where, \( E_{in} \) = Energy input, kJ
- \( W_{husk} \) = weight of husk, kg
- \( C_{husk} \) = calorific value of rice husk, kJ/kg

Thermal Efficiency of steam vessel,

\[ \eta_{eff} = \left( \frac{E_{out}}{E_{in}} \right) \times 100 \% \]  

(26)
7.1.1.2. Par-boiling system:

The parboiling system consists mainly of two parts one is the steam generation unit (steam vessel and furnace) and other part is steaming bin for parboiling paddy. Steaming bin is connected with the steam generator with a steam pipe. The steam is produced at a very low pressure in traditional rice parboiling systems in Birbhum. However, some rice miller uses high pressure and high temperature steam for producing special quality of parboiled rice.
A schematic diagram of improved per-boiling system is shown below:

7.1.2. **Pre-cleaning**:

When paddy comes into the mill it contains foreign material such as straw, weed seeds, soil and other inert material. If this is not removed prior to hulling the efficiency of the huller and the milling recovery are reduced. Most pre-cleaners separate three groups of materials:

- The first separation is done by scalping or removing the objects that are larger than the grain. Either a flat oscillating screen or a rotary drum screen that allows the grain to pass through but retains straw can do this.
The second separation retains the grains but allows broken grains, small stones and weed seeds to pass through. An air aspirator may also be incorporated to remove the dust and the light empty grains.

The capacity of the paddy pre-cleaner is usually based on the capacity of the rice mill. A pre-cleaner for a 3 t/h rice mill would normally have a 5 t/h cleaning capacity.

Types of pre-cleaner:

Grain pre-cleaners can be classified according to their cleaning mechanism. These are:

1. Oscillating Sieve type

Oscillating sieve pre-cleaners are simple and often made locally. The machine consists of two sieves of different sizes depending on the size and shape of the grain. The top sieve has a slotted profile larger than the bottom and both screens can be changed to suit the grain size or crop type.

3. Aspiration cum Oscillation Type

The aspirator grain cleaner removes lighter impurities such as dust, dirt, chaff and straw by blowing or sucking air through the mass of falling grain and removing these light impurities in the air stream. Impurities that are not removed by the air are then separated from the grain using oscillating sieves. The sieving action of this machine is similar to the sieve oscillation cleaner. Some cleaners are also equipped with magnets to remove ironic particles. Aspiration style cleaners can have either single or double action aspiration.
3. **Rotary Cleaner**

This machine consists of one or two drums; each drum is fitted with mesh of different sized hexagonal or square perforation and an oscillating sieve. Foreign matter larger than the grain is removed as the paddy or rice passes through the drums. Paddy then flows onto the oscillating sieve to separate heavier impurities such as stone.

There are two types of rotary cleaner:

- **Single drum with aspirator and oscillation sieve.** The single drum aspirator utilizes a single drum to separate large, light and heavy impurities. Lighter impurities are separated by suction aspiration and the oscillation sieves separate heavier impurities such as sand.

- **Double drums with aspirator.** This machine has two rotation drums with each drum having a different size hole on the wire mesh. It utilizes an aspirator to separate light impurities. This machine is typically used for cleaning freshly harvest paddy.

4. **De-stoner with aspiration**

This machine is the same as a single drum with aspiration and oscillating sieves but has an additional special arrangement for separating stones that have the same physical dimensions as paddy. Of particular importance is the direction of flow of the paddy compared to the direction of movement of the stones.
7.1.3. **Removing the husk**:

The husk layer is removed from the paddy by friction and the process is called either de-husking or de-hulling. De-husking was traditionally done using mortar and pestles but, in modern rice mills, it is done by passing the paddy grains between two abrasive surfaces that are moving at different speeds. After separating the husk and paddy, the husk is removed by suction (aspirated) and then transported to a storage dump outside the milling plant. The percentage of paddy that is de-hulled to produce brown rice during this process is called the *hulling efficiency*. An efficient husker will remove 90% of the husk in a single pass. After the husk has been removed the brown rice goes to a paddy separator. The kernels that were not de-husked in the first pass will be separated and then returned to the de-husker.

**Types of Husking machines**

1. **Steel Huller**

The steel huller removes the husks and whitens the rice in one pass. Paddy rice is fed into the machine and passes between a revolving steel shaft and a cylindrical shaped mesh screen. These machines are normally powered by a 15 to 20 hp engine and are very simple to operate. They are relatively cheap.

**Advantage**
- Very compact
- Easy to operate.
- Low cost and easy to maintain.
- Can mill small amount of paddy for individual farmers.
- Low cost of milling (handling and conveying equipment is minimal).

**Disadvantage**
- Low milling efficiency.
- Produces high amount of cracked and broken rice.
- By-products - husk, bran and very small broken are often mixed
3. **Under runner disc sheller**

The under-runner husker is very common in Asia. This machine has two steel discs, which have an emery coating. The upper disc is stationary and fixed to the cast iron housing. Paddy flows from a centrally located hopper between the abrasive surfaces of the revolving lower disc and the stationary upper disc. Resistance between the emery surface on the discs and the paddy grains removes the husk leaving the brown rice kernel. Brown rice and husks are then discharged circumferentially over the revolving disc and exit through an outlet. This machine is very economical to run, produces a moderate amount of cracked or broken grain, and has a hulling efficiency of about 85-90%.

**Advantage**
- Capacity is higher than steel huller type.
- Cracked and broken grain is less than steel huller type.
- More power efficient than steel huller type.
- Easy to operate.
- Low operation cost.
- Machine is very durable.
- It is nearly comparable to rubber rolls huller

**Disadvantage**
- Machine is very heavy and requires a moderate size operating space.
- This process scratches the rice kernel.
- As the abrasive stone wears, sand and silicon dislodges and mixes with rice and bran.
- Rice recovery less than the rubber rolls huller.
- Huller efficiency in this machine is 85-90%
3. **Rubber roller huller**

The rubber-roller huller is the most efficient hulling machine. As the name suggests two rubber rollers of the same diameter are operated at different speeds to remove the husk from the paddy. One roller has a fixed position and the other is adjustable to meet the desired clearance. The adjustable roller rotates slightly slower than the fixed roller. Rubber-roll hullers have an aspirator in the base of the machine to separate the hulls from the brown rice. The roll diameter varies from 150 to 250 mm and the roller width from 60 to 250 mm. The correct clearance is dependent on the varietal characteristics and the width and length of paddy. This method of hulling can achieve hulling efficiencies of 85% to 90% with minimum broken or cracked grain. This type of machine is now widely used in developed countries.

**Advantage**
- Reduce breakage of milled kernels.
- High hulling efficiency.
- By-products are free from sand and silicon.
- Bran also in higher quantities compared to disc huller.
- Very compact in comparison to disc huller.
- Less vibration

**Disadvantage**
- Cost to purchase
- Cost of rubber rollers
7.1.4. **Paddy separator**:

The output from the huller is a mixture of paddy rice, brown rice, husk, broken paddy, and sometimes bran. The huller aspirator removes the lighter material such as husk, bran and very small brokens. The remainder passes onto the paddy separator where the unhulled paddy rice is separated from the brown rice. The amount of paddy present depends on the efficiency of the husker, and should not be more 10%. Paddy separators work by making use of the differences in specific gravity, buoyancy and size between paddy and brown rice. Paddy rice has a lower specific gravity, higher buoyancy, and is physically bigger, longer and wider than brown rice.

There are two types of paddy separator -

1. **Compartment Separator**

   The compartment type of paddy separator uses the difference in specific gravity and the buoyancy to separate paddy and brown rice. When paddy and brown rice move over an inclined plane, they move at different speeds depending on their specific gravity, their shape and contact area, smoothness of inclined surface and the co-efficient of sliding friction. Brown grains are smaller, heavier, rounder and smoother and will slide faster than paddy grains. The processing capacity of the compartment separator is dependent on the compartment area. For a 2-ton/hr capacity rice mill, a 45-compartment separator made up of 15 compartments on each of three decks is used.
2. **Tray Separator**
The tray separator uses the differences in specific gravity grain length and the co-efficient of friction to separate paddy and brown rice. The oscillation and slope of the tray forces the brown rice to move up the slope and the paddy to slide down. The separation performance of this type of paddy separator is very good. This machine is very compact, easy to adjust, and consumes less power than the compartment type separator.

**Separation principle**

[Hulling Efficiency]

In principle, the huller can efficiently remove between 80 and 95% of the husk from the paddy in one pass. When setting up a rubber huller it is normal to have 10% of the paddy returned for a second hulling. If efficiencies higher than these are attempted the level of grain breakages will increases.
7.1.5. **Whitener or polisher**:

White rice is produced from brown rice by removing the bran layer and the germ. The bran layer is removed from the kernel by applying friction to the grain surface either by rubbing the grains against an abrasive surface or against each other. The amount of bran removed is normally between 8-10% of the total paddy weight but this will vary according whiteness required.

The process used to polish brown rice can be classified as abrasive or friction.

**Abrasive**: In this process the grain is whitened by the abrasive action of the rice kernel passing between a moving abrasive surface and stationary screen. The hard rough surface is usually stone or a carborundum type material. The abrasive process applies less pressure on the grain and is better suited for long grain varieties. Abrasive polishers can be either vertical or horizontal in design. The vertical cone whitener is very common in many Asian countries.

**Friction**: In the friction whitener the grain kernels are forced against each other and a metal screen by a steel-ribbed cylinder rotating inside a metal-plated cylinder. The frictional forces created between individual rice grains and between the grains and the metal screen surface remove the bran layer from the grain. Friction polishers are always horizontal in design and apply more pressure on the grain than an abrasive whitener.
The whitening process applies pressure to the grain, which generates heat and causes cracking and breakage of some kernels. To reduce the number of broken grains and the grain temperature during the whitening process, rice is normally passed through two to four whitening and polishing machines connected in series. Rice temperatures should not exceed 43-44°C during any process. The arrangement of machines to process the rice during rice whitening is dependent on the physical characteristics of rice grains. Proper sequencing of the machines will help reduce the amount of broken kernels during whitening and polishing. The normal arrangement of whitening and polishing long and short grain rice as follows:

Short grain:

![Diagram of short grain arrangement]

Long grain:

![Diagram of long grain arrangement]

7.1.6. Separation of white rice:

After polishing, the white rice is separated into head rice and large and small broken rice by a sifter. Head rice is normally classified as kernels, which are 75-80% or more of a whole kernel. The sifter is made up of a series of oscillating screens through which the rice passes. The output from the bottom screen is the very fine broken tips and is called the brewers.
To attain a higher degree of precision for grading and separation, a length or indent grader is also used. This machine is made up of 1-3 rotating indented cylinders. The broken and smaller rice pieces fall into the indents on the rotating roller surface and are removed leaving the whole rice kernels or head rice.

Different indent sizes are used according to the grain.

7.2. Rice husk technology:

7.2.1. Rice quality—an overview:

This skills section examines the different factors that affect grain quality, and explains how to measure grain quality characteristics for both paddy and milled rice.

Quality of rice is not always easy to define as it depends on the consumer and the intended end use for the grain. All consumers want the best quality that they can afford. As countries reach self-sufficiency in rice production, the demand by the consumer for better quality rice has increased. Traditionally, plant breeders concentrated on breeding for high yields and pest resistance. Recently the trend has changed to incorporate preferred quality characteristics that increase the total economic value of rice. Grain quality is not just dependent on the variety of rice, but quality also depends on the crop production environment, harvesting, processing and milling.
The quality characteristics of paddy and milled rice can be considered separately.

7.2.1.1. Quality characteristics of paddy:

A number of interrelated features determine the quality of paddy. These are:
- Moisture content of paddy,
- Purity degree,
- Varietal purity,
- Cracked grains,
- Immature grains,
- Discoloured/fermented grains and damaged grains.

These characteristics are determined by the environmental weather conditions during production, crop production practices, soil conditions, harvesting, and post harvest practices.

Moisture content

Moisture content has a marked influence on all aspects of paddy and rice quality and it is essential that paddy be milled at the proper moisture content to obtain the highest head rice yield. Paddy is at its optimum milling potential at moisture content of 14% wet weight basis. Grains with high moisture content are too soft to withstand hulling pressure which results in grain breakage and possibly pulverization of the grain. Grain that is too dry becomes brittle and has greater breakage. Moisture content and temperature during the drying process is also critical as it determines whether small fissures and/or full cracks are introduced into the grain structure.

Degree of purity

Purity is related to the presence of dockage in the grain. Dockage refers to material other than paddy and includes chaff, stones, weed seeds, soil, rice straw, stalks, etc. These impurities generally come from the field or from the drying floor. Unclean paddy increases the time taken to clean and process the grain. Foreign matter in the grain reduces milling recoveries
and the quality of rice and increases the wear and tear on milling machinery.

**VARIETAL PURITY**
A mixture of varieties causes difficulties at milling and usually results in reduced capacity, excessive breakage, lower milled rice recovery and reduced head rice. Different sizes and shaped grains make it more difficult to adjust hullers, whiteners and polishers to produce whole grains. This results in low initial husking efficiencies, a higher percentage of recirculated paddy, non-uniform whitening, and lower grade of milled rice.

**GRAIN DIMENSIONS**
Grain size and shape (length-width ratio) is a varietal property. Long slender grains normally have greater breakage than short, bold grains and consequently have a lower milled rice for recovery. The grain dimensions also dictate to some degree the type of milling equipment needed. For instance, the Japanese designed milling equipment may be better suited to short-bold, japonica grains whereas Thai made equipment will be more suitable for longer, slender grain types.

**CRACKED GRAINS**
Overexposure of mature paddy to fluctuating temperature and moisture conditions leads to development of fissures and cracks in individual kernel. Cracks in the kernel are the most important factor contributing to rice breakage during milling. This results in reduces milled rice recovery and head rice yields.

**IMMATURE GRAINS**
The amount of immature paddy grains in a sample has a major affect on head rice yield and quality. The immature rice kernels are very slender and chalky and this results in excessive production of bran, broken grains and brewer’s rice. The optimal stage to harvest grain is at about 20-24% grain moisture or about 30 days after flowering. If the harvest is too late, many grains are lost through shattering or dry out and are cracked during threshing, which causes grain breakage during milling.
Damaged grains
Paddy deteriorates through biochemical change in the grain, the development of off-odours and changes in physical appearance. These types of damage are caused from water, insects, and heat exposure.

Yellowing
Yellowing is caused by over-exposure of paddy to wet environmental conditions before it is dried. This results in a combination of microbiological and chemical activity that overheats the grain. These fermented grains frequently possess partly gelatinized starch cells and generally resist the pressures applied during grain milling. While the presence of fermented grain does not affect milling yields it does downgrade the quality of the milled rice because of the unattractive appearance.

Insect- or mould-damaged grains can be distinguished by the presence of black spots around the germ end of the brown rice kernel which are caused by the microorganisms, insects, or a combination. Mould damage in particular is increased by unfavourable weather conditions. In the process of milling, these black spots are only partly removed which consequently increases the presence of damaged grains.

7.2.1.2. Quality characteristics of milled rice:

The quality characteristics of milled rice are classified both physically, and chemically.

Review the following terms before reading about physical and chemical characteristics of milled rice:
• Paddy or rough rice = similar term for paddy, or rice retaining its husk after threshing
• Brown rice or husked rice = paddy from which the husk has been removed
• Milled rice = rice after milling which includes removing all or part of the bran and germ from the husked rice
• Head rice = milled rice with length greater or equal to three quarters of the average length of the whole kernel
• Large brokens = milled rice with length less than three quarters but more than one quarter of the average length of the whole kernel
• Small brokens or "brewers rice" = milled rice with length less than one quarter of the average length of the whole kernel
• Whole kernel = milled rice grain without any broken parts
• Milling recovery = percentage of milled rice (including brokens) obtained from a sample of paddy.
• Head rice recovery = percentage of head rice (excluding brokens) obtained from a sample of paddy.

Physical Characteristics:

Milling degree
The degree of milling is a measure of the percent bran removed from the brown rice kernel. Milling degree affects milling recovery and influences consumer acceptance. Apart from the amount of white rice recovered, milling degree influences the colour and also the cooking behaviour of rice. Un-milled brown rice absorbs water poorly and does not cook as quickly as milled rice. The water absorption rate improves progressively up to about 25% milling degree after which, there is very little effect.

Head rice
“Head rice” or head rice percentage is the weight of head grain or whole kernels in the rice lot. Head rice normally includes broken kernels that are 75-80% of the whole kernel. High head rice yield is one of the most important criteria for measuring milled rice quality. Broken grain has normally only half of the value of head rice. The actual head rice percentage in a sample of milled rice will depend on both varietal characteristics (i.e. the potential head rice yield), production factors, and harvesting, drying and milling process. In general harvesting, drying, and milling can be responsible for some losses and damage to the grain.

Whiteness
Whiteness is a combination of varietal physical characteristics and the degree of milling. In milling, the whitening and polishing greatly affect the
whiteness of the grain. During whitening, the silver skin and the bran layer of the brown rice is removed. Polishing after whitening is carried out to improve the appearance of the white rice. During polishing some of the bran particles stick to the surface of the rice which polishes and gives a shinier appearance.

**Chalkiness**
If part of the milled rice kernel is opaque rather than translucent, it is often characterized as “chalky”. Chalkiness disappears upon cooking and has no effect on taste or aroma, however it downgrades milled rice. Excessive chalkiness is caused by interruption during the final stages of grain filling. Though chalkiness disappears upon cooking and has no direct effect on cooking and eating qualities, excessive chalkiness downgrades the quality and reduces milling recovery.

**Chemical characteristics**:

Gelatinization temperature
The time required for cooking milled rice is determined by gelatinization temperature or GT. Environmental conditions, such as temperature during ripening, influence GT. A high ambient temperature during development results in starch with a higher GT. GT of milled rice is evaluate by determining the Alkali spreading value. In many rice-growing countries, there is a distinct preference for rice with intermediate gelatinization temperature.

Amylose content
Starch makes up about 90% of the dry matter content of milled rice. Starch is a polymer of glucose and amylose is a linear polymer of glucose. The amylose content of starches usually ranges from 15 to 35%. High amylose content rice shows high volume expansion (not necessarily elongation) and high degree of flakiness. High amylose grains cook dry, are less tender, and become hard upon cooling. In contrast, low-amylose rice cooks moist and sticky. Intermediate amylose rice are preferred in most rice-growing areas of the world, except where low-amylose japonicas are grown.

Based on amylose content, milled rice is classified in “amylose groups”, as follows:
• waxy (1-2% amylose),
• very low amylose content (2-9% amylose),
• low amylose content (10-20% amylose),
• intermediate amylose content (20-25% amylose) and
• high amylose content (25-33% amylose).
Amylose content of milled rice is determined by using the colorimetric iodine assay index method.

Gel consistency
Gel consistency measures the tendency of the cooked rice to harden after cooling. Within the same amylose group, varieties with a softer gel consistency are preferred, and the cooked rice has a higher degree of tenderness. Harder gel consistency is associated with harder cooked rice and this feature is particularly evident in high-amylose rice. Hard cooked rice also tends to be less sticky. Gel consistency is determined by heating a small quantity of rice in a dilute alkali.

7.2.1.3. Paddy quality determination:

Collect two samples of approximately 500 grams of fresh paddy, and determine the following characteristics by following the procedures as outlines above. Use the sheet to record your findings
• Moisture content (oven method, and moisture meter)
• Grain dimensions (L/W ratio)
• Dockage-weeds
• Dockage-inert matter
• Insects (dead, alive)
• Cracked grains
• Unfilled or immature grains
• Discoloured and damaged grains
• 1000 kernel weight
Sheet exercise: Quality of paddy or rough rice

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. grains (start)</td>
<td>No. grains (finish)</td>
</tr>
<tr>
<td>Moisture (oven)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture (meter)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LW ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dockage-weeds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dockage-inert</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cracked grains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immature grains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discolored/damaged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 kernel wt.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.2.1.4. **Procedures for measuring quality of paddy grain:**

**Crack Detector**
Using the Paddy Crack Detector, count the numbers of cracked grains in a 100 grain sample then compute the % cracked grains using the equation:

\[
\text{% Cracked grains} = \frac{\text{Number of cracked grains}}{100 \text{ grains}} \times 100
\]

**Grain Dimensions**
Using a calliper or photographic enlarger, collect 20 paddy samples at random from each replicate and measure the dimensions to obtain the average length and width of the paddy grains. To obtain the paddy shape, the following equation can be used:

\[
\text{Length to width ratio (L/W)} = \frac{\text{Average paddy length, mm}}{\text{Average paddy width, mm}}
\]
Immature Grains
Select a 25 gm grain sample and select, segregate and weigh the immature grains in sample. Calculate the percentage immature grains in the sample using the formula:

\[
\% \text{ Immature grains} = \frac{\text{Wt. of immature grains}}{\text{Total weight of samples}} \times 100
\]

Dockage in Paddy
Remove light foreign matter, stones, weed and seeds from a 100gm sample. Obtain the total weight then compute the dockage percentage as follows:

\[
\% \text{ Dockage} = \frac{\text{Wt. of dockage}}{\text{Total wt. of sample}} \times 100
\]

1000 Kernel Weight
Determined by counting and weigh 1,000 grains (paddy).

7.2.1.5. Procedures for measuring quality of milled rice:

Milling degree
Milling degree is computed based on the amount of bran removed from the brown rice. To obtain the weight of brown rice, de-hull the paddy samples using the Laboratory Huller. Estimate the percent milling degree using the following equation:

\[
\% \text{ Milling degree} = \frac{\text{Wt of milled rice}}{\text{Wt of brown rice}} \times 100
\]
Milling recovery
Using the Abrasive Whitener, mill the de-hulled samples. Compute milling recovery by dividing the weight of milled rice recovered by the weight of the paddy sample, as follows:

\[
\text{% Milling recovery} = \frac{\text{Wt of milled rice}}{\text{Wt of sample used}} \times 100
\]

Dockage in Milled Rice
Select, segregate and weigh the foreign matter. Record the number of unhulled grains collected from the sample. Determine the percentage of dockage of milled rice using the equation:

\[
\text{% Dockage (mr)} = \frac{\text{Wt. of dockage}}{\text{Total wt. of milled rice}} \times 100
\]

Broken grain
Using the Grain Grader, separate the broken grain from the whole grains. Compute the percentage of the head rice and brokens using the following equations:

\[
\text{% Head rice} = \frac{\text{Wt of whole grains}}{\text{Wt of paddy samples}} \times 100
\]

\[
\text{% Brokens} = \frac{\text{Wt of broken grains}}{\text{Wt of paddy samples}} \times 100
\]
Chalkiness
A visual rating of the chalky proportion of the grain is used to measure chalkiness based on the standard Evaluation System SES scale presented below:

<table>
<thead>
<tr>
<th>Scale</th>
<th>% area of chalkiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>less than 10</td>
</tr>
<tr>
<td>5</td>
<td>10-20</td>
</tr>
<tr>
<td>9</td>
<td>more than 20</td>
</tr>
</tbody>
</table>

Select, segregate and weigh the chalky grains (SES Scale 9). Determine the % chalky grain using the equation:

\[
\% \text{ Chalky grain} = \frac{\text{Wt of chalky grains}}{\text{Wt of milled rice}} \times 100
\]

Whiteness
Measure the grain whiteness using the Whiteness Meter. Separate and weigh yellow-fermented grains. Calculate the percentage of yellow/fermented grains using the formula:

\[
\% \text{ Yellow grains} = \frac{\text{Wt. yellow grains}}{\text{Total wt. of milled rice}} \times 100
\]

Grain Shape
Follow the procedure of determining grain shape of paddy. Based on the length to width ratio, the shape of the milled rice will be determined. L/W ration is given by:

\[
L/W \text{ ratio} = \frac{\text{Average length of rice, mm}}{\text{Average width of rice, mm}}
\]
The ISO Classification is as follows:

<table>
<thead>
<tr>
<th>Scale</th>
<th>Shape</th>
<th>UW ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slender</td>
<td>Over 3.0</td>
</tr>
<tr>
<td>3</td>
<td>Medium</td>
<td>2.1 - 3.0</td>
</tr>
<tr>
<td>6</td>
<td>Bold</td>
<td>1.1 - 2.0</td>
</tr>
<tr>
<td>9</td>
<td>Round</td>
<td>1.0 or less</td>
</tr>
</tbody>
</table>

1000 grain weight
Count and weigh 1,000 whole grains.

Amylose content
Select twenty grains and ground them in a Cyclone Mill. Amylose content is analyzed using the simplified iodine colorimetric procedure. Samples are categorized into low, intermediate and high based on the following grouping:

<table>
<thead>
<tr>
<th>Category</th>
<th>%Amylose Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waxy</td>
<td>1-2</td>
</tr>
<tr>
<td>Very low amylose</td>
<td>2-9</td>
</tr>
<tr>
<td>Low</td>
<td>10-20</td>
</tr>
<tr>
<td>Intermediate</td>
<td>20-25</td>
</tr>
<tr>
<td>High</td>
<td>25-30</td>
</tr>
</tbody>
</table>

Gelatinization temperature (GT)
GT is measured by determining the alkali-spreading value for which the alkali digestibility test is employed. Grains are soaked in 1.7% KOH and incubated in a 30 °C oven for 23 hours. Measurement ranges are based on the following: Gelatinization temperature is estimated by the extent of alkali spreading and clearing of milled rice soaked in 1.7% KOH at room temperature or at 39 °C for 23 hours. The degree of spreading is measured using a seven-point scale as follows:
1. grain not affected
2. grain swollen,
3. grain swollen, collar incomplete and narrow,
4. grain swollen, collar complete and wide,
5. grain split or segmented, collar complete and wide,
6. grain dispersed, merging with collar, and
7. grain completely dispersed and intermingled.
Gel consistency
Select from two to 10 grains and ground separately in the Wig-L Bug. Gel consistency is measured by the cold gel in a horizontally-held test tube, for one hour. Measurement ranges and category are as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Consistency, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft</td>
<td>61-100</td>
</tr>
<tr>
<td>Medium</td>
<td>41-60</td>
</tr>
<tr>
<td>Hard</td>
<td>26-40</td>
</tr>
</tbody>
</table>

7.2.1.6. Standards and grades for milled rice:

Standards can be defined as a quantitative way by which we measure and compare certain quality characteristics. This measured comparison of recognizable quality characteristics can be described as ‘grading’.

To date, there are few universally accepted international standards for paddy and milled rice. This is primarily due to a difference in emphasis on the importance of grading paddy and milled rice quality among countries. However, national standards exist and are being used as a marketing basis.

In general, grading factors for paddy are (1) purity, (2) foreign matter, (3) defectives and (4) moisture content.
For milled rice, the characteristics considered for grading are (1) head rice, broken and brewers percentages (2) defects, (3) foreign matter, (4) presence of paddy and (5) moisture content.

Objectives of establishing standards and grades
1. to ensure only edible rice reaches the consumer;
2. to improve postharvest practices so as to eliminate or reduce waste;
3. to improve agronomic practices to increase farm yields;
4. to improve processing practices for better milling recoveries and for market expansion and
5. to protect consumers from price/quality manipulation.

In relation to the first objective, the characteristics such as moisture content, foreign material, seeds and discoloured (damaged) grains are important considerations in assuring that only edible rice reaches the consumers. By setting standards for degree of milling, broken rice content, moisture and damaged grains, the second objective is addressed. Better threshing and drying, and improved storage facilities are expected to emerge to meet the required standard. The third objective provides incentives to the farmer/agricultural scientist to optimize production by considering standards for chalkiness, varietal purity, foreign seeds, immature grains and red rice. The fourth objective provides a measure of the miller’s success in delivering high milling recovery and allowing the market expansion. Characteristics considered are standards for degree of milling, broken rice, paddy kernels and foreign matters. Finally, standards which clearly identify to consumers the true value of their purchases will provide the protection required against the possibility of unfair trading practices.

7.2.1.7. Comparison of rice mill output:

Select a homogenous sample of paddy and run trials with different husking/whitening/polishing equipments.
Input results using the sheet. Make a comparative analysis of the results obtained.
- Moisture content
- Head rice percentage
- Brokens
- Chalkiness
- Whiteness
- Milling degree
- Heat damaged/discoloured grains.

Quality of milled rice

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. grains (start)</td>
<td>No. grains (finish)</td>
</tr>
<tr>
<td></td>
<td>No. grains (start)</td>
<td>No. grains (finish)</td>
</tr>
<tr>
<td>Moisture content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head rice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broken</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chalkiness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whiteness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milling degree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discolored grains</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Grade the milled rice samples based on the National standards of milled rice in the Philippines. Take recommendations on improving the paddy and rice grade.

7.2.1.8. **Testing of a rice mill for performance and quality**:

Visit a rice mill and sample the paddy before milling, brown rice after husking and the milled grain after processing. At the same time, monitor the performance of the rice mill by collecting the outputs from all of the outlets from the mill over a given time period.

The following samples need to be collected and weighed at the rice mill
- Head rice
- Course brokens
- Fine brokens
• Brewers rice
• Course bran
• Fine bran (“meal”)
• Husk.

**Time**
Samples will be collected for 10 minutes from each outlet. An open woven bag will be necessary to collect the husk.

**Weighing**
Use the miller’s scales.

**Sub-sampling**
Sub samples will be taken from each of the outlets so that they can be analyzed in the laboratory.
Sampling times
Sampling times will depend on the capacity of the mill. A good benchmark is to collect from each outlet for at least 10 minutes.

Expected outputs
A good quality mill will produce 55% head rice, 15% brokens, 10% bran and 20% husk, all on % paddy weight basis

Sampling outputs
Collect a grain sample from the paddy, brown rice and from all stages of the process.
Check the list.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Collect (yes)</th>
<th>Sample</th>
<th>Collect (yes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy</td>
<td></td>
<td>Head rice</td>
<td></td>
</tr>
<tr>
<td>Brown rice</td>
<td></td>
<td>Large broken</td>
<td></td>
</tr>
<tr>
<td>1st whitener</td>
<td></td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>2nd whitener</td>
<td></td>
<td>Small</td>
<td></td>
</tr>
<tr>
<td>Polisher</td>
<td></td>
<td>Brewers</td>
<td></td>
</tr>
<tr>
<td>Bran</td>
<td></td>
<td>Husk</td>
<td></td>
</tr>
</tbody>
</table>

Make an assessment of where in the rice mill improvements could be made to improve the milling output.

7.2.2. Insects & Rodents :

A. Insects :

Insects in stored rice can be classified into three groups according to their feeding habits namely internal feeders, external feeders and scavengers.

i. Internal Feeders
These are insects whose larvae feed entirely within the kernels of the grain. These include rice weevil, angoumois grain moth and lesser grain borer.

Rice Weevil (*Sitophilos oryzae* (Linnaeus)): Adults and larvae feed on a wide variety of grains. Female deposits a single egg in the grain by boring a hole
inside. The egg stays in the grain until it becomes an adult thus making the grain completely damaged.

**Angoumois Grain Moth** (*Sitatroga cerealella* (Olivier)): Eggs are laid on or near grain. The white larvae bore into the kernels of the grain and feed on the inside. When mature, the larvae eat its way to the outer portion of the grain, leaving only a thin layer of the outer seed coat intact. Pupation takes place just under the seed coat. When the adult emerges from the grain, it pushes aside the thin layer of seed coat leaving a small trap door covering its exit point from the kernel. They infest only the surface layer of bulk-stored grain, adults are unable to penetrate deeply.

**Lesser Grain Borer** (*Rhyzopertha dominica* (Fabricus)): The eggs are laid in the grain mass and larvae may enter the kernels and develop within or, they may feed externally in the flour-like dust that accumulates from the feeding of the adults and their fellow larvae.

  ii. **External Feeders**

External feeders are insects that feed from the outside of the grain even though they may chew through the outer coat and devour the inside.

**Cigarette or Tobacco Beetle** (*Lasioderma serricorne* (Fabricius)): Feeds on books, flax tow, cottonseed meal, rice, ginger, pepper, dried fish, crude drugs, seeds, pyrethrum powder, and dried plants.

**Flat Grain Beetle** (*Cryptolestes pusillus* (Schonherr)): The female places her eggs loosely in the grain mass. The larvae and adults are able to penetrate the seed coat of the undamaged grain.

  iii. **Scavengers**

Scavengers feed on the grain only after the seed coat has been broken either mechanically or by some other insect.

**Saw-toothed Grain Beetle** (*Oryzaephilus surinamensis* (Linnaeus)): Eggs are usually laid, either singly or in small masses, in a crevice in the food supply but in items like flour, they are laid freely.
B. Rodents:

Rodents are characterised by their teeth. They have a pair of incisor teeth in the upper and lower jaws. The incisors are curved inwards and have an extremely hard anterior coating. The softer inside layer is worn down much more rapidly than the hard, outer layer. This means that the teeth are continually kept sharp, enabling them to damage even materials such as masonry and electric cables. The incisors do not stop growing. This means that the animals are forced to gnaw steadily in order to wear them down.

The three most important rodent species are:
• Black rat or House rat (*Rattus rattus*)
• Common rat (*Rattus norvegicus*).
• House mouse (*Mus musculus*).

Storage Hygiene and Technical Measures

• Keep the store absolutely clean. Remove any spilt grain immediately as it attracts rodents.
• Store bags in tidy stacks set up on pallets, ensuring that there is a space of all round the stack.
• Store any empty or old bags and fumigation sheets on pallets, and if possible in separate stores.
• Keep the store free of rubbish in order not to provide the animals with any places to hide or nest. Burn or bury it.
• Keep the area surrounding the store free of tall weeds so as not to give the animals any cover. They have an aversion to crossing open spaces.
• Keep the area in the vicinity of the store free of any stagnant water and ensure that rainwater is drained away, as it can be used as source of drinking water.
7.2.3. **Husk problem**:

All over the world the discharge of the husk accruing in the numerous rice mills causes a serious environmental problem. This agricultural waste however has a significant calorific value and a high percentage of amorphous silica. With an innovative technology these favourable characteristics of rice husk will be used for solving the environmental problems and at the same time producing electricity and high value industrial products.

7.2.3.1. **Green technology**:

A new processing technology for production of silica using as feedstock rice husk from rice milling process is developed.

Processing technology consists of a rice husk fired power plant and a chemical plant, producing from the rice husk ash high value industrial substances, namely liquid sodium silicate, precipitated silica and activated carbon.

7.2.3.2. **Feedstock**:

Rice husks makes up about 20% of the rice (paddy) weight. The rice millers world-wide therefore should generate more than 100 million tons of rice husks. Nowadays almost 70% of the rice husks are not commercially used. Using one of the world´s major agriculture products - rice - as primary feedstock and avoiding disposal of either
• rice husks which are difficultly biodegradable or
• ash from combustion of rice husks
makes the Technology “Green” and is able to solve a huge environmental problem in the cluster as well as all over the world.

According to international estimates the rice demand by 2020 will growth to 780 million tons. Because the rice growing areas can’t be dramatically extended the rice harvest from one hectare shall increase from actual 5 tons to 12 tons by means of new improved rice seeds.
7.2.3.3. Preparation of feed stock:

- During rice milling approximately 70% of the raw rice is processed to “white” rice.
- Rice husks which are about 20% of raw rice are shelled, separated and stored in storage silos.
- The bran from rice polishing, which is about 10% of the raw rice is separated and most commonly used for animal feed.

All these processing steps are executed in classic rice mills all over the world.

7.2.3.4. Rice husk processing plant:

Now the rice husks from various rice mills are collected and will be transported to the Rice husk processing plant. Unloading will be done pneumatically or with gravity flow and excavators to intermediate silos. Before entering the silos impurities are separated by means of a riddle screen. Afterwards the husks are ground and fed to storage silos.

The caloric value of about 14 MJ/kg of the rice husks represents about 35% of the caloric value of diesel or bunker oil with a caloric value of 40.5 MJ/kg.
7.2.3.5. **Combustion and power generation unit:**

A special rice husk combustion unit generates steam and the rice husk ash is separated in hoppers. The main part of the steam is fed into a steam turbine-generator set which generates electric energy.

Electric energy is either partly used for the rice mill if it is located nearby and for the rice husk processing plant. The main part of electric energy is sold to the public grid and is a valuable product of the plant.

Depending on the combustion technology and process parameter rice husk ash with more or less carbon content (5% - 40 %) can be produced. The other components of the ash are amorphous silica and a small amount of crystalline silica as well as some inerts. The ash is collected from the several hoppers and the flue gas filters of the combustion unit and is stored in storage silos.
The lay-out of such unit is shown below:

7.2.3.6. Liquid Sodium Silicate and Activated Carbon Production

Rice husk ash is first digested with caustic soda and then filtered. In the filter diluted liquid sodium silicate is separated from unwashed carbon filter cake. The diluted liquid sodium silicate is fed to storage tanks while the carbon cake in the filter is washed and chemically cleaned before dried in the drying section.
The special serial dryers allow the production of powdered activated carbon with a residual water content of about 8%. The powdered activated carbon is screened and stored in storage silos. For distribution of activated carbon packing in bags of various sizes is executed in the packing unit. The liquid sodium silicate (~24% silicate) can be sold as commodity chemical in tank-tainers or trucks.

7.2.3.7. Precipitated Silica Production:

Liquid sodium silicate is processed with acid and filtered. The filter separates a diluted sodium sulphate (Glauber’s salt solution) and the wet silica product. The salt solution can be evaporated or fed to a reverse osmosis and solid salt is produced as valuable by-product. The wet filter cake is finally washed and fed to the drying unit. With special dryers a precipitated silica product with about 8% water content is produced. The precipitated amorphous silica powder is screened and stored in storage silos. For distribution of silica products packaging in bags of various sizes is executed in the packing unit.
7.2.3.8. **Main Applications of the Products:**

**Precipitated Silica:**
Typical properties of our products:
BET surface area 205-290 m²/g (gas adsorption), DBP oil absorption 170-240 ml/100g
- Rubber reinforcement
- Solar panels
- Plastic reinforcement
- Agriculture (animal food)
- Food, healthcare, cosmetics
- Catalyst; Coatings
- Pulp and Paper processing
- Detergents and soaps
- Adsorbents
- Anticaking agent for packing

**Activated carbon:**
- Food and beverages (decolouring)
- Pharmaceuticals
- Water purification
- Sweetener
- Solvent recovery
- Air purification

**Liquid Sodium Silicates:**
Weight ratios of SiO₂ to Na₂O from 1.6 to 3.3
- Detergents and cleaning compounds
- Adhesives & cements
- Paints& coatings
- Pulp & Paper processing
- Ceramics & binders
- Water treatment
- Textile processing
- Mining & mineral processing
- Petrochemical processing
7.3. **Water re-utilisation:**

7.3.1. **Boilers/boiler house:**

**Problem areas:**

i. Scaling and corrosion  
ii. Bio-fouling  
iii. High operation cost  
iv. High maintenance cost  
v. Reduced equipment life  
vi. High water consumption.

**Solutions:**

i. Reverse osmosis/de mineralization  
ii. Softening & filtration  
iii. Recycling water  
iv. Chemical dosing & pH controllers
7.3.2. Cooling towers:

Problem areas:

i. Scaling and corrosion
ii. Bio-fouling
iii. High operation cost
iv. High maintenance cost
v. Reduced equipment life
vi. High water consumption.

Solutions:

i. Reverse osmosis/de-mineralization
ii. Softening & filtration
iii. Recycling water
iv. Chemical dosing & pH controllers
7.3.3. Drinking water:

Problem areas:

i. Foul taste & odour
ii. Dissolved salts
iii. Microbiological contamination
iv. Chlorine levels
v. Organic contaminants
vi. Low water pressure

Solutions:

i. Reverse osmosis
ii. UV systems
iii. Filtration
iv. Ultra-filtration
v. Pressure boosting
7.3.4. **Water recycling**:

**Problem areas:**

i. Waste water from backwash of boilers
ii. Waste water from backwash of boiler-house
iii. Waste water from parboiling
iv. Softener backwash

**Solutions:**

i. Re-cycling water
ii. Sewage treatment plant
iii. Effluent treatment plant
7.3.5. **Water treatment in rice mill:**

A model set-up of a rice mill having water recovery and recycling system is shown here:
8. Optimal Design of a Rice Mill Utility System with Rice Husk Logistic Network:

Abstract:

Thermal energy for drying and electricity for milling operations typically comprise a significant 55% of a rice mill operating cost. Optimal design of rice mill utility system that efficiently utilizes rice husk biomass has potential to increase profitability of rice milling industry. This paper presents a mathematical approach for simultaneous optimal planning of rice husk logistic network as well as optimal design of a rice mill utility system that efficiently utilizes rice husk supplied from various locations in order to satisfy the electricity and drying requirements of the rice mill throughout the year. A mixed integer linear programming (MILP) problem was formulated to determine: (1) the optimal logistic network for the rice husk supply, (2) the economic scale of the rice husk cogeneration system, and (3) an optimal utility supply network for a series of dryers consisting of a combination of cyclonic husk furnace (CHF) and cogeneration systems.
NOMENCLATURE:

Subset:

b = biomass boiler and turbine with different performance parameter capacity

\(c\) = CHF with different performance parameter and capacity

\(i\) = inclined bed dryer \(i\)

\(j\) = rice husk from internal rice mill \(j\)

\(k\) = rice husk from external rice mill \(k\)

\(f\) = fluidized bed dryer \(f\)

\(t\) = period

Variable:

\(\text{ACCOSTB}_b\) = annualized capital cost of biomass boiler \(b\) (RM/year)

\(\text{ACCOSTC}_c\) = annualized capital cost of CHF \(c\) (RM/year)

\(\text{ACRHI}_j\) = annual transportation of rice husk from internal rice mill \(j\) (t/yr)

\(\text{ACRHK}_k\) = annual transportation of rice husk from external rice mill \(k\) (t/yr)

\(\text{AElecO}\) = annual electricity required from outsources (MWh)

\(\text{ElecGB}_{bt}\) = electricity generated from condensing extraction turbine \(b\) at period \(t\) (MWh)

\(\text{ElecD}_t\) = electricity demand at period \(t\) (MWh)

\(\text{ElecG}_t\) = electricity generated at period \(t\) (MWh)

\(\text{ElecO}_t\) = electricity required from outsources at period \(t\) (MWh)

\(\text{HP}_{bt}\) = HP steam from boiler \(b\) to condensing extraction turbine \(b\) at period \(t\) (t/h)

\(\text{HEATCF}_{cft}\) = heat supplied by CHFc to FBDf at period \(t\) (MJ/h)

\(\text{HEATCHF}_{ct}\) = heat supplied by CHFc at period \(t\) (MJ/h)

\(\text{HEATCLI}_{cit}\) = heat supplied by CHFc to IBDi at period \(t\) (MJ/h)

\(\text{HEATLPI}_{it}\) = heat supplied by LP stream at period \(t\) (MJ/h)

\(\text{HEATMPF}_{mt}\) = heat supplied by MP stream at period \(t\) (MJ/h)

\(\text{LP}_{bt}\) = LP saturated steam extracted from condensing extraction turbine \(b\) at period \(t\) (t/h)

\(\text{LPC}_t\) = LP saturated steam extracted from condensing extraction turbine \(b\) to cooling tower at period \(t\) (t/h)
LPI_{bt} = LP saturated steam extracted from condensing extraction turbine b to IBD coil at period t (t/h)
MP_{bt} = MP saturated steam extracted from condensing extraction turbine b at period t (t/h)
MPD_{bt} = MP saturated steam extracted from condensing extraction turbine b to d internalstream process at period t (t/h)
MPF_{bt} = MP saturated steam extracted from condensing extraction turbine b to FBD coil at period t (t/h)
RH_{t} = amount of rice husk consumed at period t (t/h)
RHB_{bt} = amount of biomass feed into boiler b at period t (t/h)
RHC_{ct} = amount of rice husk feed into CHF c at period t (t/h)
RHJ_{jt} = amount of rice husk transfer from internal rice mill j at period t (t/h)
RHK_{kt} = amount of rice husk transfer from external rice mill k at period t (t/h)

_Binary variables:_

YO_{bt} = binary variable in operating biomass boiler b at period t
YOC_{ct} = binary variable in operating CHF c at period t
YP_{b} = binary variable in purchasing biomass boiler b
YPC_{c} = binary variable in purchasing CHF c

_Parameter:_

AARH_{j} = annual available RH at internal rice mill j (t/yr)
AARH_{k} = annual available RH from external rice mill k (t/yr)
BElecD_{t} = basic electricity demand of drying equipment and office accessories at period t (kWh)
CCOST = capital cost of equipment (RM)
CCRH = calorific value of rice husk (MJ/t)
EFFFC = efficiency of FBD coil
EFFIC = efficiency of IBD coil
ElecBB<sub>bt</sub> = electricity requirement of biomass boiler and turbine b at period t (kWh)
ElecCHF<sub>ct</sub> = electricity requirement of CHF c at period t (kWh)
ElecF<sub>ft</sub> = electricity requirement of FBD at period t (kWh)
ElecI<sub>it</sub> = electricity requirement of IBD at period t (kWh)
Electariff = electricity tariff (RM/MWh)
ENBB<sub>b</sub> = enthalpy change across biomass boiler (MJ/t)
ENLP<sub>b</sub> = enthalpy change between HP and LP across condensing extraction turbine b (MJ/t)
ENMP<sub>b</sub> = enthalpy change between HP and MP across condensing extraction turbine b (MJ/t)
ENFBD = enthalpy change of MP across FBD (MJ/t)
ENIBD = enthalpy change of LP across IBD (MJ/t)
HEATF<sub>ft</sub> = required heat of FBD at period t (t/h)
HEATI<sub>it</sub> = required heat of IBD at period t (t/h)
LWBB<sub>b</sub> = lower bound of biomass boiler b (t/h)
LWCHF<sub>c</sub> = lower bound of CHF c (t/h)
LWLP<sub>b</sub> = minimum extraction rate of LP stream at turbine b (t/h)
LWMP<sub>b</sub> = minimum extraction rate of MP stream at turbine b (t/h)
n = life span of equipment (year)
PCRHK<sub>k</sub> = purchase cost of rice husk from external rice mill k (RM/t)
Period<sub>t</sub> = duration of period t (h)
r = interest rate
TCRHK<sub>k</sub> = transportation cost of rice husk from external rice mill k (RM/t)
UPBB<sub>b</sub> = upper bound of biomass boiler b (t/h)
UPCHF<sub>c</sub> = upper bound of CHF c (t/h)
Year = operating hours in a year (h)
ηBB<sub>b</sub> = efficiency of biomass boiler
ηCHF<sub>c</sub> = efficiency of CHF
ηTURB<sub>b</sub> = efficiency of condensing extraction turbine b
9.1. **Introduction**

Rice milling companies often operate at marginal profit due to energy-intensive drying and milling operations that contribute to the high operating costs of rice processing. Thermal energy for drying and electricity for milling operations typically comprise a significant 55% of a rice mill operating cost. To effectively reduce operating costs and increase profitability while satisfying the electricity and drying needs of a rice mill at appropriate times of the year, it is vital to design an optimal rice mill utility system that efficiently utilizes rice husk as the main by product of rice milling and an important source of renewable energy.

Rice husk typically amounts to between 22 and 24 wt % of the total paddy input. Its moderate heating value between 3000 and 3500 kcal/kg allows rice husk to be utilized in rice mill for power generation, for cogeneration system, and most extensively, for paddy drying. For the latter, rice husk is typically combusted in a cyclonic husk furnace (CHF) to produce hot gas for paddy dryers. It was reported that 20 kg of husk can generate 60 000 - 70 000 kcal heat, enough to reduce the moisture content of 1 ton of paddy from 20 - 14%.

Rice husk has also been widely used as a fuel for cogeneration system, which must be designed with the flexibility to supply electricity for rice milling operations throughout the year, and heat for dryers during harvesting seasons (peak drying period). During the peak drying period, a cogeneration system should generate electricity for rice mill operations and provide extensive amount of thermal heat to dry paddy within 72 h of harvesting in order to preserve its quality. At other times of the year after the paddy drying season (i.e., during off-peak season), cogeneration should maximize electricity generation for rice milling.

To date, many studies on optimization of rice processing revolve around rice milling operations, particularly drying. A few other studies focus on synthesis and optimization of rice processing plants excluding the utility system. Note that most studies on modelling and optimization of biomass-based cogeneration system have not considered rice husk logistic network. Arivalagan et al. made an early attempt to formulate an
integrated energy optimization problem for a cogeneration system. They present an MILP model to determine the economic optimum energy-mix for a process plant. Uran modelled a cogeneration system for a wood processing plant into a multi period problem and identified the lowest heat capacity and the payback period for the system. Gamou et al. determined the optimal cogeneration system size to match the energy demand. Their work however, do not consider biomass logistic network. Caputo et al.9 considered logistic variables in formulating a model to evaluate the economics of biomass utilization in combustion and gasification plants. However, the model was not formulated into an optimization problem.

An optimal combination of rice husk-based cogeneration and CHF systems can offer ample cost-saving opportunities for a rice mill to meet its electricity and drying demands. However, to maximize the economic impact of the cogeneration and CHF systems, the following constraints need to be considered:

(a). Variation of Heat and Power Demands during Different Periods of the Year

The energy profile of a rice mill with a drying facility varies throughout the year. During harvesting period which typically last for 30 days in a paddy growing season, the harvested paddy will be dried to reduce its moisture content to a level that allows its quality to be preserved for storage, within 72 h of harvesting. This narrow time frame where predominantly thermal energy is being consumed in dryers is known as the peak drying period. During this period, electricity is also consumed to operate the rice mill’s machinery and appliances. The off-peak drying period covers the remaining duration of paddy growing season outside the 30-day paddy harvesting and drying periods. During the off-peak season when the dryers are not operating, energy is mainly consumed in the form of electricity. A detailed assessment must therefore be made to economically exploit the marked difference in heat and energy demands during the peak and off-peak drying periods for the proposed utility system.
(b). Energy Supply Options

Several options can be considered in order to meet the heat and power demands of an integrated rice mill and drying facility. The heat demand can be fulfilled by a combination of cogeneration and CHF systems which utilize rice husk as a source of fuel. From the point of view of thermal energy requirement, CHF is an attractive option as the large amount of calorific value available from rice husk combustion can be used to satisfy the huge quantity of heat required during peak drying season. On the other hand, cogeneration can supply bulk of the electricity requirement for rice milling during off-peak season, and supply heat, as well as electricity for drying and milling operations during peak season. Without a cogeneration system, the rice mill electricity demand has to be supplied from the national grid. The efficiency and cost-effectiveness of the various energy options are vital to consider for an optimal utility systems design.

(c). Rice Husk Supply Limitation.

Rice husk as the main by product of rice milling is an important and easily accessible source of renewable energy for a rice mill. However, the amount of rice husk from a given rice mill is typically limited and may not be able to sustain the heat and power demands of energy intensive milling and drying operations. Hence, there is a need to transport and purchase rice husk from other rice mills. The limited amount of rice husk and the required transportation as well as purchasing costs are key factors to consider in the design of a rice mill utility system.

Limited supply of rice husk, the rice husk cost as well as logistic cost, varying heat and power demands during different periods of the year, and various energy supply options are the key factors influencing the optimal design of a rice mill utility system. To date, no study has simultaneously explored all these factors. There is a need to develop a new systematic tool for the optimal planning and design of a utility system configuration comprising of cogeneration and CHF systems that considers the logistic network.
This portion presents a mathematical approach for simultaneous optimal planning of rice husk logistic network, as well as design of a rice mill utility system that efficiently utilizes rice husk from various locations to satisfy the electricity and drying requirements of the rice mill at appropriate times of the year. To address this problem, here is formulated an integrated superstructure that consists of all logistics and utility system configurations of practical interest, transform the superstructure as a mixed integer linear programming (MILP) problem, and develop an optimal solution methodology.

9.2. **Problem statement**:

A rice producing company has planned to install a cogeneration system within its centralized drying facility which is located in one of its rice mills. The proposed drying facility is aimed to dry approximately 100,000 tons of paddy annually. A combination of CHF and cogeneration system shall be designed to meet the heating requirements of the drying facility and also to generate power in order to meet some (if not all) of the mill’s electricity demand. This setup which includes a proper coordination for the rice husk logistic network is expected to provide ample cost-savings opportunity for the rice producing company.

As mentioned earlier, the ratio between paddy to be dried (to reduce moisture content from 20% to 14%) and the required rice husk is around 50:1. However, the moisture content of paddy collected from the field in a humid area like Birbhum can reach up to 25%. It is therefore estimated that 4,000 tons of rice husks are required to dry 100,000 tons of paddy, to give a ratio of 25:1 between paddy to be dried and the required rice husk in the case of Birbhum. More rice husks are therefore required to be purchased and transported from other mills make up for the limited amount of rice husk being produced by a single rice mill.

Given the different heating and electricity requirements during peak and off-peak drying seasons for a rice mill, a cogeneration system in operating conditions, capital cost for various sizes of cogeneration system, distance
between rice husk supply locations and utility system and transportation cost, the problem consists of simultaneously determining:
(1) The optimal logistic network for rice husk supply
(2) The economic scale of rice husk-based cogeneration system
(3) The optimal utility network configuration

The relevant variables to be determined are the rice husk logistic network (rice husk transported from other rice mill locations), the cogeneration system design parameters (size, rice husk consumption, steam flow rate, electricity generation) and the utility system configuration which consists of cogeneration and CHF (steam flow rate from cogeneration system and hot gas from selected CHF units). The proposed utility system’s design takes into account typical heat losses of operating equipment to the ambient. The objective is to achieve the required heat and electricity demands at the minimum total annualized cost of equipment, utilities, and logistic costs.

9.3. Problem formulation:

Superstructure:

This figure shows a schematic of a rice mill utility system that utilises
rice husk as a fuel. The CHF supplies heat to a dryer system which may consist of a combination of commonly used dryers including fluidized bed dryer (FBD) and inclined bed dryer (IBD). Electricity is supplied by the national grid.

This figure illustrates the proposed superstructure that consists of two substructures, namely rice husk logistic network and utility system network. Rice husk is transported from internal rice mills (represented by subset j) and external rice mills (represented by subset k). The cogeneration system, CHF, IBD and FBD are represented by b, c, i, and f respectively.

The details for each substructure are explained below:

(a). Rice Husk Logistic Network. Rice husk supply comes from internal rice mills j, or external rice mills k at various locations. The distance between rice husk supply locations and the cogeneration facility affects the transportation cost. The internal rice mills are the rice mills owned by the company which also operates the cogeneration facility. Hence, the rice husks from the internal rice mills are free of charge. For the external rice mill, the rice husk cost must be added on top of the transportation cost.
(b). Utility System. Utility system includes a cogeneration system (consisting of a boiler and a turbine), a CHF system and electricity grid. The utility system configuration highly depends on the rice mills heat as well as electricity demands within a fixed period $t$. High pressure steam generated in the boiler is used to drive steam turbine and convert mechanical energy to electricity. During peak drying period, the exhaust medium pressure (MP) and low pressure (LP) saturated steams from turbine are utilized to satisfy the dryers’ heating requirements. However, during off-peak drying period where there is no heat demand for dryers, cogeneration can maximize its power output and be the main source of electricity supply for the rice mill.

9.4. Model formulation:

The proposed linear model is formulated with the following assumptions:

a. Electricity load factor variation is not considered since the machines and equipment are assumed to operate at full load.

b. The heat loads of the dryers are fixed, by assuming:
   i. Moisture content of collected paddy and the targeted moisture contents are constant.
   ii. The dryers operate at full load throughout the peak drying period.
   iii. Temperatures of the dryers are uniform throughout the drying process.

c. Piping cost for the steam distribution system is assumed negligible in comparison to equipment cost.

d. No binary variables have been defined for the rice mill locations for the following reasons:
   i. No limit has been imposed on the number of rice mills selected.
   ii. Unlike machines or equipments that need to be purchased or installed, no cost is involved in selecting rice mills. The cost of rice husk actually depends on the transportation as well as purchased cost.
9.4.1. **Objective function:**

The objective of this study is to simultaneously synthesize an optimal structure of rice husk logistic network, as well as a rice mill utility system, which includes a cogeneration system and CHF units, aimed at meeting the rice mill heat and power demands at minimum cost. The minimum total annual cost function consists of the capital costs for cogeneration system and for CHF, and the operating costs comprising of electricity, transportation, and rice husk costs.

\[
f(x) = \sum YPB_b(ACCOStB_b) + \sum YPC_c(ACCOStK_c) + \Delta ElecO(Electariff) + \\
\sum ACRHJ_j(TCRHJ_j) + \sum ACRHK_k(TCRHK_k + PCRH_k) \quad (1)
\]

1\textsuperscript{st} term : capital cost for cogeneration system.
2\textsuperscript{nd} term : capital cost for CHF.
3\textsuperscript{rd} term : electricity cost.
4\textsuperscript{th} term : rice husk cost from internal rice mill.
5\textsuperscript{th} term : rice husk cost from external rice mill.

The annualized capital cost of equipment is given by

\[
ACCOST = CCOST\left(\frac{e^r(e^r - 1)}{e^r - 1}\right) \forall t \quad (2)
\]

9.4.2. **Rice husk demand and supply:**

\[
\sum_j RHJ_{jt} + \sum_k RHK_{kt} = \sum_c RHC_{ct} + \sum_b RHB_{bt} \forall t \quad (3)
\]

Equation 3 describes the relationship between rice husk demand and supply. The left hand side of eq 3 states that rice husk supply comes from internal rice mills (j), as well as external rice mills (k). The right-hand side of the equation states that rice husk’s demand comprises of CHF and cogeneration system, which provide the rice mill heat and power demands within a given period t.
9.4.3. **Steam generation from rice husk**:

HP steam is generated when rice husk is burnt as fuel in the boiler. The amount of HP steam generated depends on the amount of rice husk burnt, its calorific value, the boiler efficiency and the enthalpy change across boiler as given by eq 4.

\[ HP_{bt} \times ENBB_b = CCRH \times RHB_{bt} \times \eta_{BB} \forall b \forall t \]  

(4)

9.4.4. **Turbine work output**:

The HP steam produced by the boiler is then extracted as MP and LP steam, as given by eq 5.

\[ HP_{bt} = MP_{bt} + LP_{bt} \forall b \forall t \]  

(5)

The ideal work done by the turbine is the total enthalpy change of MP and LP steam across the extraction-condensing turbine. Considering the turbine efficiency (\(\eta_{TURBb}\)), electricity produced by the turbine is given by eq 6.

\[ ElecGB_{bt} = \frac{(MP_{bt} \times ENMP_b \times LP_{bt} \times ENLP_{b}) \times \eta_{TURB} \forall b \forall t}{3600} \]  

(6)

9.4.5. **Steam Generation for FBD or Cooling Water**:

Equations 7 and 8 show how the MP and LP steam are utilized. The MP steam extracted from turbine is directed to heat exchanger coils at the FBD to heat up the dryer air.

\[ \sum_b MP_{bt} = \sum_f MP_{Ft} \forall t \]  

(7)
The LP steam is directed to IBD heat exchanger coils or to cooling water system.

\[
\sum_b L_{pt} = \sum_i L_{pi}i + LPC_t \forall t \quad (8)
\]

The heat supplied to FBD coil by MP steam is dependent on the flow rate of MP steam, the heat transfer efficiency of FBD coil and the enthalpy change across FBD coil.

\[
\text{HEATMPF}_{ft} = \text{MPF}_{ft} \times \text{ENFBD} \times \text{EFFFC} \forall f \forall t \quad (9)
\]

The flow rate of LP steam, the heat transfer efficiency at IBD coil and the enthalpy change across IBD coil influence the heat supply to IBD coil by LP steam.

\[
\text{HEATLPI}_{it} = \text{LPI}_{it} \times \text{ENIBD} \times \text{EFFIC} \forall i \forall t \quad (10)
\]

9.4.6. CHF heat balance:

The heat produced by CHF depends on the amount of rice husk fed into it, the rice husk calorific value and the efficiency of the CHF, as given by eq 11.

\[
\text{HEATCHF}_{ct} = \text{CCR} \times \text{RHC}_{ct} \times \eta_{CHF} \forall c \forall t \quad (11)
\]

The heat produced by CHF is utilized to heat up FBD and IBD dryer air.

\[
\text{HEATCHF}_{ct} = \sum_f \text{HEATCF}_{ct} + \sum_i \text{HEATCI}_{ct} \forall c \forall t \quad (12)
\]
The dryer heat requirement of FBD is supplemented by MP steam extracted from turbine and CHF units.

\[
\text{HEAT}_{F_{ft}} = \text{HEAT}_{MPF_{ft}} + \sum \text{HEAT}_{CF_{ct}} \forall f \forall t \quad (13)
\]

The IBD heat demand is satisfied by LP steam extracted from turbine and CHF units.

\[
\text{HEAT}_{I_{it}} = \text{HEAT}_{LPI_{it}} + \sum \text{HEAT}_{CI_{cit}} \forall i \forall t \quad (14)
\]

Electricity is generated by cogeneration system.

\[
\text{Elec}_{G_t} = \sum_b \text{Elec}_{GB_{bt}} \forall t \quad (15)
\]

Equation 16 is used to calculate the total electricity demand for the rice mill and drying facilities.

\[
\text{Elec}_{D_t} = (\text{BElec}_{D_t} + \sum_b \text{YOB}_{bt}(\text{Elec}_{BB_{bt}}) \\
+ \sum_c \text{YOC}_{ct}(\text{Elec}_{CHF_{ct}}) + \sum_f \text{Elec}_{F_{ft}} \\
+ \sum_j \text{Elec}_{I_{jt}})/1000 \forall t \quad (16)
\]

If electricity produced by cogeneration system is insufficient to meet electricity demand, the additional electricity requirement will be outsourced from the national grid. Electricity produced from cogeneration system is related to outsource electricity as follows:
\[ \text{Elec}O_t = \text{Elec}D_t - \text{Elec}G_t \quad \forall \ t \]  \hspace{1cm} (17)

Equation 18 is used to annualize the seasonal requirement of rice husk.

\[ \text{A ElecO} = \sum_t (\text{Period}_t \times \text{ElecO}_t) \times \frac{\text{Year}}{\sum_t \text{Period}_t} \quad \forall \ t \]  \hspace{1cm} (18)

9.4.7. Rice husk availability:

The total annual rice husk transported from each rice mill to the drying facility must not exceed the annual rice husk availability. This limitation is described by eq 19.

\[ \text{ACRHJ}_j \leq \text{AARHJ}_j \quad \forall \ j \]  \hspace{1cm} (19)

The following constraints ensure that rice husk transported from each external rice mill to the drying facility does not exceed the specified annual rice husk availability.

\[ \text{ACRHK}_k \leq \text{AARHK}_k \quad \forall \ k \]  \hspace{1cm} (20)

In the rice processing industry, one season comprises of the peak period (involve drying) and off-peak period. Equation 21 represents the amount of annual rice husk transported from internal and external rice mills during both periods.

\[ \text{ACRHJ}_j = \sum_t (\text{Period}_t \times \text{RHJ}_{jt}) \times \frac{\text{Year}}{\sum_t \text{Period}_t} \quad \forall \ j \]  \hspace{1cm} (21)
9.4.8. Selection of cogeneration system:

An integer variable is assigned to ensure only one biomass boiler is purchased throughout the periods, as described in eq 22.

\[ \sum_b YPB_b \leq 1 \quad (22) \]

9.4.9. Design constraint for cogeneration system:

The hourly steam generated is governed by the boiler capacity, or the upper bound for boiler steam generation. To ensure boiler operability, a boiler must be operated above the boiler turndown ratio, which is typically 50% of the boiler maximum capacity. In eq 23, an Integer variable, YPBb is assigned to design constraints, to ensure the capacity constraint is observed for the selected boiler.

\[ YPB_b \times LWBB_b \leq (HP_{bt}) \leq YPB_b \times UPBB_b \quad \forall \ b \ \forall \ t \]

(23)

Equations 24 and 25 ensure that the MP and LP steam from the extraction-condensing turbine b are bounded by the given minimum extraction rates.

\[ YPB_b \times LWMP_b \leq MP_{bt} \quad \forall \ b \ \forall \ t \]

(24)

\[ YPB_b \times LWLP_b \leq LP_{bt} \quad \forall \ b \ \forall \ t \]

(25)

The CHF will only be purchased if only it operates at period t. Note that there is no limit on the number of CHF to be purchased. This constraint is formulated as eq 26.

\[ YOC_{ct} \leq YPC_c \quad \forall \ c \ \forall \ t \]

(26)
The rice husk consumption in a CHF is bounded by the given minimum and maximum values for the respective CHF unit, as described in eq 27.

\[ \text{YOC}_t \times \text{LWCHF}_c \leq (\text{RHC}_{ct}) \leq \text{YOC}_t \times \text{UPCHF}_c \ \forall \ c \ \forall \ t \]

(27)

9.5. Conclusion:

The design of an optimal rice mill utility system configuration with consideration of rice husk biomass logistic network is a complex problem that involves the trade-offs between various capital and operating costs for the overall rice mill utility system and its biomass fuel logistic network. By combining the economics and process data, optimization offers a comprehensive solution for the plant management to address this complex problem.

A mathematical approach has been developed for simultaneous optimal planning of rice husk logistic network, as well as optimal design of a rice mill utility system that efficiently utilized rice husk from various locations, to satisfy the electricity and drying requirements of the rice mill at appropriate times of the year. A mixed integer linear programming (MILP) problem was formulated to determine the optimum cogeneration system size, the optimal rice husk logistic network as well as the optimal utility supply network. Solution to the MILP problem yielded an optimal utility system configuration consisting of a specified network of rice husk logistic network, a 15 tons boiler and 8 units of CHFs to satisfy the rice mill heat and power requirements.
9. **Conclusion:**

An ideal cluster should be a centre of better eco-friendly environment, quality production, user friendly workstation and tools with sustainable practices and processes in the place.

Therefore, there is an urgent need of modernizing the methods and machinery by new innovations and popularizing the new innovations and the new techniques of paddy processing such as parboiling, drying, milling, handling, storage, transport and byproduct utilization to reduce the substantial losses.