McGill University

Rice Preparation Process Proposal

For Aliments Koyo Foods Inc.

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Executive Summary

Objectives

Aliment Koyo Foods, is a major Canadian producer of rice cakes. At Aliments Koyo Foods, the rice cake production process can be broadly divided into the pre-cooking and cooking stage. The cooking stage is completely automated but the pre-cooking stage is highly labour intensive and ergonomically hazardous. Thus, the objectives of this project are:

1. Reduction of manual labour through use of automation.
2. Reduction of overall labour time.
3. Improvement in cost efficiency.

Solution

The recommended solution is an automated rice washing and soaking machine. A single rice washing vessel would accommodate a day's rice supply, eliminating manual lifting and carrying of several heavy buckets filled with rice and water. An auger would circulate rice in the vessel to first wash the rice and remove impurities and to then maintain consistent distribution of moisture in the rice after the water is drained. The rice washing vessel and auger would be combined with a pneumatic conveyor for transporting rice into and out of the washing vessel. Labour time required would be significantly reduced and heavy lifting effectively eliminated.

Savings

The recommended solution saves four hours and ten minutes of labour per day, resulting in a savings of labour cost of $21,660 annually.

The Implementation of the vertical auger proposal will require an initial investment of $40,800. The payback period is 1.9 years and the return on investment is 53%.

Results

Physical labour which leads to repetitive physical strain will be eliminated through the implementation of the vertical auger proposal. This, will thus minimize the risk of accidents and injuries of the worker.

Acknowledgements

The team would like to thank Ms. Lucie Parrot, Mr. Josef Slanik and Professor Paul Zsombor-Murray for their support and guidance throughout this value engineering project.

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Introduction

Value Engineering

Value Engineering is a systematic methodology used to increase the value of a product, process or service by designing or redesigning to ensure the satisfaction of the client's needs at the lowest cost possible.

Value can be defined as,

$$Value = \frac{Satisfaction\ of\ Needs}{Cost\ of\ Resources}$$

Ideally, value can be increased by maximizing the satisfaction of needs and minimizing the cost of resources.

MECH 497: The Value Engineering Workshop

MECH 497 - Value Engineering is a 40-hour workshop that is accredited by the Canadian Society of Value Engineers. Students are divided into teams of six members each. Each group is assigned to a particular company that presents a particular problem. The team has to then propose a solution using the principles of value engineering.

The successful completion of this workshop certifies each student as a Class 1 Value Engineer.

A typical value engineering process consists of:

1. Organization Phase
2. Information Phase
3. Functional and Cost Analysis Phase
4. Creativity Phase
5. Evaluation Phase
6. Development and Presentation Phase
7. Implementation and Follow-Up Phase

The teams in MECH 497 are responsible for modules 2 through 6 of the value engineering process.

Client: Aliments Koyo Foods Inc

The client for this project is Aliments Koyo Foods Inc., hereinafter referred to as AKF.

Since founded in 1976 as a small Japanese foods distributor, Aliments Koyo Foods Inc. has grown immensely and continues to expand and branch out in all aspects of natural foods and healthy products to meet growing demands. Today, AKF is a major Canadian producer of rice cakes (shown in Figure 1.2.1) and distributes over 2000 brand name foods, personal care, and supplement items and manufactures the internationally well known and enjoyed Koyo Rice Cakes.

Figure 1.2.1: Koyo Foods rice cakes

Figure 1.2.2: Koyo Foods logo

Team Members

Figure 1.3.1: Team picture on client site - Friday, September 28, 2012

The team members from left to right, as shown in the Figure 1.3.1, are:

- Baha Balaa
- Burke Gillis
- Tamara Barbouti
- Jithin Abraham
- Nicolas Seifert
- Rami Osman

Current Production Process

Description of Current Production Process

The rice cake manufacturing process can be broadly divided into the pre-cooking and cooking stages, as seen in Figure 2.1.1.

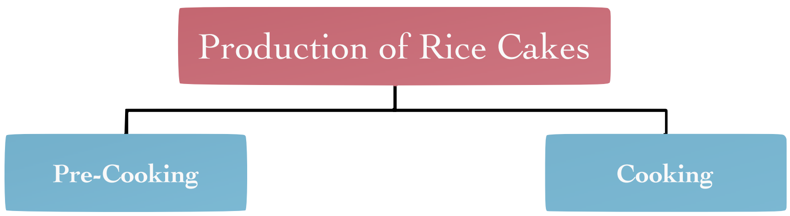

Figure 2.1.1: Division of production of rIce cakes

Cooking Stage

Currently, the cooking stage is completely automated, as shown in the figures below.

Figure 2.1.2: Assembly line of cooking process

Figure 2.1.3: Assembly line of cooking process

Pre-Cooking Stage

The pre-cooking stage, however, involves a high degree of manual labour through the unpacking, washing, soaking and transportation of rice grains, as shown in Figure 2.1.4.

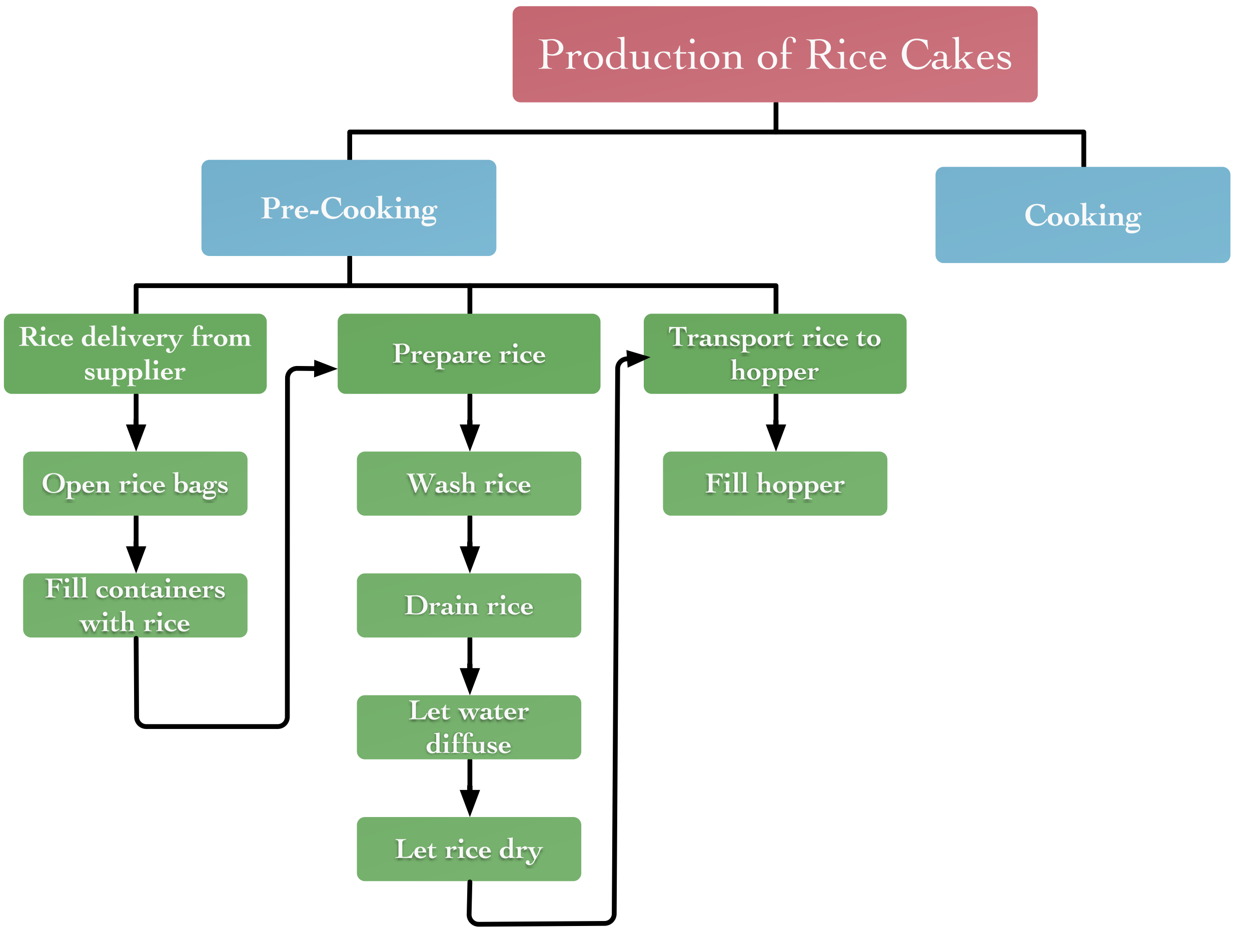

Figure 2.1.4: Flow chart depicting process of producing rice cakes

Unpacking of Rice Bags

Figure 2.1.5: Bags of rice used for rice cakes

Each day, the worker must unpack 25 bags weighing a total of 50 lbs each, shown in Figure 2.1.5, and pour them into 50 buckets, as shown in Figure 2.1.6.

Figure 2.1.6: Buckets filled by rice

Washing of Rice

The worker then fills the buckets with water and manually stirs each bucket, for a total of 50 buckets per day, as shown in Figure 2.1.7.

Figure 2.1.7: Worker stirring bucket of rice and water

Draining of Buckets

The draining of buckets consists of a five steps:

1. Put perforated lid on bucket
2. Flip bucket upside-down
3. Wait for each bucket to drain
4. Flip bucket right side-up
5. Transfer bucket to rice absorption area

This process can be seen in Figure 2.1.8.

Figure 2.1.8: Draining of buckets

Transporting of Buckets to Waiting Area & Moisture Absorption

After each bucket is drained, the worker must transport each bucket from the sink area to the waiting area. At the waiting area, the rice sit for approximately 16-18 hours overnight to ensure proper diffusion of moisture to 16-19% and to achieve a dry surface.

Figure 2.1.9: Buckets of rice in waiting area

In the morning, the rice moisture may not be homogenous as throughout the night, water falls to the bottom of the container due to gravity. Therefore, the rice grains at the bottom of the bucket have greater moisture than those at the top.

Thus, after the diffusion process, the worker re-stirs each bucket to ensure homogeneity in rice moisture. This is sometimes further done by splitting the rice into two buckets and stirring each new bucket. This can be seen in Figure 2.1.10.

Figure 2.1.10: Splitting of rice into two further buckets to ensure proper moisture distribution

Transporting of rice to hopper

After the rice has properly diffused, it is taken from the waiting area and transported to the hoppers; this can be seen in Figure 2.1.10. Each rice bucket must be lifted over the worker's head for the pouring into the hopper, as shown in Figure 2.1.11.

The repetitive strain caused by stirring and lifting of buckets is physically strenuous. This makes the pre-cooking stage ergonomically hazardous and can lead to serious health effects such as acute or chronic orthopedic disorders or even sudden trauma that may be caused by a fall.

Figure 2.1.11: Lifting of buckets over worker's head to transport rice to hopper

Project Objectives

The goal of the project is to investigate various automation options, requiring search for and selection of a variety of conveying and other subsystems, integrating various combinations and applying value engineering principles to produce a solution.

Thus, the objectives of this project are:

1. Reduction of manual labour through use of automation.
2. Reduction of overall labour time.
3. Improvement of cost efficiency.

Methodology

Function and Cost Analysis

Intuitive Research

This is the first stage of function identification where members of the team are encouraged to think and speak freely about ideas.

Environmental Analysis

For this project the ‘product’ is the rice preparation process. The environmental analysis is the first stage in functional decomposition. It involves the following steps:

1. Identification of environmental elements that interact with the process
2. Definition of element characteristics
3. Description, in terms of functions, of the relation between each element and the process
4. Identification of possible links between elements through the process

The process is put into a ‘black box’ and the environmental elements are identified, as shown in Figure 3.1.1. The functions can be classified into two types:

a) Adaptation function: Functional relation between element and process
b) Interaction function: Functional relation between elements

Sequential Analysis

As the name suggests, functions are identified and analyzed in the sequence in which they are performed. This analysis not only helps in identifying functions but also places emphasis on the order of performance and therefore identifies action verbs. This can be seen in Table 3.1.1.

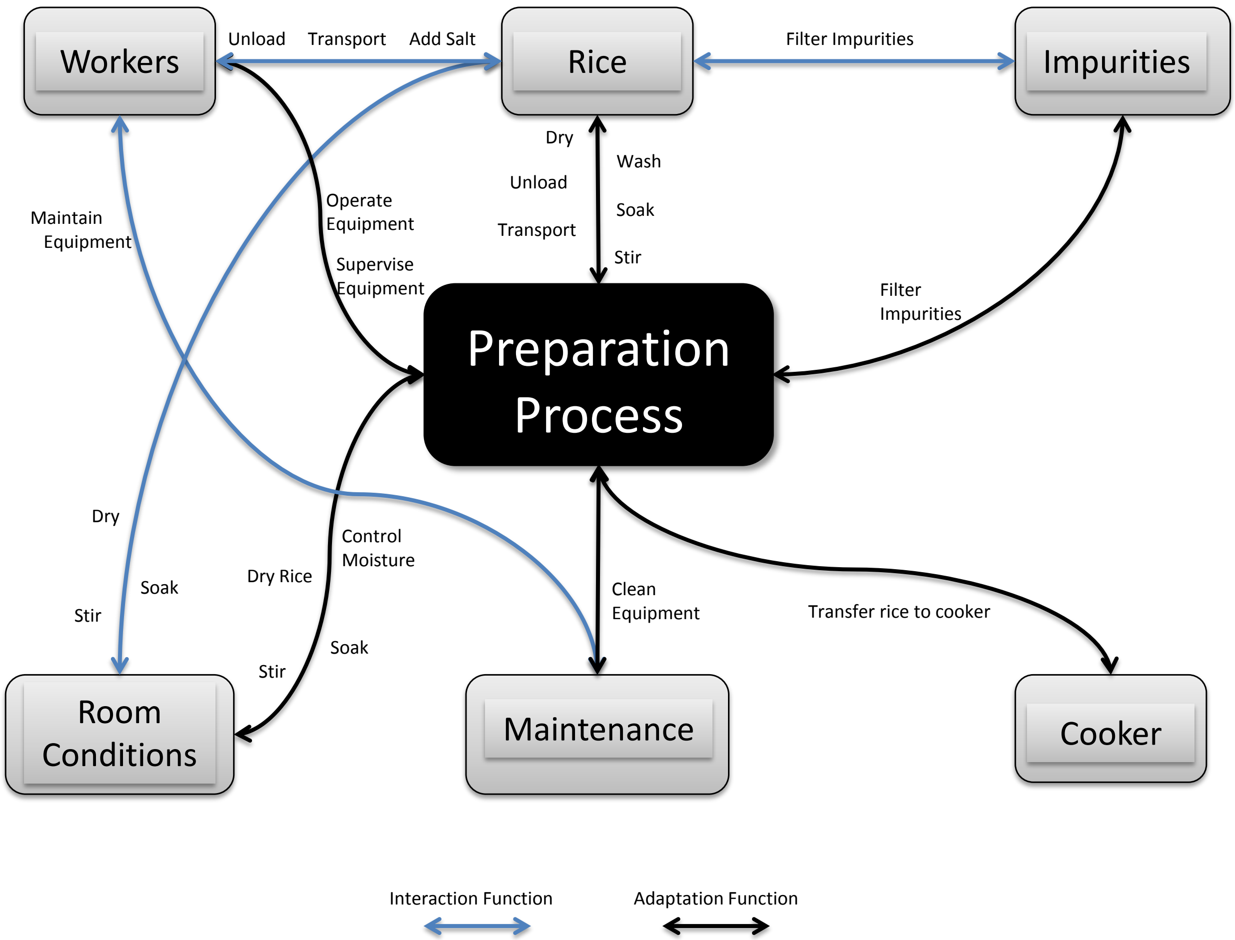

Figure 3.1.1: Environmental analysis: preparation process

Table 3.1.1: Sequential analysis

Sequence of activities	Function	Function noun
Rice Delivery	Unload	Rice bags
Open rice bags	Open	Rice bags
Fill container with rice	Empty	Rice bags
Washing rice	Wash	Rice/water mixture
Drain mixture	Remove	Water
Diffuse water	Absorb	Water
Move to hopper	Transport	Rice
Fill hopper	Fill	Hopper

Functional Diagram

Functions are broken down in a hierarchical fashion. They are identified by asking two questions throughout the chain as indicated by the legend shown below.

Due to space constraints the functional diagram is oriented vertically instead of horizontally. The functions are therefore read from top to bottom instead of left to right

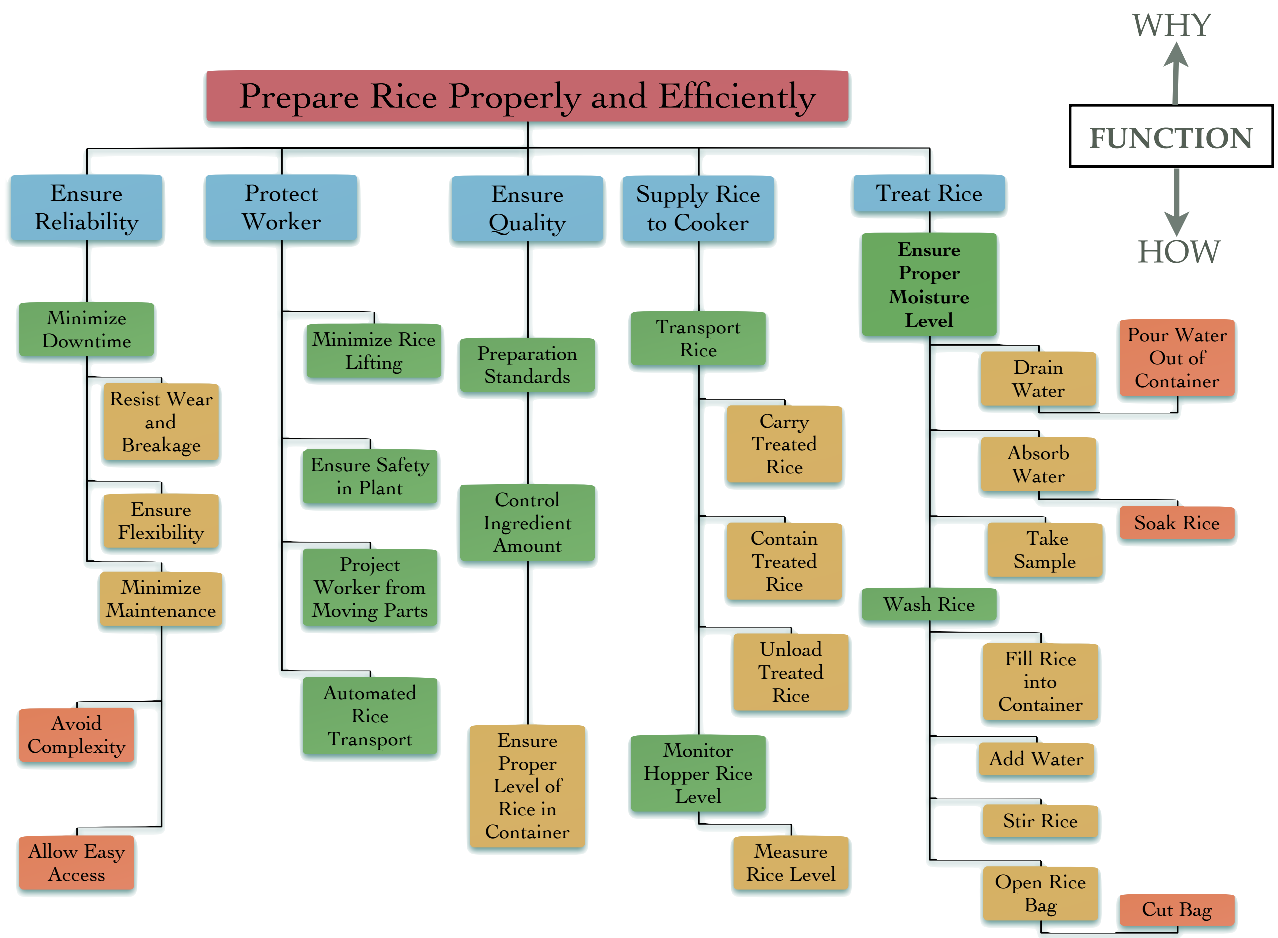

Figure 3.1.3: Functional diagram

Flexibility Table

After functions have been identified they can be characterized by measures of performance. The following are identified for each function:

- Criteria: How the function is accomplished or measured
- Level: Acceptable result for each criterion which could be a minimum, maximum or a fixed value.
- Flexibility: Indication of how much a level can be negotiated.

Each function is then given one of the following values:

- F0: No flexibility
- F1: Little flexibility
- F2: Some flexibility
- F3: Very flexible

This method puts into perspective the rigidity requirements of each function which is taken into further consideration in the development phase.

Table 3.1.2: Flexibility Table

Number	Function	Criteria	Level	Flexibility
1	prepare rice			
1.1	treat rice			
1.1.1	wash rice			
1.1.1.1	open rice bag			
1.1.1.2	fill container from bag			
1.1.1.3	add water			
1.1.1.4	stir rice			
1.1.1.1.1	cut bag	bag type		F3
1.1.1.2.1	pour rice into container	amount of rice	292.3 gallons	F1
1.1.1.2.2	measure rice	amount of rice	292.3 gallons	F1
1.1.2	ensure proper moisture	ensure absorption		F1
1.1.2.1	drain water	amount left	1 inch from the top of bucket	F2
1.1.2.1.1	pour water out of container	know amounts to be poured		F2
1.1.2.2	absorb water	moisture %	16-19%	F1
1.1.2.3	take sample	sample size		F2
1.1.2.2.1	soak rice	time soaking	16 -18 hours	F1
1.2	supply rice to cooker	amount of rice (rate)	9 (g/s) per cooker	F1
1.2.1	transport rice to hopper	time taken	1 hour/day	F2
1.2.1.1	unload treated rice	time taken		F2
1.2.1.2	contain rice	size of container	5.8 gallons	F3
1.2.1.3	carry rice	capacity		F2
1.2.2	monitor hopper rice level	frequency	re-filll 3 times a day	F1
1.2.2.1	measure rice level	always full	cannot empty	F1
1.3	ensure quality	meet requirements	16-19% inner moisture	F1
1.3.1	follow dry food standards	meet standard		F0
1.3.2	control ingredient amounts	amounts of minerals		F1
1.3.2.1	ensure proper rice level in container	monitor levels		F1
1.4	protect workers	frequency of accidents		F1
1.4.1	ensure safety	frequency of accidents per hour		F0

Number	Function	Criteria	Level	Flexibility
1.4.2	minimize loads	mass of bucket	maximum load of 50 lb	F1
1.4.3	assist material transport	avoid carrying heavy weights	maximum load of 50 lb	F1
1.4.4	protect workers from moving parts	no exposed parts	case for moving parts	F1
1.5	ensure reliability	how can you afford shutting down	losses per hour,due to shutting down	F1
1.5.1	minimize downtime	lost time		F1
1.5.1.1	resist wear/breakage			F1
1.5.1.2	minimize maintenance			
1.5.1.3	ensure flexibility			
1.5.1.2.1	avoid complexity			
1.5.1.2.2	allow easy access			

Cost Analysis

After functional analysis was completed, it was necessary to quantify the functions in the present process. For each function, the cost of completing that function was calculated. There were different costs that could be investigated such as:

- Monetary cost
- Weight
- Duration

In this project, the most important cost was the duration of manual labour required, thus time costs were analyzed. During the team visit to the Koyo Foods factory, precise measurements were taken of each stage of the process. The rice preparation process required approximately six hours of direct manual labour each day, with over four and a half hours devoted to functions associated with washing, mixing, and draining the rice by hand. In these functions there were mismatches between the time costs and the perceived relative contribution of that function to the overall process. Thus, these were the areas that offered the greatest potential for time savings.

Creativity Methods

Introduction

The fourth stage of Value Engineering applications, "Creative Brainstorming". In the creativity phase, the team worked to collect innovative ideas to perform the required functions most efficiently with the least cost possible. To get the most out this phase, the facilitator has to stimulate the team members to spill ingenuity without censorship. No matter how ridiculous the proposed concept is, it should be discussed among the team members. Issues such as budget, complications, time needed to implement the concept or any negativities that would block the flow of creativity shouldn't be taken into consideration at this point.

All our team members, with the aid of the facilitator may use creativity inducers such as having positive attitudes, using work tools like the functional diagram. Also choosing an informal/public work zone to discuss the problems and their potential solutions helps stimulate creativity. In addition, the members of our team come from diverse backgrounds and experiences which helped fill up several blank sheets with different sketches, descriptions and calculations of original ideas and how implementing them would improve the system.

Moreover, parts from different creative suggestions could be combined to come up with new concepts to reinforce the strong points and reduce the weak points of our proposed system (better known as morphological combination). Other creativity tools may include Pugh matrices, Lotus flower (by Daniel Couger), Scenarios (by Bernard Demory). In the brainstorming section, the suggested ideas/solutions to perform the main functions will be listed.

Creative Brainstorming

Cut rice bag

- Knife/saw.
- Scissors.
- Conveyor belt/cutting device.
- Table to hold bag.

Fill rice with container

- Pour all open rice bags onto a conveyor belt moving it to a big container and then rice can be transported to the machine to start washing/soaking.
- Conveyor belt with sieve netting to separate rice from bags.
- Vacuum tube/push with high pressure.

Add water to rice

- Pouring rice into container filled with water.
- Pour rice (through conveyor belt) to container, water will be sprayed.
- Move rice to container with water in pipe water jet from bottom of container.
- Water jet into the container where rice is being collected with a screw mixing rice/water in the container.
- Small containers being filled with water from bottom
- Small containers with porous material, where you can wash the rice.

Stir water and rice

- Use of propellers / giant screw.
- Use water jets.
- Manually by a lever/use a fly wheel.
- Compressed air.
- Spin or shake container.

Drain water from rice-water mixture

- Remove solid sheet, water drains out of container
- Plug valve to open tap.
- Pump water out of container.
- Big flat area to dry the rice grains, ventilated.

Allow homogenous moisture absorption into rice grains

- Leave it in same container/wait for 16-24 hours for soaking.
- Mixing the rice while soaking.
- Control temperature/humidity in container/pressure

Note that the rice needs to soak until the inner grain is 16-19% humid, while having a dry outer surface.

Take rice sample

- Physical test (dryness)
- Smash hygrometer

Unload rice into hopper

- As noted, rice is transported to an elevated container, by a conveyor belt, then through an inclined ramp to fill the hoppers.
- By the aid of a compressed air flexible hose, rice is transported to the hopper.
- Use trolley/conveyor belt to move small containers closer to hoppers.
- Elevate rice buckets and use ramps.
- Use pulley/winch/strings to pull buckets closer to hopper.

- Use paddles to elevate rice to container level and then by the use of flexible hoses, rice is distributed to the hoppers.

Contain treated rice

- Container is at a high level above the ground, gravity will help rice fall into hoppers.

Measure rice level

- The minimum rice level in the hopper should be 5 cm, refill if less than that.

Evaluation Methods

Gut Feel Index

The ideas were then evaluated and eliminated using the "gut feel" index method, shown in Table A. 2.1 in Appendix 2.

This method gave the team insight into what solutions to consider for each of the functions. Ideas with a score of less than 5 were discarded and those with a score greater than 5 were considered for further exploration and development.

Proposals

Summary

The creativity and evaluation phases of the job plan resulted in six alternative scenarios. These unique concepts were generated from combinations of the solutions proposed to satisfy the client needs identified in the functional decomposition. The scenarios produced offer varying degrees of automation, over wide range of capital cost. A selection of concepts—two horizontal concepts using continuous processing, two vertical concepts implementing batch processing, and a single manual process which optimizes the existing processing techniques—are proposed.

Concepts at a glance

- Vertical auger proposal
- Vertical venturi proposal
- Horizontal proposal
- Multiple vessels proposals
- Manual operation of single vessel proposal

Vertical Auger Concept

Description

This concept, shown in Figure 4.2.1, uses a single large vessel to wash and drain the rice. After the water has been drained, compacted rice can ferment because of elevated temperature, or incur inconsistent distribution of moisture throughout the vessel; therefore it is necessary to constantly circulate the rice by means of an auger.

Discussion

The auger, in a a cylindrical casing, requires less torque than other mixing mechanisms due to the fact that only a small portion of the rice is being lifted in the center of the vessel and gravity is used to recirculate it to the bottom. This mechanism allows constant circulation of the rice (when mixed with water as well as after the water is drained), with no manual labour during the washing or circulation. Water can be recycled from one washing process to the next because water is filtered during the process. Additionally, the water level is maintained above that of the rice, so floating debris can be removed by draining off the top layer of water.

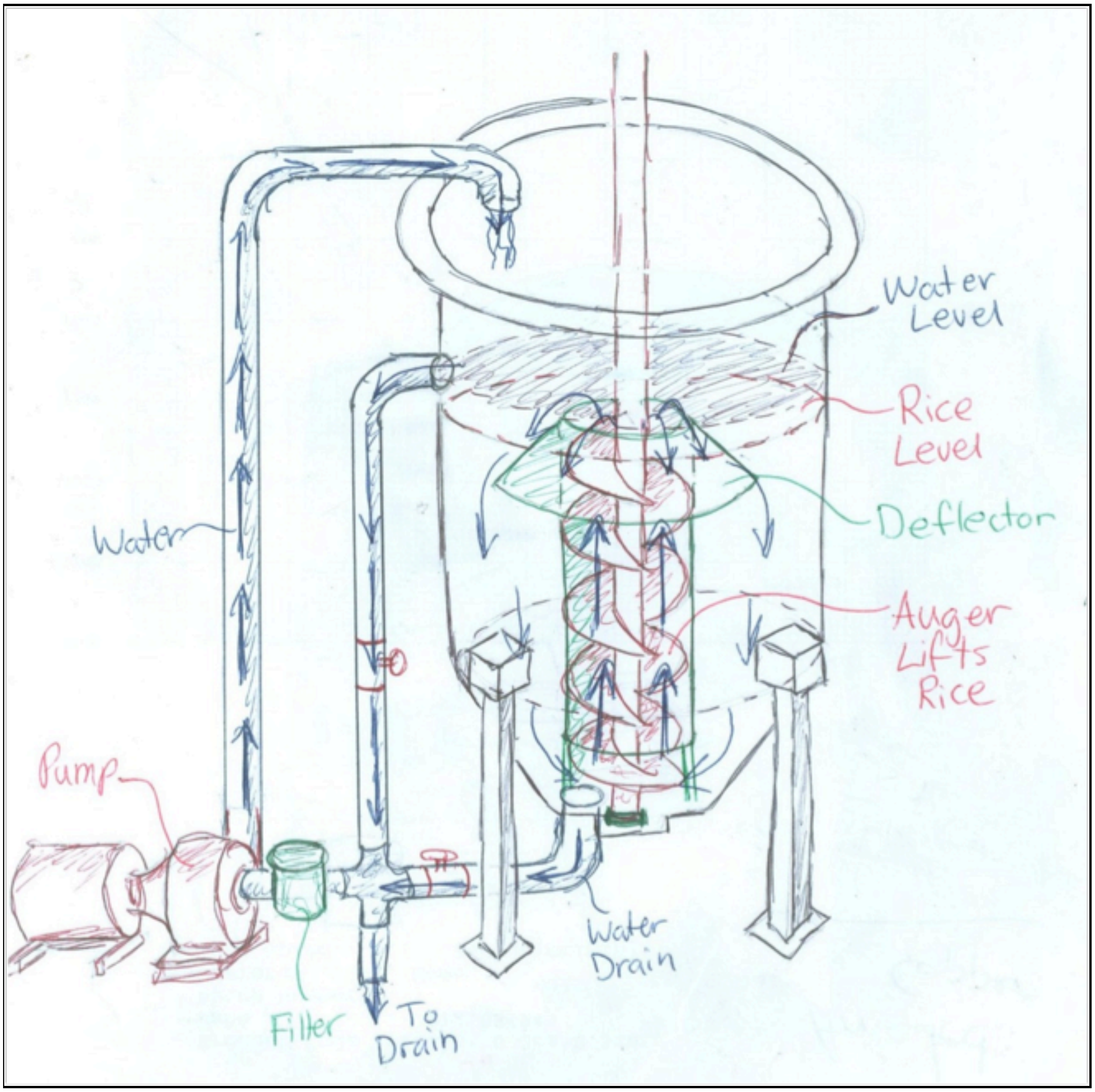

Figure 4.2.1: Auger concept

Vertical Venturi Concept

Description

The venturi concept uses a single vessel similar to that implemented with the auger for rice circulation. However, the auger is replaced by a compressed air venturi which directs a jet of high velocity air into the container to create a water/air jet to lift the rice to the surface of the water. Here the rice falls over the deflector to the outer edge of the vessel and returns to the bottom of the vessel where it is recirculated.

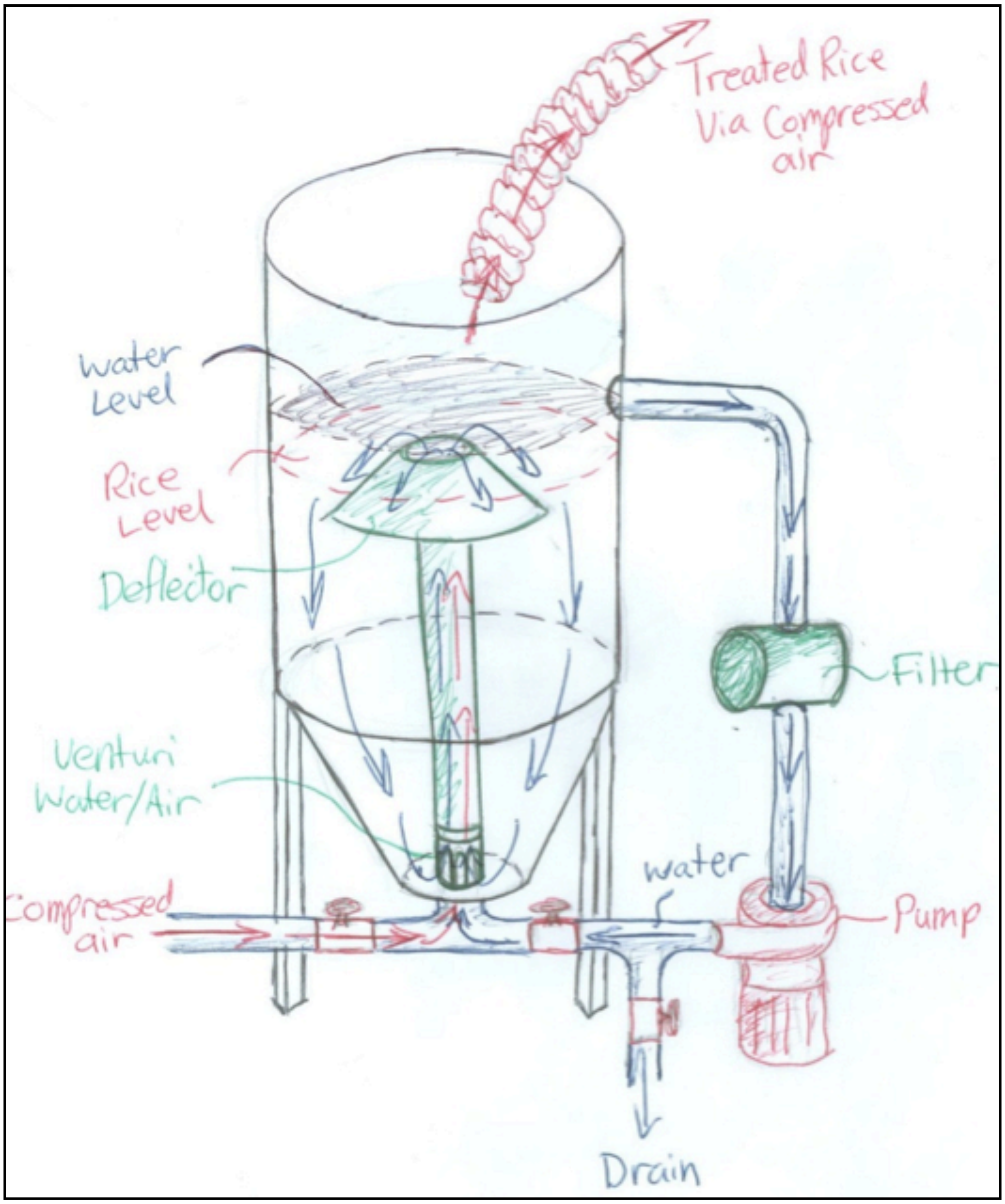

Figure 4.2.2: Venturi concept

Discussion

The venturi nozzle has no moving parts, so compared to the auger concept this arrangement has less moving parts overall, making it a low maintenance option. Using compressed air to circulate the rice is a novel idea, but there is insufficient proof that it would be able to push a heavy mixture such as rice and water. Systems exist which use this principle to lift bulk solids such as grain using high velocity airstreams, but it is uncertain whether circulation of water could be achieved with this mechanism. Further testing and research would be needed to prove the feasibility of this concept.

Horizontal Concept

Description

This design incorporates a screw conveyor which washes the rice while it transports it to an inclined container, where the rice spreads out in a thin layer and water drains through the mesh bottom. The water is captured and pumped back to the screw conveyor so it can be recycled. The inclined container ensures that the rice stays in a thin layer so moisture can diffuse evenly and then dry on its surface, after the moisture has been absorbed into the center of the rice grains.

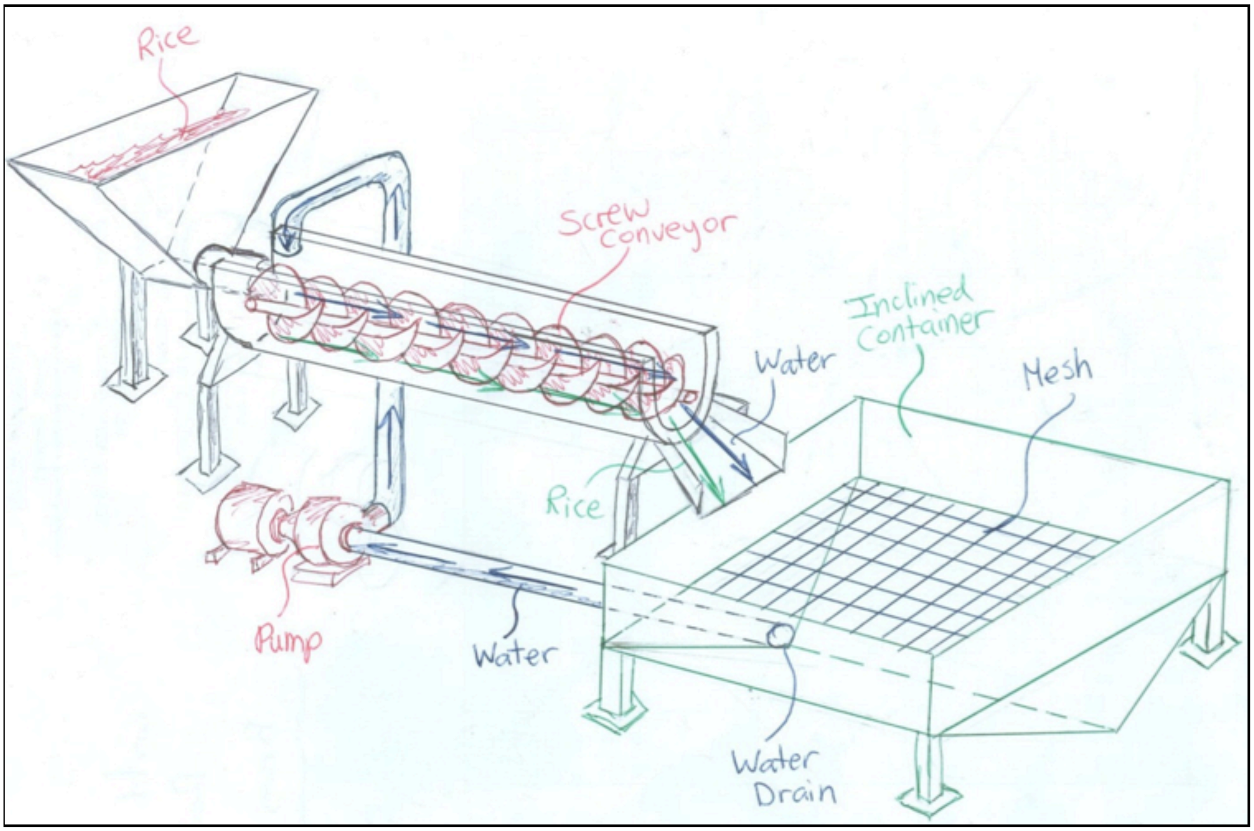

Figure 4.2.3: Horizontal concept

Discussion

Using a single piece of equipment (screw conveyor) to mix and move the rice makes this design more cost effective. However, a large amount of factory area would be occupied by this arrangement. Also, this design still requires manual labour for rice input and transport to the hopper of the cooker.

Multiple Vessels with Rotating Paddles

Description

This multiple vessel concept operates in a similar manner to the horizontal concept. It differs in that the rice/water mixture is sent to several separate enclosed vessels and the containers are equipped with fittings to which a pneumatic conveyor can be attached to transport the rice to the cooker.

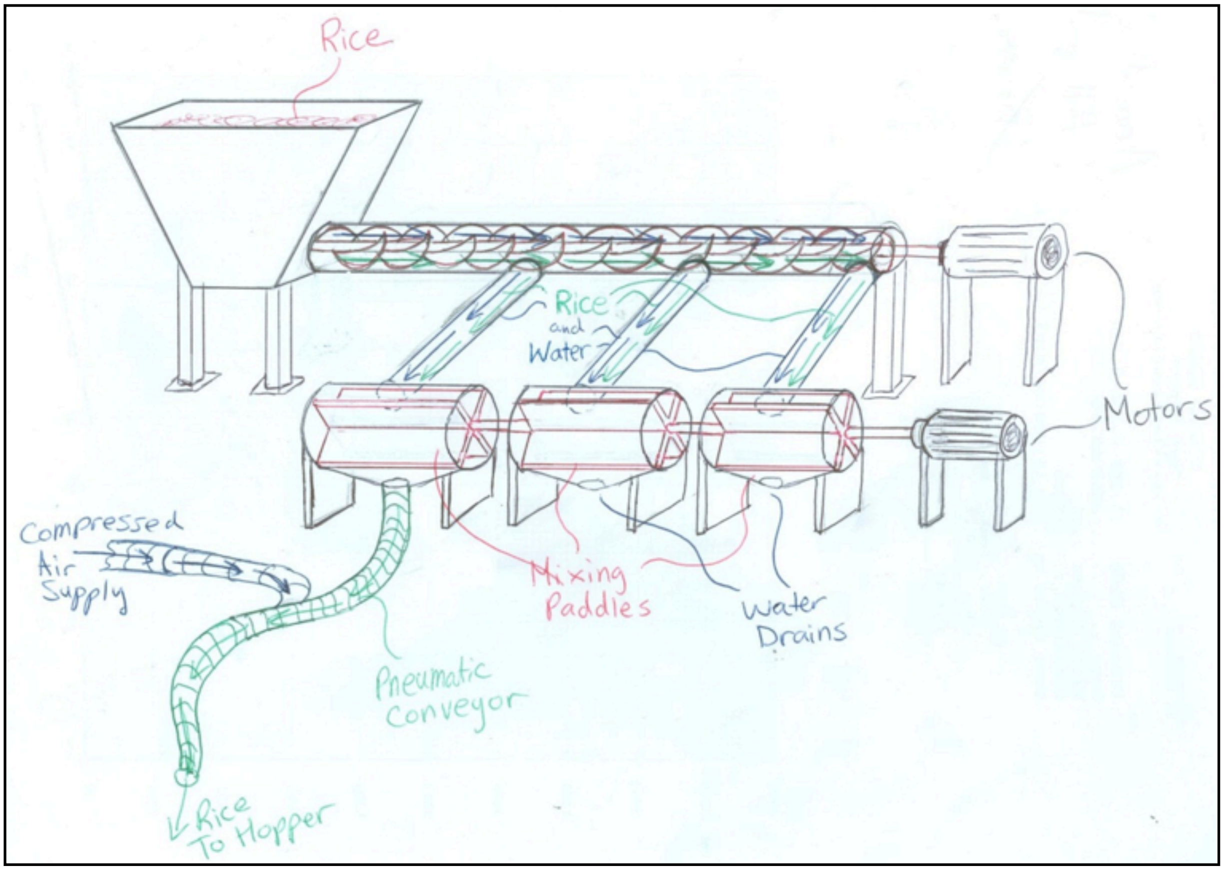

Figure 4.2.4: Multiple Vessel concept

Discussion

This configuration allows more flexibility in varying levels of rice production because more or fewer containers can be used as required. This arrangement is inherently more complex mechanically, and the mixing paddles would require a large torque as they are mixing the entire volume of rice at all times. Also, because the rice vessels are contained, moisture diffusion is inhibited, so more time is needed for the rice to absorb moisture into the center of the grains and for the grains to dry on their surface. Enclosed containers facilitate movement of rice into the pneumatic conveyor by gravity.

Manual Operation: Single Vessel

Description

The simplest of all the proposals is this manual concept. This is no more automated than the present scenario, but it has the potential to greatly decrease the labour requirements for this process, especially in terms of the physical difficulty of the work. It uses a single vessel in which rice and water are mixed manually and water is drained through a mesh bottom. Water is recycled between batches and is pumped into the mixing container.

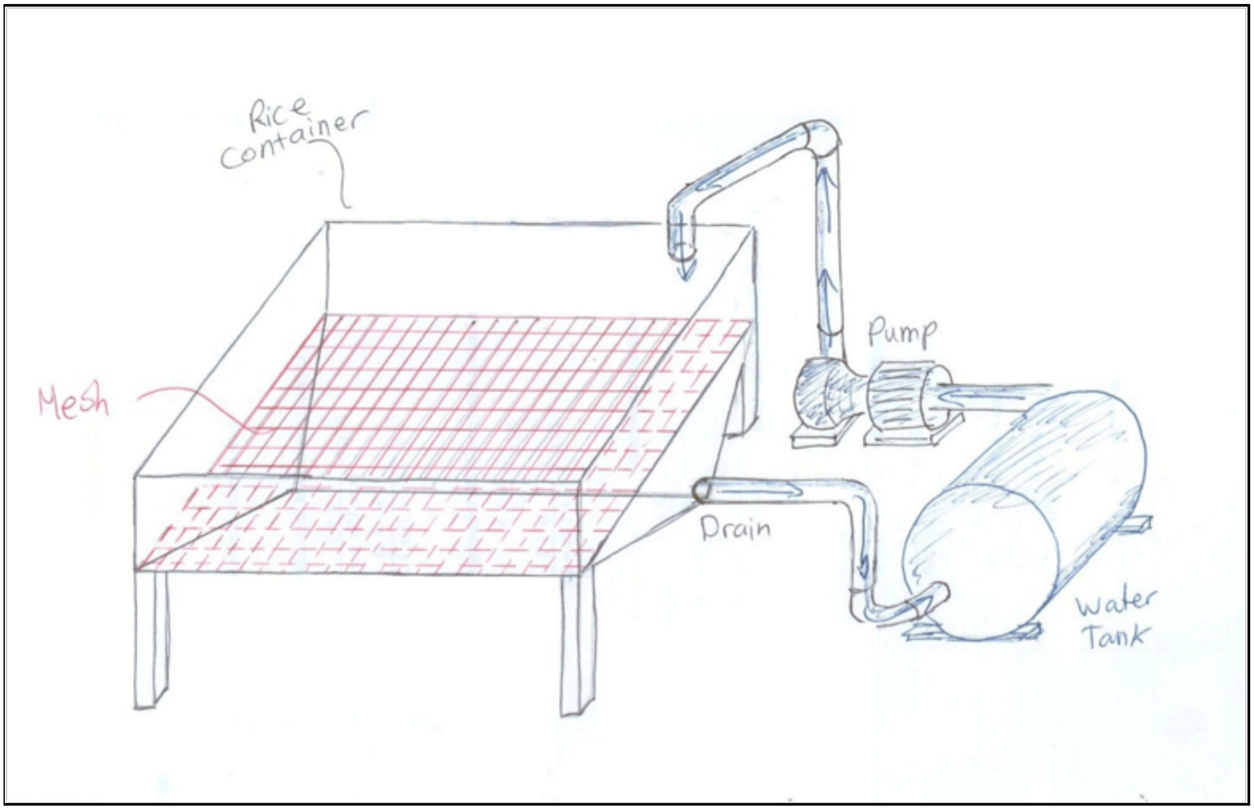

Figure 4.2.5: Manual concept

Discussion

Using a single large vessel eliminates most of the physical labour associated with the washing, mixing, and draining processes. The ability to reuse the water in different batches offers an added environmental benefit over the current process.

Development Phase

To have a comprehensive well-rounded analysis, the cost analysis was divided into the following:

1. Time cost
2. Labor Cost
3. Equipment cost
4. Combined cost

Each analysis addresses an aspect of the process and will be explained below.

Cost Analysis

Time Analysis

First, time intervals required for each part of the process were measured. This was done during the team's visit to Koyo Foods. All functions had a certain time interval associated with them. For instance, the washing process took 40 minutes; each was timed using a stopwatch. Similarly, time analysis for all the other concepts was done, functions were accordingly given estimated time intervals. This comparison proved that our proposed concepts cut down on process time, as we can see in the table.

Labour Analysis

Labor cost is connected to the time analysis. Time intervals were converted to "money". The Total function cost was multiplied by the hourly rate of employees at Koyo Foods, $20/hour, giving a total annual Labor Cost. In addition, $2,400 was added as an annual insurance cost for employees.

Table 5.1.1 summarizes all total function costs and corresponding annual labor costs.

Table 5.1.1: Total Function Cost and Labor Cost

Concept	Total Function Cost (hrs:mins)	Annual Labour Cost
Present	6:20	$32,920
Auger	2:10	$13,670
Horizontal	3:02	$17,350
Multiple Vessels	2:17	$14,320
Venturi	2:10	$13,670
Manual	5:16	$29,850

Equipment Analysis

To implement each concept proposed, an initial investment is required by the client. To get a precise cost of the equipment required for each concept, the professional consulting engineer, Mr. Josef Slanik, provided equipment costs for the proposals. To obtain the most reliable equipment cost approximations, Mr. Slanik's expertise with equipment was used. Lastly, different catalogues from several heavy duty machine suppliers were used in the data analysis for the equipment cost.

Table 5.1.2 summarizes the corresponding initial investments (equipment cost) for each concept.

Table 5.1.2: Equipment Cost

Concept	Equipment, Engineering & Assembly Cost
Present	No cost
Auger	$40,800
Horizontal	$49,750
Multiple Vessels	$75,450
Venturi	$36,000
Manual	$9,700

Combined Cost Analysis

Finally, both the Labor and the Equipment cost were combined to give an estimate of the implementation of each concept. The way the combined cost was calculated:

$$Annual\ Combined\ Cost = \frac{Equipment\ Cost}{3} + Annual\ Labour\ Cost$$

Dividing the Equipment Cost serves, as a factor to divide the initial investment required over three consecutive years, hence giving reasonable installments for clients. Being done for calculating all the concepts.

Merit Analysis

To compare the different proposals, a cost/merit graph was prepared. Merit is a measure of how well each proposal satisfies the client's needs, so from the cost/merit graph value can be determined by looking at the slope of the line for each proposal. To determine a value of merit for each proposal a list of criteria was chosen, corresponding to the most important functions which must be fulfilled. A weight is given to the criteria to favor those which are more important. To obtain a merit count for each proposal, points (between 0 and 10) are awarded for each criterion depending on how well the proposal fulfills that criterion. This score is multiplied by the weight and the total merit is obtained from the summation of all scores.

Criteria

Safety and Ergonomics

One of the primary needs of the client is a reduction in the physical difficulty of the labour. Any reduction in the weight that a worker has to lift, or the number of times they must lift it is desirable in a solution. Also, safety is a concern in any work environment. Both of these considerations have the aim of preserving the employees' well-being, so they are combined in this criterion.

Degree of Automation

Systems with a higher level of automation contribute to the reduction in direct and indirect labour hours. A completely automated process is most desirable because it can completely eliminate the need for a worker where one was required before. Partially automated solutions are also very helpful, even when they require a worker to manually control certain aspects of the process, because they reduce the duration of the worker's involvement, giving flexibility to work in other areas throughout the process.

Minimize maintenance Cost

Systems that require less maintenance offer savings through minimization of maintenance and repair expenses as well as limiting lost production due to equipment shutdowns.

Moisture Consistency

To maintain the quality of the finished rice cake, moisture in the rice must be kept between 16-19% by mass, with a dry outer surface of the rice grain. If there is too much moisture the rice grains can explode during cooking and if there is too little moisture the rice cakes will be too hard and brittle, or burnt. Ensuring consistent moisture guarantees a high quality final product and reduces waste.

Ease of Operating System

Simpler processes limit the probability of human error and reduce the need for highly skilled operators, leading to savings in labour costs and reduction in wasted product.

Ease of Cleaning

In a food environment, surfaces in contact with the product must be kept sufficiently clean. Equipment that can be easily cleaned reduces time spent on cleaning and reduces strenuous physical labour.

Tidiness and Packaging

More compact and well packaged equipment can reduce the likelihood of accidents, allows easy access for cleaning and maintenance, and provides extra free space in case it is needed.

Processing Time Saved

Reducing the amount of labour directly involved in the process is a primary objective. This can lead to direct reductions in labour costs, or give flexibility to reassign employees to other tasks.

Weighting of Criteria

Comparison tables are used to give weights for each criteria. Grading each criteria from 0 to 10, gives a summation of Total Merit count. For example, taking Degree of automation with a weight of 9, gives this criteria a high importance. On the other hand, Tidiness and packaging was given a weight of 3 because it had less effect on fulfillment of the most important functions. An example is shown below with the Comparison table for the combined cost.

Table 5.1.3 Criteria weight table & combined cost-merit table

Criteria	Weight	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Present
Safety and Ergonomics		9	6	6	9	4	2
	7	63	42	42	63	28	14
Degree of Automation		8	6	6	8	0	0
	9	72	54	54	72	0	0
Minimize Maintenance Cost		6	7	5	6	8	10
	7	42	49	35	42	56	70
Moisture Consistency		8	7	7	4	6	4
	8	64	56	56	32	48	32
Ease of Operating System		8	6	6	7	5	4
	7	56	42	42	49	35	28
Ease of Cleaning		7	7	7	6	8	4
	6	42	42	42	36	48	24
Tidiness and Packaging		7	5	4	7	6	2
	3	21	15	12	21	18	6
Processing Time Saved		9	7	7	9	5	10
	9	81	63	63	81	45	40
Total		441	363	346	396	278	214
Annual Cost ($1000's)		27.27	33.93	39.47	25.67	33.09	35.33

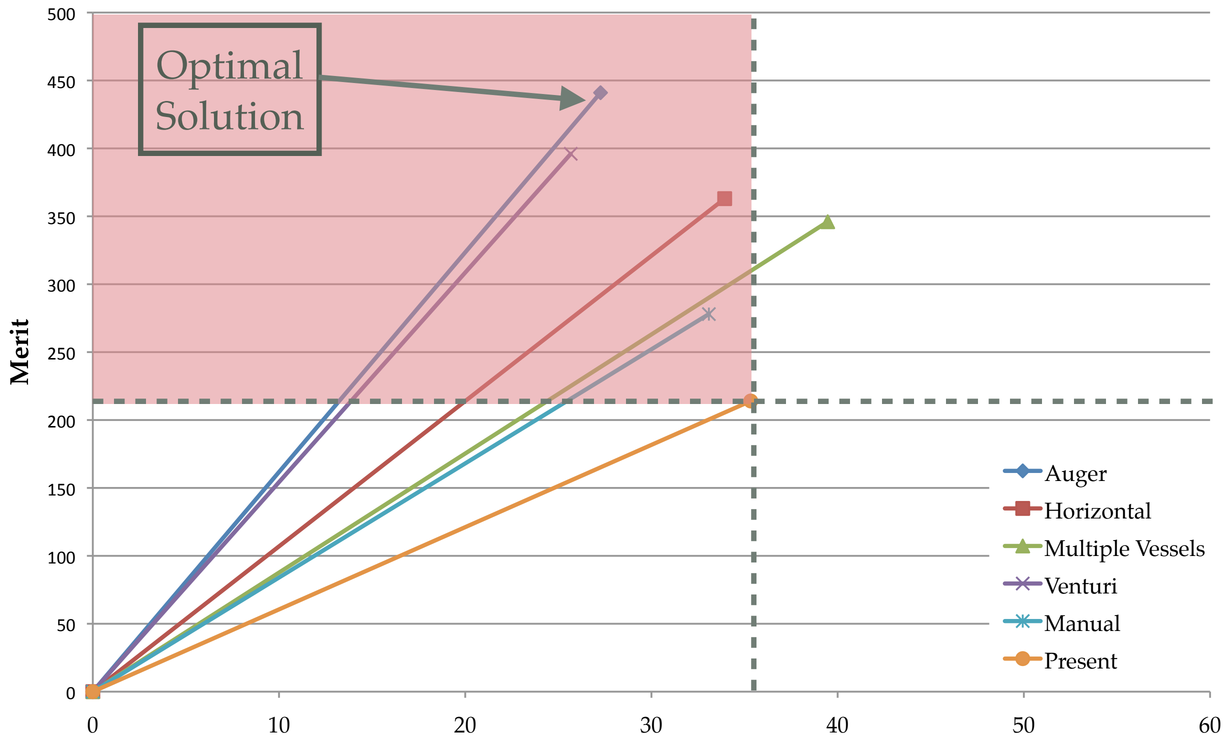

Figure 5.1.1: Combined Cost-Merit Graph.

Drawing a vertical line at the present cost and looking at the left area, this is an area of less expensive concepts. Similarly, drawing a horizontal line at the present Merit count, looking at everything above that, reflects concepts of higher merit count compared to present scenario.

The overlapping areas section is highlighted in light red on the graph. This area shows concepts, which are better than the present scenario. Nevertheless, by definition of a cost merit graph, the highest slope curve is always the winning scenario, giving the highest merit count for that cost.

As seen on the graph, the highest slope was for the auger concept with nearly 450 merit points (highest compared to all concepts) vs. a cost of $27,000, fairly less than the $36,000 for the present case.

One may thus conclude that the optimal solution is the vertical auger concept.

Cost Justification

Return on Investment

Currently, the client is paying $35,330 annually in labour cost.

Implementing the vertical auger concept promises a decrease in labour cost to $13,670 annually, due to a reduction of hours of labour in the rice preparation process.

Hence, an annual savings of $21,660 is calculated through:

$$Annual\ Savings\ from\ Labour\ Cost = Present\ Cost - Projected\ Cost$$

$$Annual\ Savings\ from\ Labour\ Cost = \$35,330 - \$13,670 = \$21,660$$

Given that the initial investment cost of equipment for this concept is $40,800, the return on investment is:

$$R.O.I. = \frac{Annual\ Savings}{Initial\ Investment} \cdot 100$$

$$R.O.I. = \frac{\$21,660}{\$40,800} \cdot 100 = 53.1\%$$

Thus, the return on investment is 53%.

Payback Period

The payback period can be calculated through:

$$Payback\ Period = \frac{Initial\ Investment}{Annual\ Savings}$$

$$Payback\ Period = \frac{40,800}{21,660} = 1.88$$

Thus, the payback period is 1.9 years.

Conclusions

Thus, implementing the auger concept will require initial investment of $40,800 and will give a payback period of 1.9 years and a subsequent annual return on investment of 53%.

Final Concept: Detailed Analysis

A combination of the previous design concepts was used in conjunction with value engineering methodologies to create a final version to be evaluated and detailed. This concept is described as the Vertical Auger Design. The major components of this design feature one large containment vessel with inlets and outlets for water and rice, as well as a vertical hanging auger to perform the washing and moisture homogenization process.

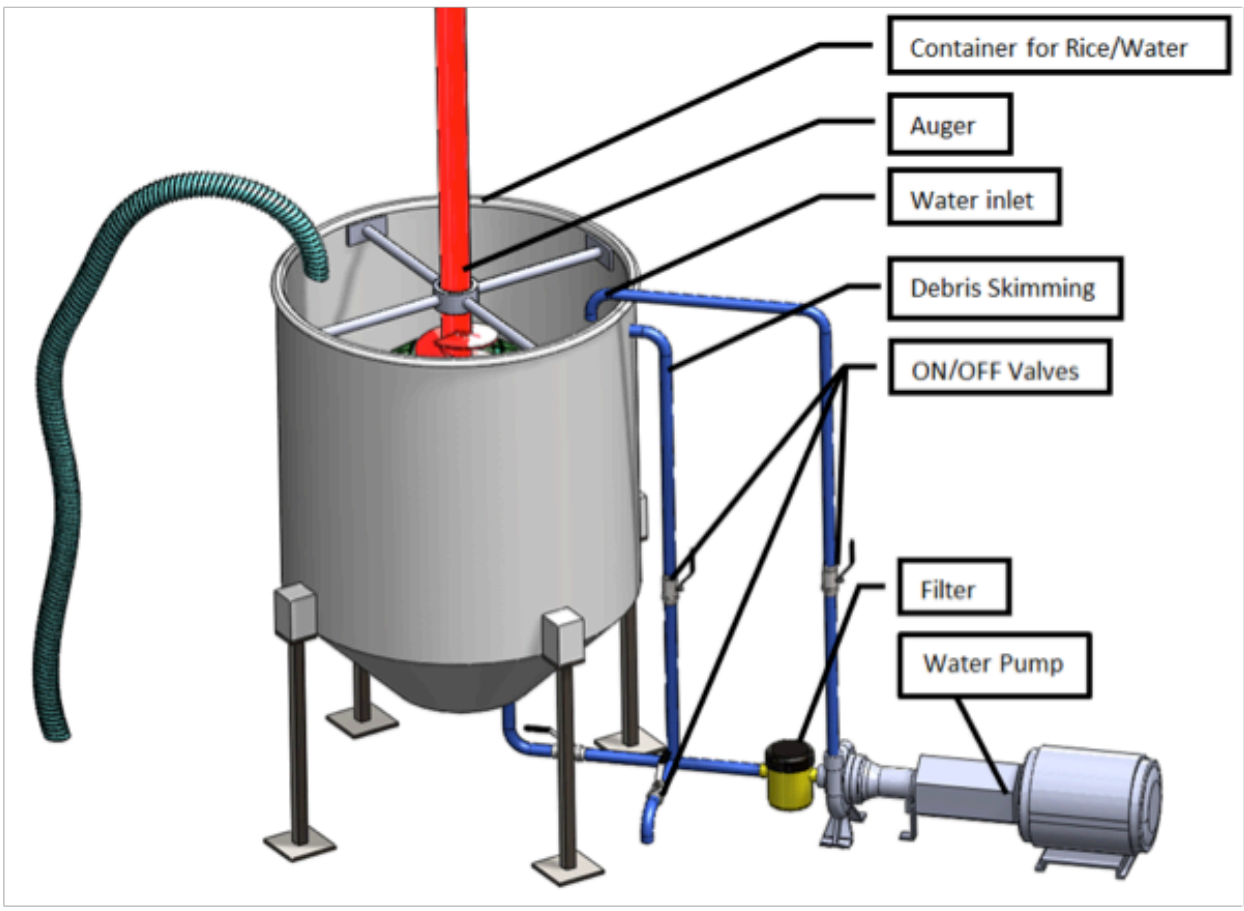

Figure 6.1.1 – Exterior view of vertical auger design

Features

Container

The current process of individually filling and transporting 25 bags of rice into 50 buckets is the one task that takes most time to perform. One large cylindrical vessel for all the rice is an effective way to eliminate frequent heavy lifting. This container will have converging walls towards the bottom half in order create a funnel effect for the rice and water. During the washing process the rice-water mixture must be in constant motion, meaning any edges can create areas of stagnation.

The container is suspended from the ground and supported by 4 bolted down legs to ensure sufficient support and reducing the risk of tipping. The legs will be attached to rectangular blocks mounted to the outer walls of the container. Since the major force acting on the legs will be in the vertical direction, the rectangular blocks will also be mounted vertically to withstand the large shear force with the container. Water outlets will be mounted long side oriented vertically in the container as well as an implementation of a stone filter at the bottom of the container for any larger sediment which does not float to the water surface in the mixing process.

Rice Delivery System

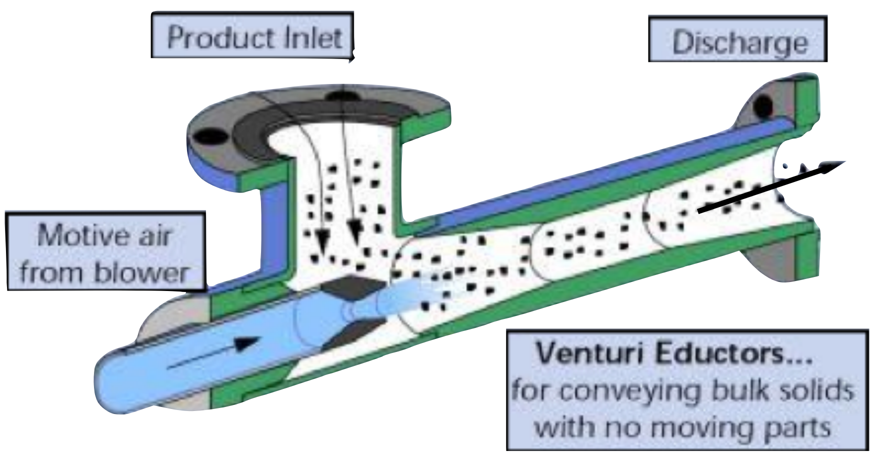

Figure 6.2.1 – Venturi principle

The rice will be delivered to the container using a pneumatic conveyer system. The center piece of this system will be the use of a venturi educator. A venturi nozzle has three channel attachments; one input for compressed air from a pump, as well as the passage of the product through the inlet and outlet of the nozzle. The principle behind the venturi is the method of creating a negative pressure at the inlet of the nozzle by forcing the compressed air through a constricting channel. This negative pressure results in a suction force at the inlet. A flexible tube is attached to the venturi nozzle to complete the design of the pneumatic conveyor.

An employee of Koyo Foods Inc. will cut open each rice bag and directly insert the tube into the rice. The tube will act like a vacuum as it suctions the rice through the nozzle and is then driven with the compressed air to the container. An important consideration to this method however, is the presence of oil particulates in the stream of compressed air which interacts with the rice. The regulations of the food industry have guidelines for levels of exposure a product may have to health hazardous chemicals.

An alternative to the regular venturi is a more sophisticated design of the venturi which is used in the pharmaceutical industry. This advanced nozzle creates two separate airflow streams. The first is a stream with oil particulates to create the negative pressure, while another separate flow mixes with the product and conveys it along the tube free of any hazardous components. This venturi operated pneumatic conveyor will be used to deliver the rice to the container as well as suction it back out once the washing and water diffusion process has been completed.

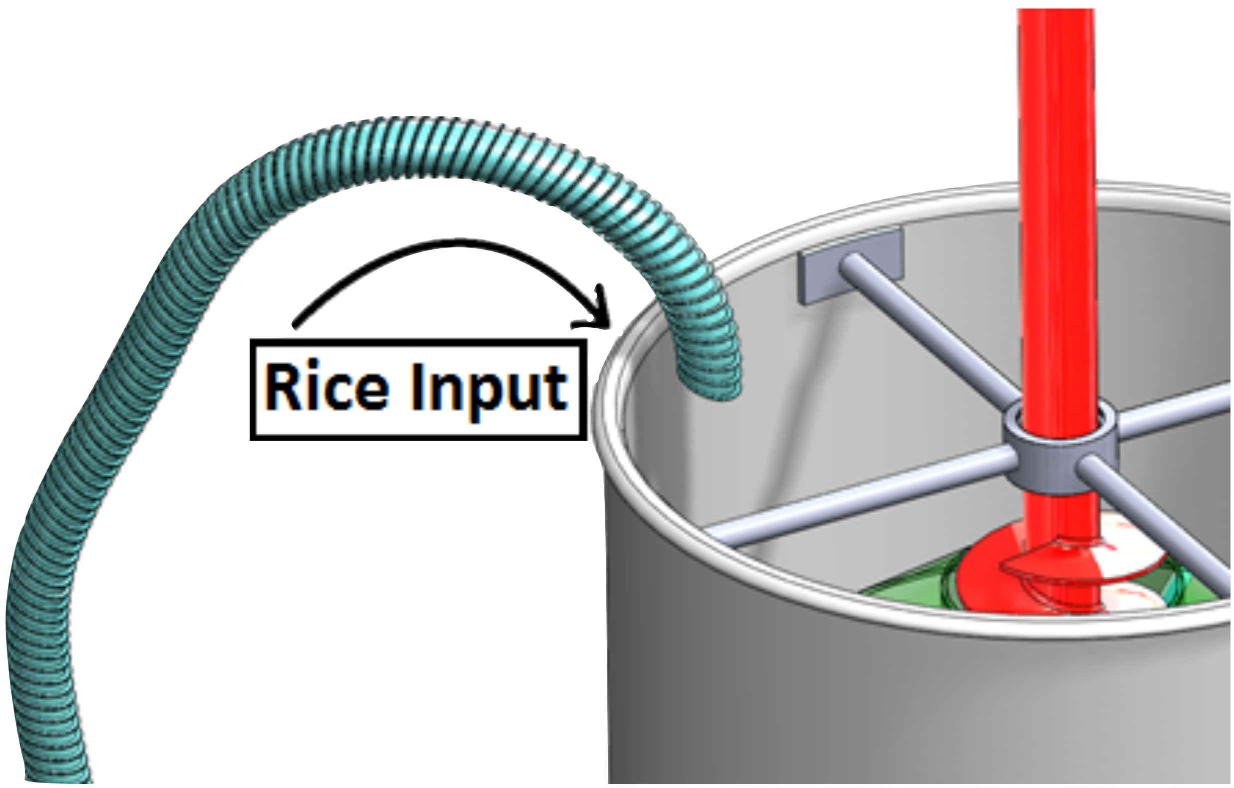

Figure 6.2.2 – Venturi delivery system

Water System

A series of interconnected pipes will accomplish the task of circulating fresh and filtered water. The first pipe hovers directly over the top of the container and serves as a water inlet. A water pump will drive the water through the piping system. The second pipe is located at the bottom surface of the container to drain the water after the washing cycle is complete. The draining outlet will function under the force of gravity to remove the excess water from the system. In addition, the final pipe attachment will be placed directly through the wall of the container about 10 inches below the rim. This will serve as a debris skimmer in order to remove any accumulation to the water surface. A small amount of water will be continuously removed since the water will be held level with the skimmer.

All pipes will be operated by individual ON/OFF valves. This way the water flow through the pipes can be regulated as well as directed to the appropriate locations. For permanent removal of debris, a filter will be included into the design. This way any drained water can be reintroduced into the system or held separate to save the cost of having to refill the large container.

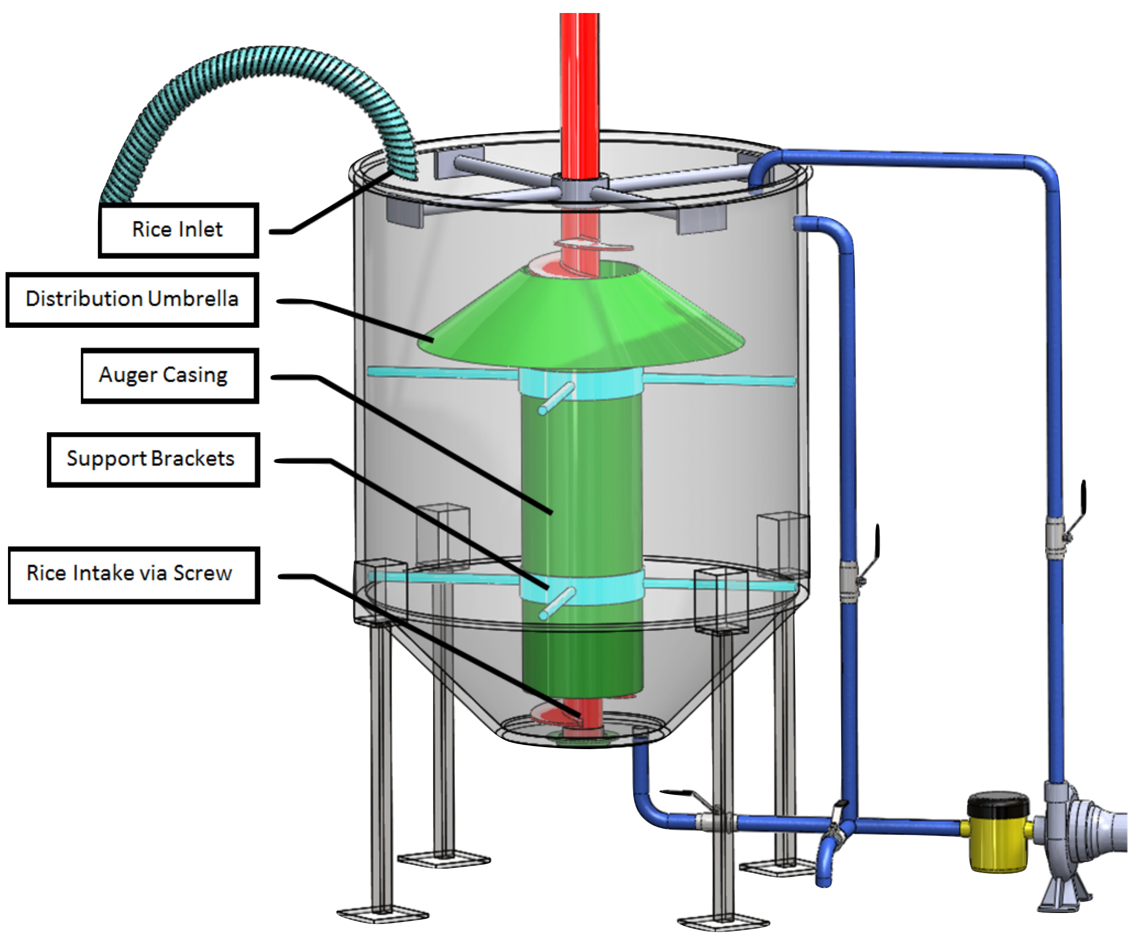

Figure 6.2.3 – Transparent container view

Auger Principle

With the rice in the container and the water level submerging the rice, the washing process was considered. The rice needs to be lifted vertically or rotated horizontally to create sufficient motion for the washing process. With a large amount of rice, estimated at 300 gallons, the torque required to rotate the rice water-mixture in a horizontal rotating motion is relatively low. However, this presents the problem that the rice is still densely compacted without much free space since the rotation does not create much separation between rice grains in the vertical direction.

On the other hand, if the rice is washed by lifting it vertically, there will be a more space for each individual grain of rice as it moves from the bottom of the container to the top. Implementing this idea however requires lifting not only the rice but taking on the additional load of lifting the water against the force of gravity as well. This would require a larger amount of torque.

As a solution, the rice in this design is circulated with the aid of an auger. An auger is a rotating helical screw which is capable of transporting a material within its groves. The auger will be placed into the center of the container and as it rotates, it intakes rice from the bottom and transports it upwards. In order for the rice not to slip off of the blades of the screw, there will be an outer casing closely fitted around the auger. The auger will only emerge and be exposed from its casing at two locations; 3 inches at the bottom for rice-water intake as well as 3 inches on the top where rice will be allowed to trickle back down. The auger now accomplishes two main goals. It rotates the rice vertically while greatly minimizing torque and stress on mechanical components. Making sure the auger remains concentric with the container is also an important feature.

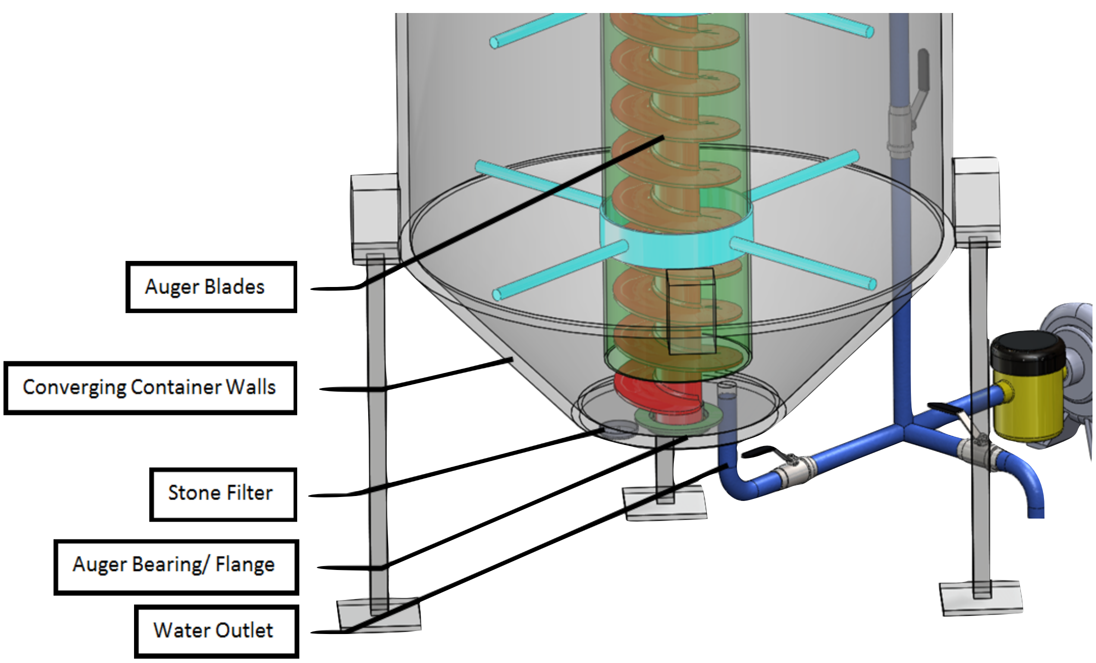

Figure 6.2.4 – Zoomed in view highlighting essential components

The upper and lower portions of the shaft leading to the auger blades will be secured to the container with ball bearings and support brackets. The bearing at the bottom of the container will include a water seal and a flange to hold it in place. The upper bearing will be held by a bracket extending to the inside walls of the container. This way the auger shaft will be allowed to rotate freely while being safely mounted.

Stagnation Prevention

Stagnation of rice, as previously mentioned, also needed to be minimized. Having the auger lift rice from the bottom center and expelling it again at the top center of the container creates localized movement of rice and water.

To combat the stagnation on the outer edges of the cylindrical container, an umbrella like sheet metal is placed around the top edge of the auger casing. This means that as the lifted rice falls away from the top 3 inches of the exposed auger blades, it will fall along the umbrella to the outer edges of the container. The umbrella and auger casing will be secured to the inside of the container by a set of support brackets. The umbrella feature adds an additional guided path for the rice as it completes the repeating cycle from top to bottom. The first, being the converging walls which feed the rice from the outer portions of the container to the bottom center for the auger. In addition the second, is the umbrella which moves the rice from the center back to the outer perimeter. These considerations will be sufficient in minimizing stagnation of rice.

Water Diffusion Consideration

After the washing process has been completed and the water has been drained from the vessel, any remaining moisture between the rice grains will be allowed to diffuse into the core of the grain overnight in a period of 16-18 hours. The current process of keeping 50 buckets of treated rice motionless is sufficient to provide homogeneous moisture content. However, when considering all 1,250 lb of rice in a large vessel, the hydrostatic pressure and increased heat development can cause the rice to ferment if left motionless throughout the night. In addition, the moisture from the higher laying rice may seep down, resulting in uneven moisture content between grains.

The auger presents an ideal solution to this problem because it may be operated continuously at low speeds after the water has been drained. The auger can rotate throughout the night to ensure that the rice has a homogeneous moisture content for it’s delivery to the cookers the next morning.

Washing Process Outline

The washing process is summarized by the sequence of the following steps. Figure 6.8.1 illustrates this process.

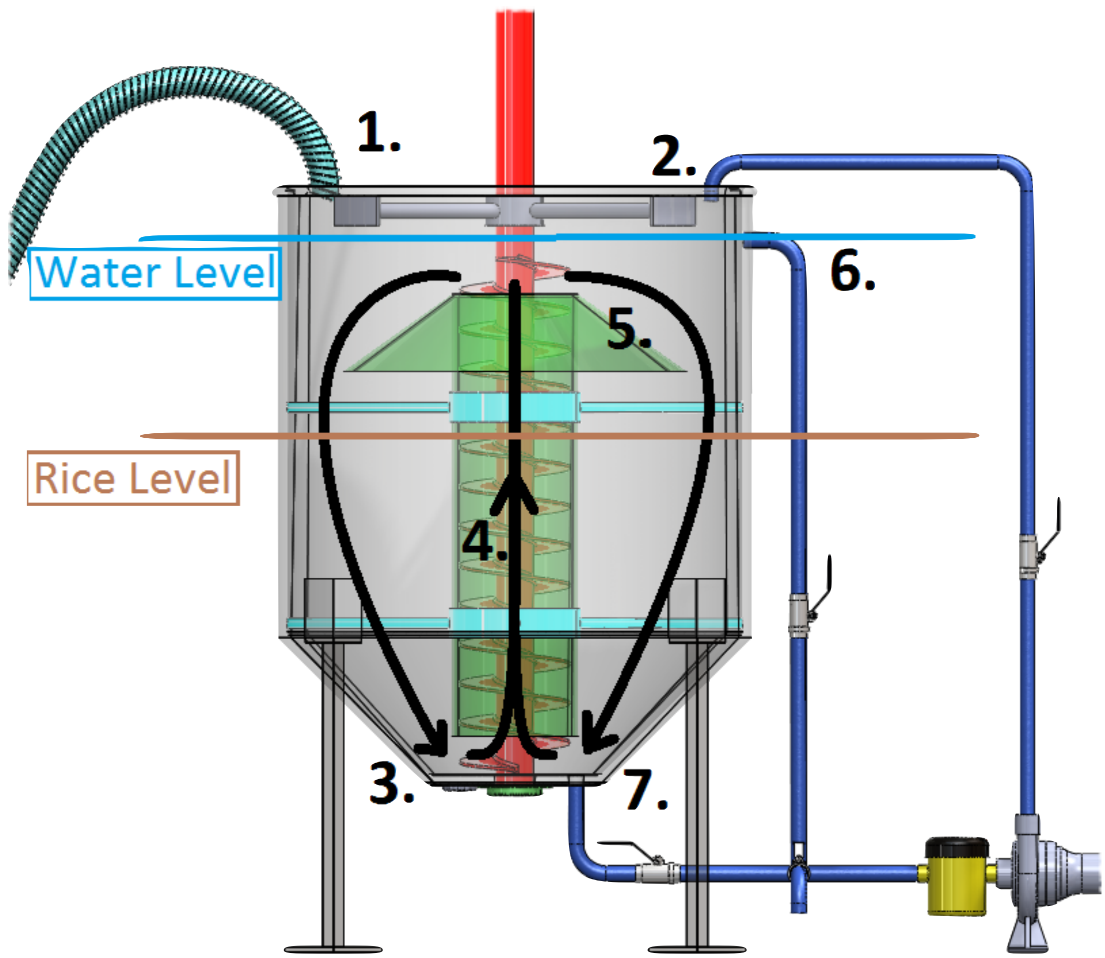

Figure 6.3.1 – Rice washing sequence

1. Rice addition via compressed air pump - Rice occupies 60% of the container
2. Water input - Water will submerge rice and fill container 80% up to debris skimmer
3. Auger rotates for rice intake - Screw blades lift water-rice mixture from the center
4. Cylindrical casing guides rice upwards
5. Umbrella distributes rice to outer edges
6. Surface skimmer removes rice debris - Due to low density, debris rises to water level
7. Water is drained after sufficient rice circulation
8. Auger continues rotating slowly overnight to ensure homogeneous moisture content in rice
9. Treated rice is removed from container, again using pneumatic conveyor

Power Requirement of Screw Conveyors

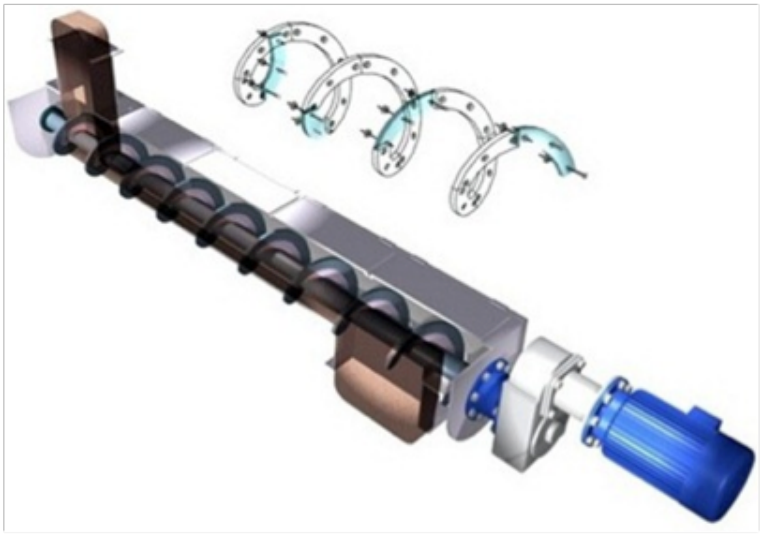

Figure 6.4.1: Illustration of force distribution on auger blades

The driving power of the loaded screw conveyor is given by:

$$P_{tot} = P_h + P_n + P_{st}$$

Where,

P_h = Power necessary for the progress of the material

P_n = Driving power of the screw conveyor at no load

P_{st} = Power requirement for the inclination of the conveyor

Power necessary for the progress of the material, P_h

For a length L of the screw conveyor (feeder), the power P_h in kilowatts is the product of the mass flow rate of the material by the length L and an artificial friction coefficient λ, also called the progress resistance coefficient.

$$P_h = \frac{\dot{m}\lambda L g}{3600}$$

Where,

$\dot{m}$= Mass flow rate in t/hr

λ = Progress resistance coefficient

L = Length of screw conveyor in meters = 48.5 in = 1.23 m

l = Length of one spiral = π(8in)/cos45 = 33 in = 0.838 m

g = Acceleration due to gravity = 9.81 m/s^2

D = Nominal diameter of screw = 12 in = 0.305 m

d = Diameter of screw shaft = 4 in = 0.102 m

The first step is making some general engineering assumptions in order to determine the mass flow rate through the auger. Rice is assumed to have the approximate density of water 1,000kg/m^3. However, once the rice is mixed with water and circulated through the system, the bulk mass reduces the density of the overall material to 700 kg/m^3. The auger is set to rotate at 60 RPM.

Thus,

$$\dot{m} = \frac{\pi}{4}\left(D^2 - d^2\right)(l)(\varrho)(RPM) = 2.28\ \frac{ton}{hr}$$

Each material has its own coefficient λ. The rice grain is given a value of around 7.5. In this connection it should be noted that the sliding of the material with itself gives rise to additional internal friction.

Therefore,

$$P_h = \frac{\dot{m}\lambda L g}{3600} = \frac{(2.28)(7.5)(1.23)(9.81)}{3600} = 0.0574\ kW$$

Drive power of the screw conveyor at no load, P_n

This power requirement is very low and is proportional to the nominal diameter and length of the screw.

$$P_n = \frac{DL}{20} = \frac{(0.305)(1.23)}{20} = 0.0187\ kW$$

Power due to inclination, P_{st}

This power requirement will be the product of the mass flow rate by the length of the vertical screw conveyor and the acceleration due to gravity, g. It is important to note that due to the back-flow of rice inside the screw conveyer, the mass flow for power due to inclination can safely be taken at half the original value.

$$P_{st} = \frac{\dot{m}Lg}{3600} = \frac{\left(\frac{2.28}{2}\right)(1.23)(9.81)}{3600} = 0.0038\ kW$$

H should be taken positive for ascending screws and will be negative for descending screws.

Total power requirement

The total power requirement is the sum of the above items.

$$P_{tot} = P_h + P_n + P_{st}$$

$$P_{tot} = 0.0574 + 0.0187 + 0.0038 = 0.0799\ kW$$

$$P_{tot} = 0.0799\ kW = 0.107\ hp$$

The power is delivered to the auger through a connecting gear speed reducer. Due to frictional forces the power transmission is set to be at 70%.

$$P_{tot} = \frac{0.107}{0.70} = 0.152\ hp$$

Taking a safety factor of 2.5 into consideration, the total power required the system is:

$$P_{tot} = (0.152)(2.5) = 0.38\ hp$$

The nearest suitable motor is 0.5 HP type TEFC.

A standard motor operates at 1,750 RPM. Therefore, a speed reducer with a gear ratio of 10:1 will be installed at the output of the motor. The motor speed will be controlled by a variable frequency drive which will have adjustable torque limit and will allow the system to operate between 60 and 180 RPM. The overall control of the system such as timing, water supply and draining will be provided by a programmable linear controller (PLC). (Siemens, Symantec or equivalent.)

Conclusion

Final Recommendations

Value engineering methodology was used to analyze the existing process in terms of time, labour, and ergonomics. This led to identification of several possible areas for potential savings and generation of proposals to improve the rice cake preparation process. A comparative analysis between the different proposals was conducted, which led to the conclusion that the vertical auger offers the best value and provides the client with the requested functions.

If implemented, this solution will eliminate physical labour, reduce required labour hours, and provide Koyo Foods with significant cost savings compared to the existing process. Physical labour such the lifting of 25 lb. buckets over the head and the carrying of 50 lb. rice bags which leads to repetitive physical strain will be eliminated through the implementation of the vertical auger proposal. This will thus minimize the risk of accidents and injuries of the worker. This proposal has a convenient payback period of 1.9 years as well as an excellent return on investment of 53%.

Thus, the team recommends the vertical auger proposal.

Appendix 1

Cost Analysis

Table A.1.1: Time-cost analysis for present process

Components	Treat Rice	Supply rice to cooker	Ensure quality	Protect Worker	Ensure reliability	Total	Component Worth
Mixing to homogenize			0:30:00	0:00:00	0:00:00		
Machine warm up / initial filling / split into 2 buckets for less weight		0:07:30		0:07:30			
Refilling Hoppers / day		1:00:00					
Cut & Empty bag	0:37:30						0:37:30
Lift bucket into sink	0:16:42						0:08:00
Fill bucket with hose	0:16:42						0:05:00
Mixing	0:25:00						0:05:00
Put on lid and flip	0:12:30						0:03:00
Drain	2:05:00						0:01:00
Flip back / remove lid / carry back to loading area	0:41:42						0:00:00
Function cost	4:35:06	1:07:30	0:30:00	0:07:30	0:00:00	6:20:06	
	72.4%	17.8%	7.9%	2%	0%	100%	0%
Function worth	25%	10%	5%	5%	10%		
Function worth time	0:59:30	0:38:00	0:19:00	0:19:00	0:38:00	2:53:31	
Value index	4.62	1.78	1.58	0.39		2.19	

Table A.1.2: Time-cost analysis for auger with compressed air delivery

Components	Treat Rice	Supply rice to cooker	Ensure quality	Protect Worker	Ensure reliability	Total	Component Worth
Mixing to homogenize			0:00:00	0:00:00	0:00:00		
Machine warm up / initial filling		0:15:00					
Refilling Hoppers / day		0:45:00					
Cut & Empty bag	1:00:00						1:00:00
Lift bucket into sink	0:00:00						0:08:00
Fill Large Vessel with water	0:05:00						0:05:00
Mixing	0:00:00						0:05:00
Put on lid and flip	0:00:00						0:03:00
Drain	0:05:00						0:01:00
Flip back / remove lid / carry back to loading area	0:00:00						0:00:00
Function cost	1:10:00	1:00:00	0:00:00	0:00:00	0:00:00	2:10:00	
	53.8%	46.2%	0%	0%	0%	100%	0.0%
Function worth							
Function worth time	0:59:30	0:38:00	0:19:00	0:19:00	0:38:00	2:53:31	
Value index	1.18	1.58				0.75	

Table A.1.3: Time-cost analysis for vertical concept with venturi

Components	Treat Rice	Supply rice to cooker	Ensure quality	Protect Worker	Ensure reliability	Total	Component Worth
Mixing to homogenize			0:00:00	0:00:00	0:00:00		
Machine warm up / initial filling		0:15:00					
Refilling Hoppers / day		0:45:00					
Cut & Empty bag	1:00:00						1:00:00
Lift bucket into sink	0:00:00						0:08:00
Fill Large Vessel with water	0:05:00						0:05:00
Mixing	0:00:00						0:05:00
Put on lid and flip	0:00:00						0:03:00
Drain	0:05:00						0:01:00
Flip back / remove lid / carry back to loading area	0:00:00						0:00:00
Function cost	1:10:00	1:00:00	0:00:00	0:00:00	0:00:00	2:10:00	
	53.8%	46.2%	0.0%	0.0%	0.0%	100.0%	0.0%
Function worth							
Function worth time	0:59:30	0:38:00	0:19:00	0:19:00	0:38:00	2:53:31	
Value index	1.18	1.58				0.75	

Table A.1.4: Time-cost analysis for single container manual

Components	Treat Rice	Supply rice to cooker	Ensure quality	Protect Worker	Ensure reliability	Total	Component Worth
Mixing to homogenize			0:30:00	0:00:00	0:00:00		
Machine warm up / initial filling / split into 2 buckets for less weight		0:15:00		0:07:30			
Refilling Hoppers / day		1:00:00					
Cut & Empty bag	0:37:30						0:37:30
Lift bucket into sink							0:08:00
Fill bucket with hose	0:16:42						0:05:00
Mixing	0:25:00						0:05:00
Put on lid and flip							0:03:00
Drain	2:05:00						0:01:00
Flip back / remove lid / carry back to loading area							0:00:00
Function cost	3:24:12	1:15:00	0:30:00	0:07:30	0:00:00	5:16:42	
	64.5%	23.7%	9.5%	2.4%	0.0%	100.0%	
Function worth							
Function worth time	0:59:30	0:38:00	0:19:00	0:19:00	0:38:00	2:53:31	
Value index	3.43	1.97	1.58	0.39		1.83	

Table A.1.5: Time-cost analysis for horizontal with incline tank under

Components	Treat Rice	Supply rice to cooker	Ensure quality	Protect Worker	Ensure reliability	Total	Component Worth
Mixing to homogenize			0:30:00	0:00:00	0:00:00		
Machine warm up / initial filling / split into 2 buckets for less weight		0:15:00					
Refilling Hoppers / day		1:30:00					
Cut & Empty bag	0:37:30						0:37:30
Lift bucket into sink							0:08:00
Fill bucket with hose							0:05:00
Mixing							0:05:00
Put on lid and flip							0:03:00
Drain							0:01:00
Start-up	0:10:00						0:00:00
Function cost	0:47:30	1:45:00	0:30:00	0:00:00	0:00:00	3:02:30	
	20.0%	30.8%	9.5%	2.4%	0.0%	100.0%	
Function worth							
Function worth time	0:59:30	0:38:00	0:19:00	0:19:00	0:38:00	2:53:31	
Value index	0.63	2.57	1.58	0.39		0.99	

Table A.1.6: Time-cost analysis for multiple vessels

Components	Treat Rice	Supply rice to cooker	Ensure quality	Protect Worker	Ensure reliability	Total	Component Worth
Mixing to homogenize			0:30:00	0:00:00	0:00:00		
Machine warm up / initial filling / split into 2 buckets for less weight		0:15:00					
Refilling Hoppers / day		0:45:00					
Cut & Empty bag	0:37:30						0:37:30
Lift bucket into sink							0:08:00
Fill bucket with hose							0:05:00
Mixing							0:05:00
Put on lid and flip							0:03:00
Drain							0:01:00
Start-up	0:10:00						0:00:00
Function cost	0:47:30	1:00:00	0:30:00	0:00:00	0:00:00	2:17:30	
	11.8%	30.8%	9.5%	2.4%	0.0%	54.5%	
Function worth							
Function worth time	0:59:30	0:38:00	0:19:00	0:19:00	0:38:00	2:53:31	
Value index	0.63	2.57	1.58	0.39		0.99	

Table A.1.7: Detailed equipment-cost comparison

Component	Rice delivery via compressed air	Vertical Auger		Venturi		Horizontal	Multiple Vessels	Single Container Manual
		Basic	With rice delivery	Basic	With rice delivery			
Drive	$0	$750	$750	$0	$0	$750	$2,250	$0
Controls	$250	$1,500	$1,750	$1,500	$1,750	$2,500	$2,000	$0
Vessel	$0	$5,000	$5,000	$5,000	$5,000	$4,500	$1,000	$0
Screw conveyor	$0	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$0
Water recalculating pump	$0	$500	$500	$1,000	$1,000	$100	$500	$0
Water valves and piping	$0	$600	$600	$600	$600	$600	$1,500	$500
Interior of vessel, baffles, etc	$0	$2,000	$2,000	$2,000	$2,000	$0	$6,500	$0
Mechanics of the screw conveyor	$0	$2,500	$2,500	$0	$0	$2,000	$2,000	$0
Multiple vessels	$0	$0	$0	$0	$0	$0	$9,500	$0
Structural, stand, brackets, etc	$100	$2,000	$2,100	$450	$550	$3,000	$6,500	$1,200
Air pump and flex. hoses	$200	$1,000	$1,200	$6,000	$6,200	$500	$1,500	$500
Rice/air separator	$500	$500	$1,000	$500	$1,000	$500	$1,500	$500
Large rice retainer	$0	$0	$0	$0	$0	$2,500	$0	$2,500
Water drainage and recovery	$0	$0	$0	$0	$0	$1,800	$3,200	$0
Engineering design ($70.00/hr)	$1,400	$10,500	$11,900	$8,000	$9,400	$17,500	$21,000	$3,500
Assembly, testing and commissioning		$10,000	$10,000	$7,000	$7,000	$12,000	$15,000	$1,000
Total	$2,450	$38,350	$40,800	$33,550	$36,000	$49,750	$75,450	$9,700

Concept Comparisons

Table A.1.8: Equipment cost comparison

Criteria	Weight	Auger	Horizontal	Multiple Vessels	Venturi	Manual
Safety and Ergonomics		9	6	6	8	4
	7	63	42	42	56	28
Degree of Automation		8	6	6	8	0
	9	72	54	54	72	0
Minimize Maintenance Cost		6	7	5	5	8
	7	42	49	35	35	56
Moisture Consistency		8	7	7	4	6
	8	64	56	56	32	48
Ease of Operating System		8	6	6	5	5
	7	56	42	42	35	35
Ease of Cleaning		7	7	7	6	8
	6	42	42	42	36	48
Tidiness and Packaging		7	5	4	7	6
	3	21	15	12	21	18
Processing Time Saved		9	7	7	8	5
	9	81	63	63	72	45
Total		441	363	346	359	278
Equipment Cost ($1000's)		40.8	49.75	75.45	36	9.70

Table A.1.9: Time cost comparison

Criteria	Weight	Auger	Horizontal	Multiple Vessels	Venturi	Manual	Present
Safety and Ergonomics		9	6	6	9	4	2
	7	63	42	42	63	28	14
Degree of Automation		8	6	6	8	0	0
	9	72	54	54	72	0	0
Minimize Maintenance Cost		6	7	5	6	8	10
	7	42	49	35	42	56	70
Moisture Consistency		8	7	7	4	6	4
	8	64	56	56	32	48	32
Ease of Operating System		8	6	6	7	5	4
	7	56	42	42	49	35	28
Ease of Cleaning		7	7	7	6	8	4
	6	42	42	42	36	48	24
Tidiness and Packaging		7	5	4	7	6	2
	3	21	15	12	21	18	6
Cost		5	4	2	6	9	10
	4	20	16	8	24	36	40
Total		380	316	291	339	269	214
Labour Cost ($1000's)		13.67	17.35	14.32	13.67	29.85	35.33

Table A.1.10: Combined cost comparison

Criteria	Weight	Auger	Horizontal	Multiple Vessels	Venturi	Manual	Present
Safety and Ergonomics		9	6	6	9	4	2
	7	63	42	42	63	28	14
Degree of Automation		8	6	6	8	0	0
	9	72	54	54	72	0	0
Minimize Maintenance Cost		6	7	5	6	8	10
	7	42	49	35	42	56	70
Moisture Consistency		8	7	7	4	6	4
	8	64	56	56	32	48	32
Ease of Operating System		8	6	6	7	5	4
	7	56	42	42	49	35	28
Ease of Cleaning		7	7	7	6	8	4
	6	42	42	42	36	48	24
Tidiness and Packaging		7	5	4	7	6	2
	3	21	15	12	21	18	6
Processing Time Saved		9	7	7	9	5	10
	9	81	63	63	81	45	40
Total		441	363	346	396	278	214
Annual Cost ($1000's)		27.27	33.93	39.47	25.67	33.09	35.33

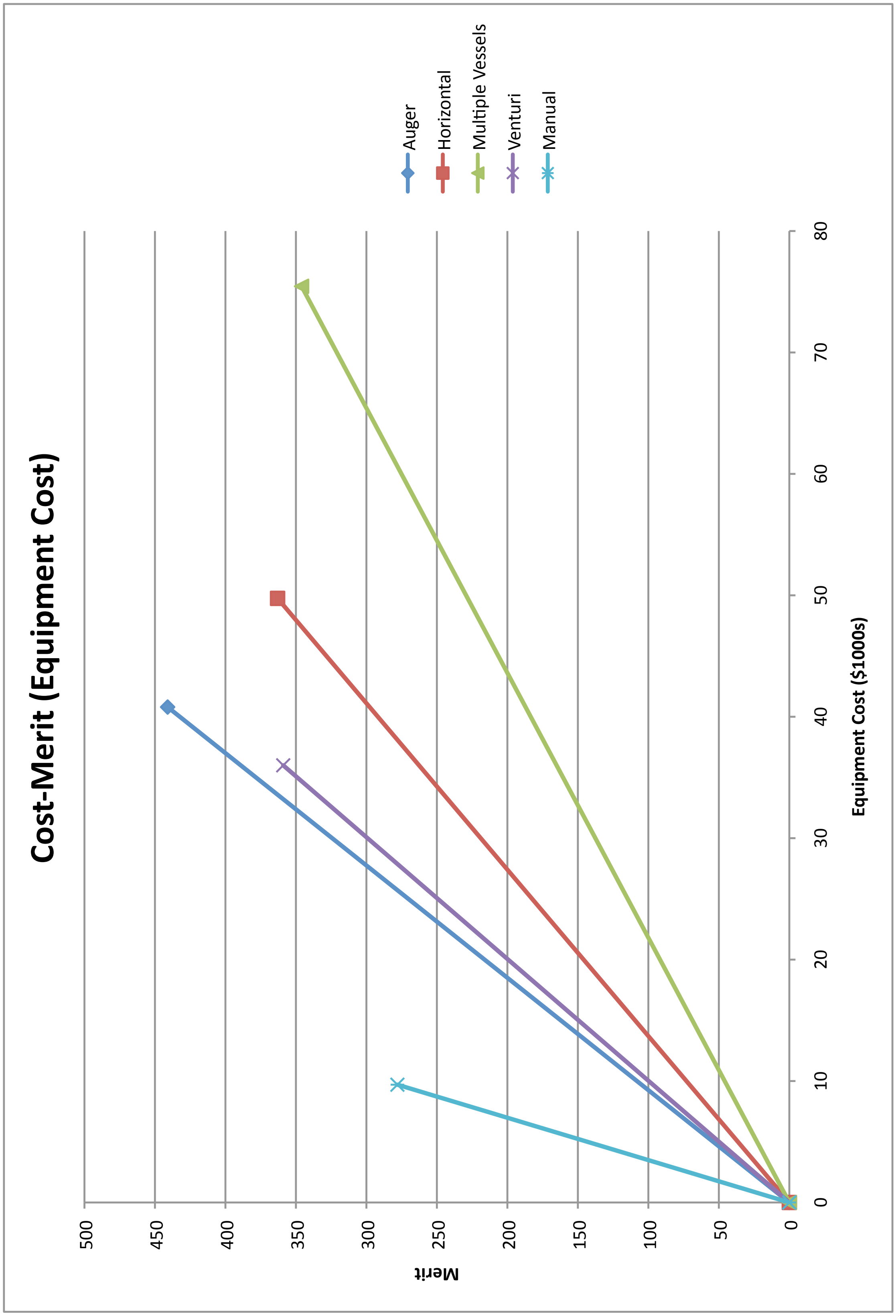

Figure A.1.1: Equipment cost-merit graph

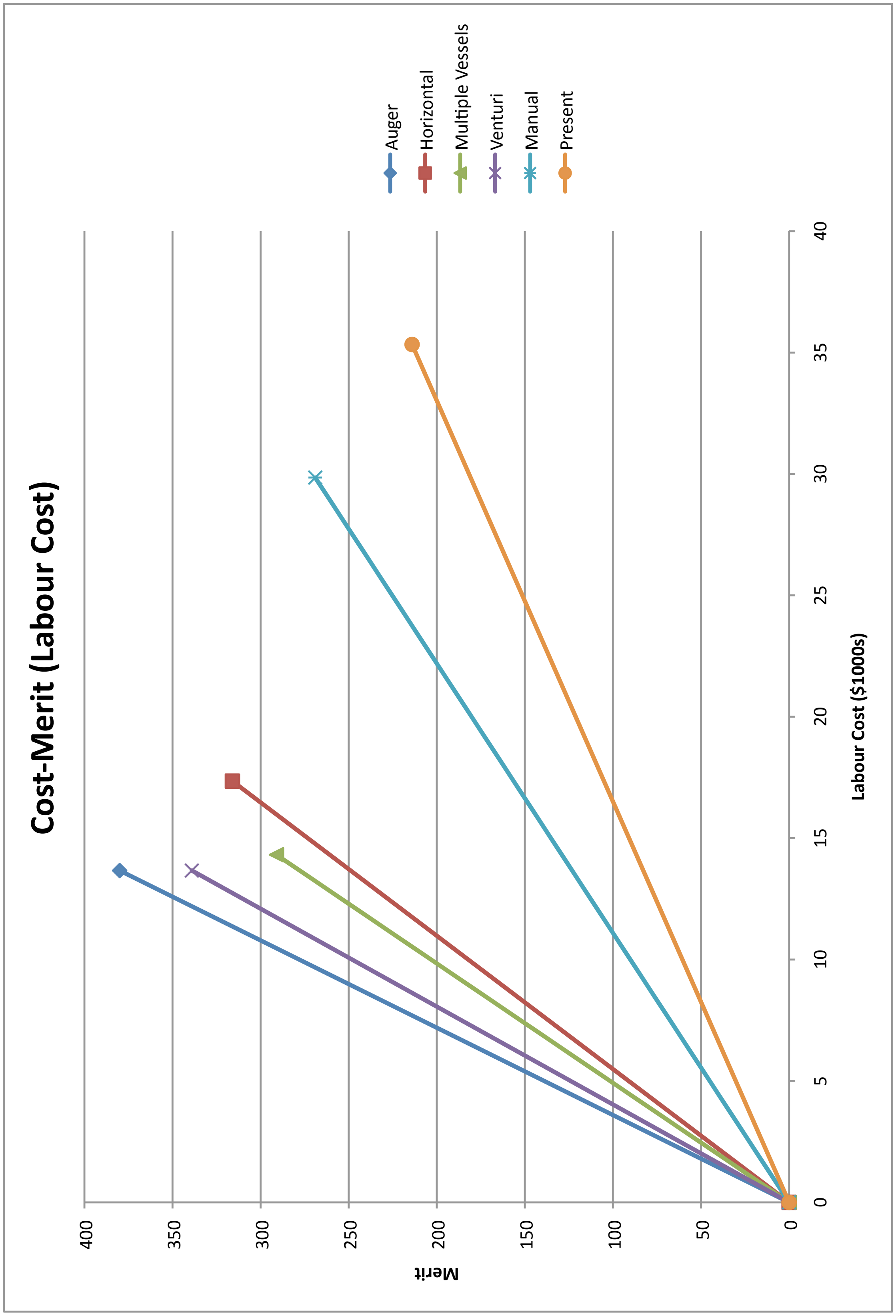

Figure A.1.2: Time cost-merit graph

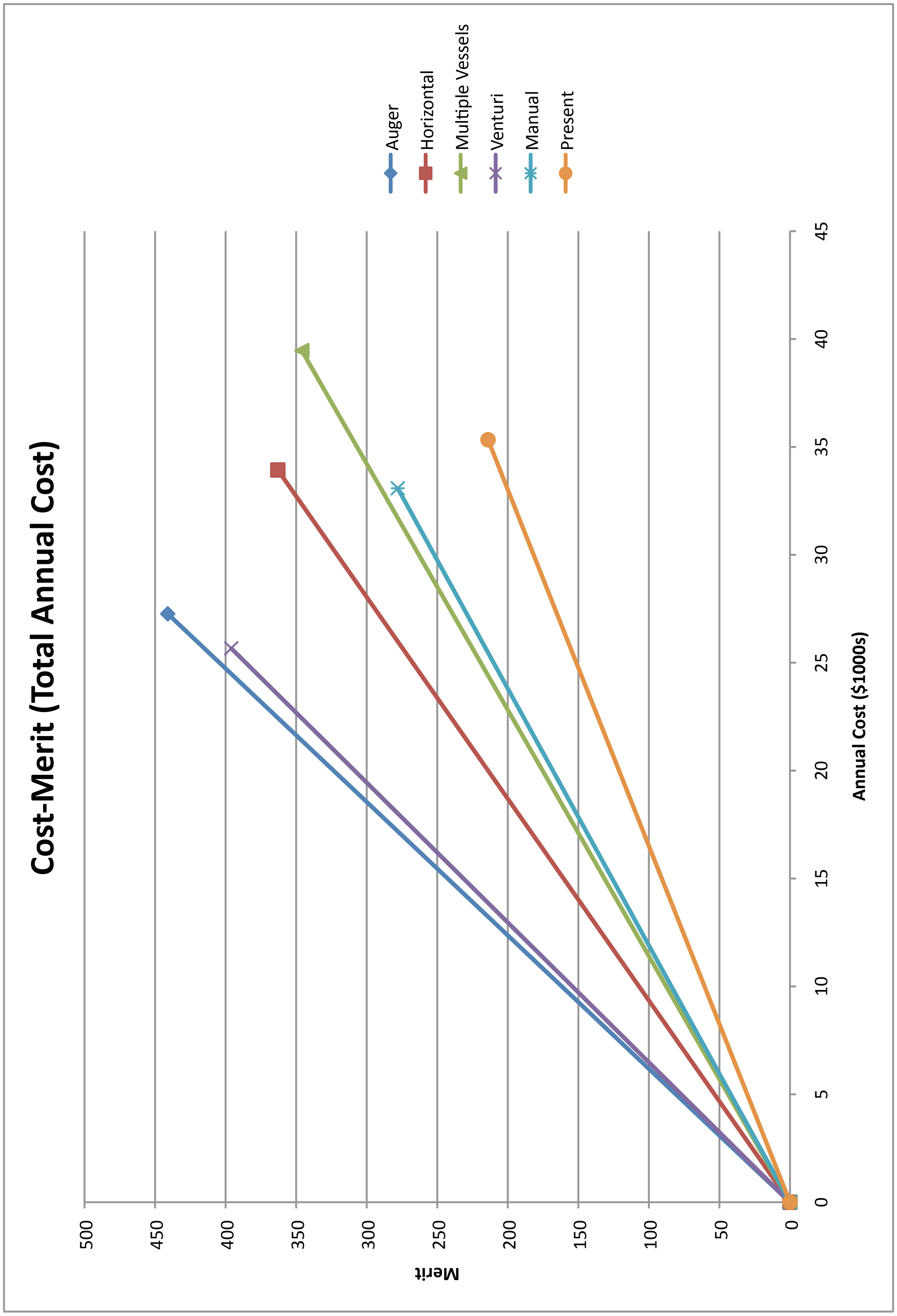

Figure A.1.3: Combine cost-merit graph

Appendix 2

Creativity Methods

Gut Feel Index

Table A.2.1: Gut feel index

Function	Idea	Gut feel index
Cut rice bag	Knife/saw.	1
	Scissors.	2
	Conveyor belt/cutting device.	6
Fill container with rice	Pour rice from open bags into a conveyor belt that conveys the rice into a big container	6
	Vacuum tube/Pressure suction device used to transfer the rice into a big container	10
Add water to rice	Pour rice into container filled with water.	6
	Pour rice into container, water will be sprayed.	6
	Move rice to container with water in pipe.	8
	Water jet from bottom of container.	7
	Water jet into the container where rice is being collected with a screw mixing rice/water in the container.	9
	Small containers being filled with water from bottom	2
Stir water and rice	Use of propellers / giant screw.	9
	Use water jets.	7
	Manually by a lever/use a fly wheel.	2
	Spin or shake container.	2
Drain water from rice-water mixture	Water drains out of 'seive-bottom' container	9
	Pipe outlet at the bottom of container	9
	Pump water out of container.	6
	Big flat area to dry the rice grains, ventilated.	6
Allow homogenous moisture absorption into rice grains	Leave rice overnight in container for 16-24 hours.	9
	Continuos and slow mixing of rice overnight.	10
	Control room temperature/humidity/pressure	9
Take rice sample	Inspection by physical touch	6
	Hygrometer device for measurement	6

Function	Idea	Gut feel index
Unload rice into hopper	Rice is transported to an elevated container, by a conveyor belt, then to the hoppers through a declined ramp.	4
	Rice delivery with compressed air/pressure device	10
	Use trolley/conveyor belt to move small containers closer to hoppers.	2
	Elevate rice buckets and use ramps.	7
	Use paddles to elevate rice to container level and then by the use of flexible hoses, rice is distributed to the hoppers	9