RYERSON UNIVERSITY

Faculty of Engineering and Architectural Science

Department of Mechanical and Industrial Engineering

Course Number	IND 400
Course Title	Facilities Design
Semester/Year	Winter 2021
Instructor	Arya Russell

Final Project Report

Report Title	IND 400 Project

Section No.	2
Submission Date	April 11th, 2021
Due Date	April 11th, 2021

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ABSTRACT

The objective of this report is to identify and apply key facility design techniques to a production facility to increase the output in the plant and reduce transportation costs. Specifically, Glengarry Cheesemaking, a cheese manufacturing facility, was selected and investigated to determine changes that could be implemented to optimize the production line. Analysis was conducted on the machinery used in the workplace, its placement, as well the cost/benefit of introducing additional workers and machinery to improve the line. Various alternative concepts were considered, and Concept 3 was selected for its optimal production and minimize cost. The current process produces 450lb of cheese everyday and the cost per pound of cheese was determined to be $1.78. Concept 3 on the other hand was determined to produce 900lb of cheese every day with a cost per pound of 1.50. Based on analysis, though the implementation of Concept 3 was determined to cost an excess of $109,289 as compared to the original design, it was determined after 162 days, the facility would break even on its investment and save money thereon.

TABLE OF CONTENTS:

INTRODUCTION

The production of cheese is an intricate process that follows a number of simple steps. Cheese has been produced for over 4000 years but has been gradually optimized over the last couple of centuries ever since the industrial revolution.

This project will be looking at the facility design of a cheese making factory which produces for a certain niche of cheese enthusiasts with high quality that is produced only at the location being worked on. The factory is a boutique producer which prefers quality over quantity. Many times blocks of cheese would be disregarded if standards are not met up to par. This will be kept in mind when designing the alternative facilities. The current process requires a lot of manual labor and does not utilize several machines that are employed in other factories. It also has unfavourable transportation costs, all of which could be improved to optimize the facility.

This report will go over the existing design by explaining the current process, the cost of manufacturing plus equipment and the output of the system. After that, the several other design alternatives will go experience the same analysis that the original design experienced. Once all the designs are properly explained, they will all be compared. Several aspects of the designs will be compared such as the physical load, total amount of cheese produced, the cost of the equipment, the time it takes to produce the cheese and several other aspects. Several in depth calculations will be used to determine which parts can be improved upon.

OBJECTIVE

The goal of this project is to improve several aspects of the cheese making process occurring in a manufacturing facility. Ideally the redesign of the layout would allow for increase in the output of cheese produced, lowered costs, as well as shortened amount of time for the process to run its cycle. This will be done by optimizing the layout of the facility to lessen how much the employees need to move around to decrease transportation and increase production. Other methods of improvement that result in optimization will also be investigated, whilst considering the implementation and working costs associated with them. Such considerations may range from minor relocations of the machinery to completely redesigning it.

When considering a facility design under a general approach, a good design is one that will accurately depict the current state of a facility and underline the relevant factors and parameters necessary for the process being executed to be improved. Factors such as resource availability (i.e. rennet, machine parts, tuing, etc.), space requirements necessary for housing essential machines for operations (i.e. pasteurizer size, VAT size, table size, etc.), material handling solutions (i.e. the heating and cooling of cheese within the process), and racking/storage system requirements (i.e. how much storage space is required for the necessary materials) would be considered. A good design would encompass all these factors and aim to fulfill each requirements respective demand whilst also considering worker safety and relevant operational costs (i.e. transportation and other relevant variables)

RESULTS

*Calculations used to find time can be found in the Appendix under "Assumptions"

Original Design

The current design as shown in Figure 1.2 was obtained from Glengarry Cheesemaking from Lancaster, ON. This layout depicts a small cheese making factory where only 150lbs of cheese is produced every time the process is completed. On a daily basis, the cheese making process is completed 3 times, resulting in the production of 450lbs of cheese.

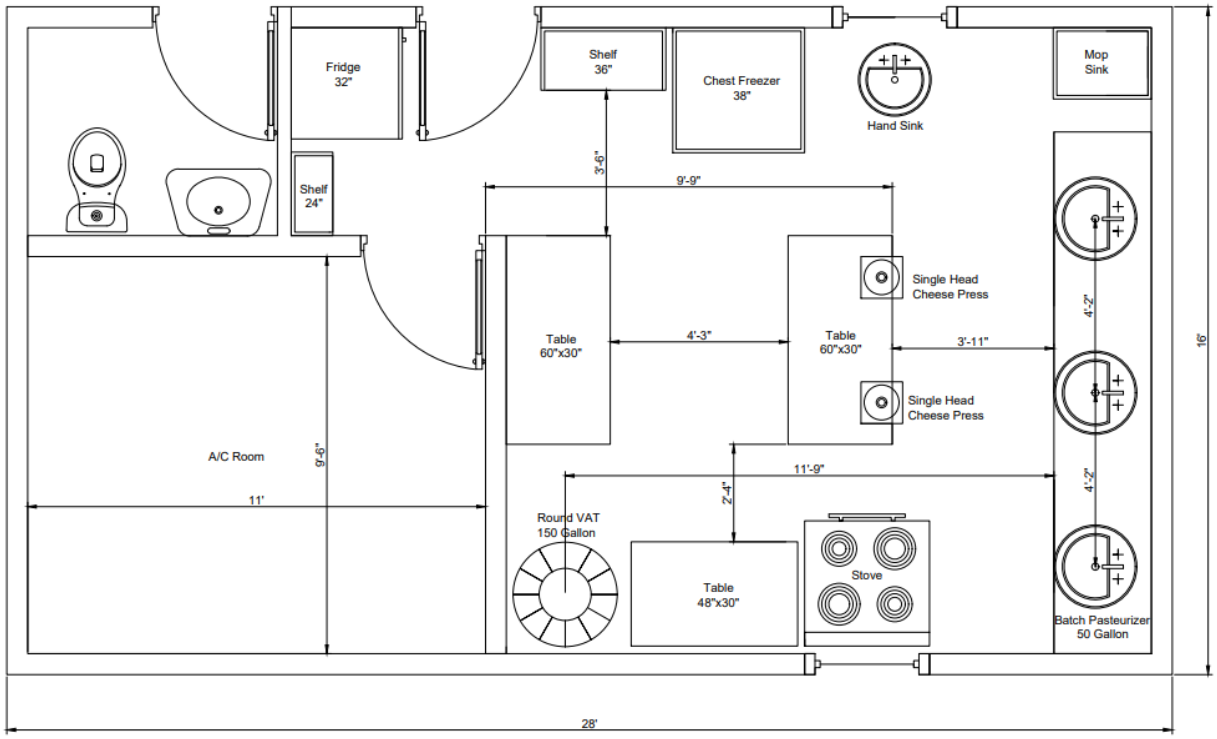

Figure 1.1: Layout of Original Design

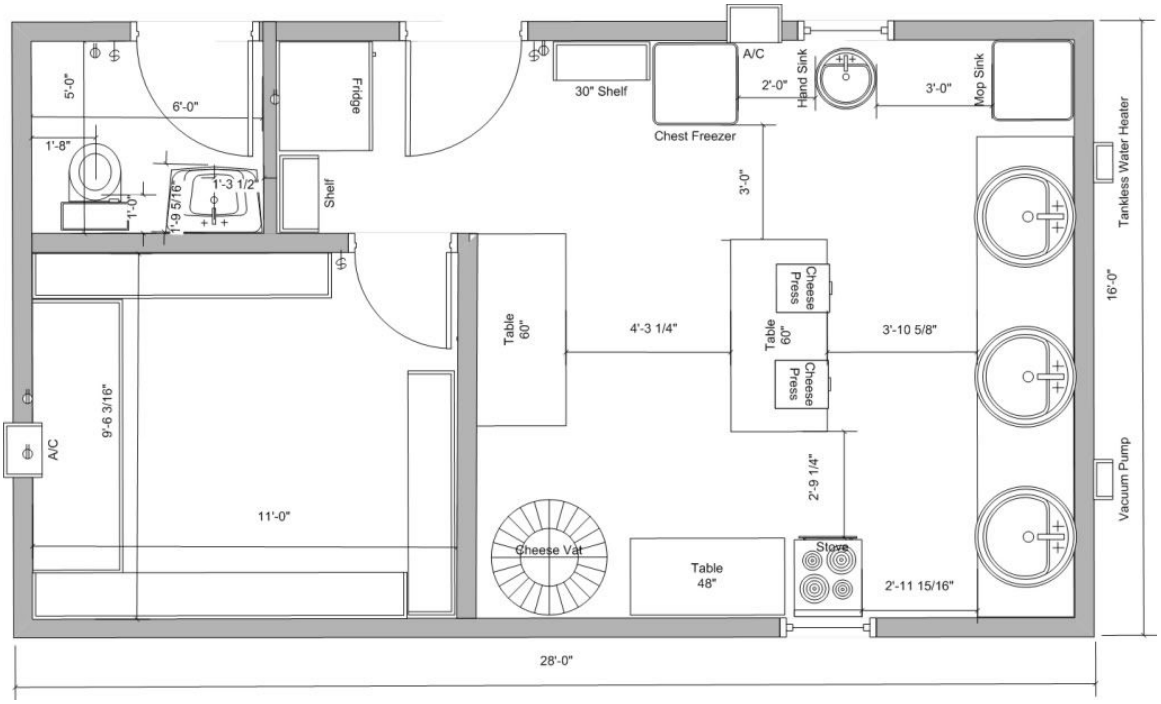

Figure 1.2: Layout of Original Design as received from Glengarry Cheese making

Table 1.1: Cost of Facility Items for the Original Design

Qty	Item	Price
3	50 gallon open top batch pasteurizer [1]	$16,575
1	150 gal cheese round cheese VAT with pmo [2]	$27,275
2	Single Head Vertical A-Frame Cheese Press [3]	$3,500
1	48”x 30” table [4]	$788
2	60”x 30” table [5]	$857
1	38” Chest freezer [6]	$1,699
1	24” shelf [7]	$266
1	36” shelf [8]	$234
1	32” Fridge [9]	$1,840
1	Stove [10]	$4,099
60	Bucket [11]	$453

2	Annual Worker Salary [12]	$33,150
	TOTAL:	$159,700

The current layout represents a small cheese making factory consisting of two workers. The work process requires two workers to transport pasteurized milk in buckets to the VAT. After this is complete, they monitor the churning process. The workers are responsible for adding the flavour to the cheese by mixing various cultures, rennet, and seasoning during the standard 30 minutes it takes to churn. As the cheese forms curds, the workers hand compress the cheese curds at the table and place them in buckets. Following this, both workers compress the curds even further by using a cheese press and ultimately store the final product in the A/C room to age.

Original Design Layout Process:

1) Pasteurized milk is extracted from the vacuum pump into buckets
2) The buckets are emptied out into the VAT
3) Grab rennet, culture, and seasoning, to add to the milk in the VAT
4) After curds are formed in the VAT, transfer them over to a table
5) After hand compressing the curds, put it in the cheese press
6) Move the pressed cheese to the A/C room to age

Table 1.2: Flow Process Chart of Original Layout

Process	Distance (ft-inch)	Time per longest worker (min)	Symbol	Description
Milk enters pasteurizers		4.167 min		150 Gallons (50 gallons per pasteurizer)
Fill buckets with pasteurized milk		34.09 min		Bucket is filled up to 2.5 gallons, each worker must fill 30 buckets
Transport bucket to VAT	11’9” - 20’1”	4.57 + 5 min		2 workers are required to do 30 trips from pasteurizer to VAT
Churn the milk		40 min		Worker will start churning process
Inspect milk		-		Worker will inspect the VAT process and inspect the cheese curd
Transport ingredients from shelf to the VAT	10’10”	-		Worker will bring ingredients from the shelf to mix into the milk

Mixes the ingredient		-		Worker will mix the needed ingredients into cheese mixture
Inspect ingredients are in		-		Worker inspects that the necessary ingredients are being mixed
Transport ingredients back to the shelf	10’10”	-		Worker puts ingredients back in the shelf
Inspect milk		-		Worker will inspect the VAT process and inspected the cheese curds after completed
Fill bucket with curds		6.82 min		Workers fill buckets with 75 lbs of curds[1]
Empty curds at table	2’4”	0.54 +5 min		Workers will do 30 trips back and forth[2] to empty the curds onto the table
Compress the curd		56.82 min		Workers will hand compress 75 lbs of curds into larger form
Fill up compressed curd in a bucket		6.82 min		Workers will fill 75 lbs of compressed curds into bucket
Move compressed curd to Cheese Press	4’3” - 6’9”	1.54 + 5 min		Workers will transport all the buckets to the cheese press table within 30 trips
Press the cheese in the bucket		60 min		Each worker uses cheese press used to further compress 30 buckets of cheese curds in the bucket
Transport pressed cheese to A/C room	9’9” - 24’3”	5.52 + 5 min		Workers moves 30 buckets of the pressed cheese curds to the A/C room
Store pressed cheese		-		Worker places the pressed cheese to age in the A/C room

Total Time: 240.89 Minutes
Work Day: 12 Hours
Number of Processes: 3
Lbs of Cheese Produced: 450lbs/day

[1] 1 gallon of milk produces 1 lb of curd
[2] Each bucket holds 5lbs of curds

Concept 1

This design was inspired by reducing the stress placed on workers, both physically and mentally, by implementing tools to assist with the work process. The objective of this concept is to reduce physical strain on the workers by using high end tools and creating a layout that will assist in reducing possible slips/lapse that can occur.

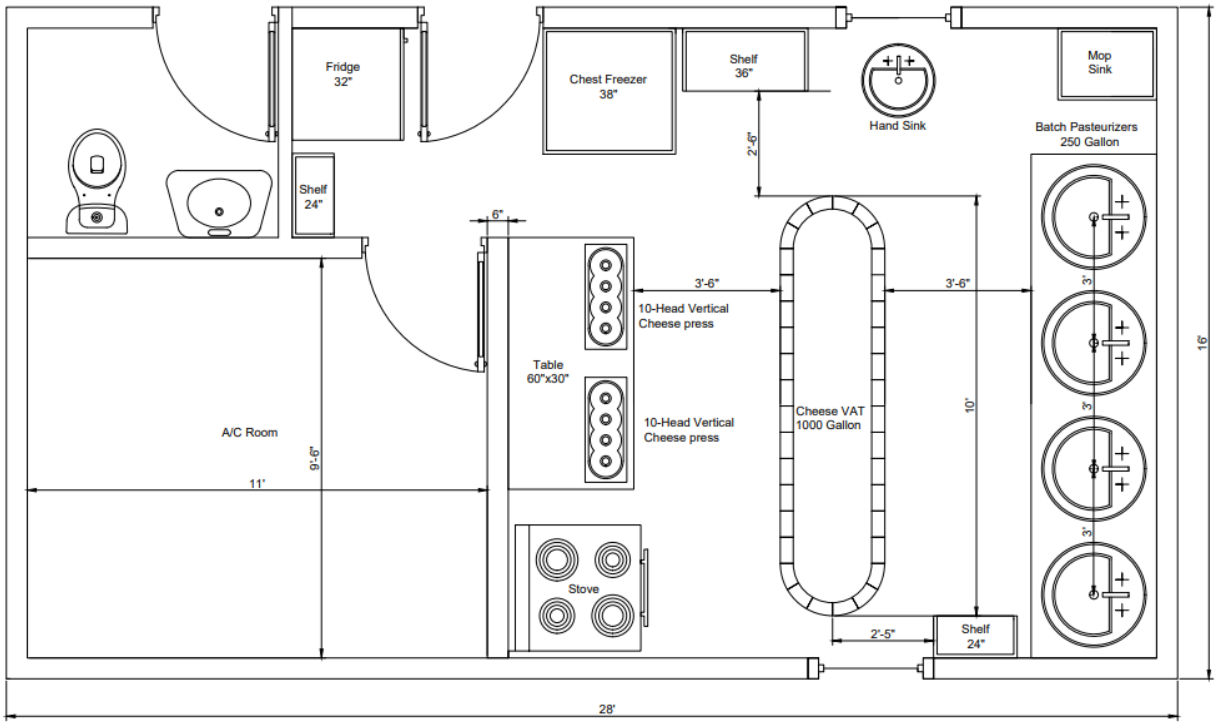

Figure 2: Layout of Concept 1

Table 2.1: Cost of Facility Items for Concept 1

Qty	Item	Price
4	250 gallon open top batch pasteurizer [1]	$22000
1	1000 gal cheese VAT [2]	$50450
2	10-Head Vertical A-Frame Cheese Press [3]	$18500
1	60”x 30” table [5]	$857
1	38” Chest freezer [6]	$1,699
2	24” shelf [8]	$266
1	36” shelf [8]	$234

1	32” Fridge [9]	$1,840
1	Stove [10]	$4,099
400	Bucket [11]	$3020
4	Annual Worker Salary [12]	$33,150
	TOTAL:	$320,331

This concept uses four 250 gallon pasteurizers. The pasteurized milk from these four pasteurizers are transported in buckets to the new VAT that will hold 1000 gallons of cheese. Additional shelves have been implemented into this layout as higher quantities of cheese are being produced, requiring more ingredients and ultimately requiring more room to store these ingredients. Changes to the layout were made to ensure that the workers will require less walking from station to station while also having a linear process. Lastly, one adjustment made to the process was that the curds will now be hand compressed inside the massive VAT instead of having to remove the cheese from the original VAT to a table and then to the cheese press. Now, the cheese will go straight from the VAT to the cheese press, ultimately reducing the transportation for workers.

This workstation requires 4 workers. Each of the 4 workers would transport pasteurized milk in buckets to the VAT, where the automated churning process takes place. 2 of the workers would monitor the process while 2 others get ingredients to put in the milk. After curds have been formed, all the workers would hand compress within the VAT, as this VAT design allows for it. Following this, the hand compressed curds would be transported by 2 workers to the cheese press where the other 2 workers would use the 10 head vertical cheese press to further compress. While those 2 workers are using the cheese press, the other 2 workers would reset the factory for another process after they are done transporting all the buckets. After all the buckets full of cheese have been compressed, all 4 workers would transport the cheese to the A/C room to age.

Concept 1 Layout Process:

1) Pasteurized milk is extracted from the vacuum pump into buckets
2) The buckets are emptied out into the VAT
3) Grab rennet, culture, and seasoning, to add to the milk in the VAT
4) Hand compress curds formed in the VAT
5) After hand compressing the curds, put it in the cheese press
6) Move the pressed cheese to the A/C room to age

Table 2.2: Flow Process Chart of Concept 1

Process	Distance (ft-inch)	Time per longest worker	Symbol	Description
Milk enters pasteurizers		20.835 min		1000 Gallons (250 gallons per pasteurizer)
Fill bucket with pasteurized milk		113.64 min		Each worker fills 100 bucket is filled up to 2.5 gallons
Transport bucket to VAT	3’6”	2.66 + 16.67 min		Each worker is required to do 100 trips from pasteurizer to VAT
Churn the milk		40 min		Workers will start churning process
Inspect milk		-		Workers will inspect the VAT process and inspect the cheese curd
Transport ingredients from shelf to the VAT	2’5”-2’6”	-		Workers will bring ingredients from the shelf to mix into the milk
Mixes the ingredient		-		Workers will mix the needed ingredients into cheese mixture
Inspect ingredients are in		-		Workers inspects that the necessary ingredients are being mixed
Transport ingredients back to the shelf	2’5”-2’6”	-		Workers puts ingredients back in the shelf
Inspect milk		-		Workers will inspect the VAT process and inspected the cheese curds after completed
Compress the curd inside the VAT		189.39 min		Each worker will hand compress 250lbs of curds into larger form
Fill up compressed curd in a bucket		22.72 min		Each workers will fill 250 lbs of compressed curds into 100 bucket

Move compressed curd to Cheese Press	3’6	5.32 + 33.33 min		Two workers will transport 200 buckets to the cheese press table
Press the cheese in the bucket		60 min		Two workers uses a 10 head vertical cheese press to further compress 200 buckets of cheese curds
Transport pressed cheese to A/C room	3’6”	2.66 + 16.67 min		Each worker moves 100 buckets of pressed cheese curds to A/C
Store pressed cheese		-		Worker places the pressed cheese to age in the A/C room

Total Time: 523.90
Work Day: 12 Hours
Number of Processes: 1
Lbs of Cheese Produced: 1000lbs/day

Table 2.3: Pros and Cons table for Concept 1

Pros of new design	Con of new design
● More technology to assist workers ● Less distance between workstations ● Shelves are more easily accessible ● Removes need for transporting curds to a table to compress ● Significantly higher pasteurizer volume ● Significantly higher VAT volume	● More Workers ● Expensive to implement ● More buckets to transport

*Note: this is in comparison to the original

Concept 2

This design was constructed in an attempt to reduce the amount of walking distance from related areas of the workplace. The objective of this concept is to minimize worker cost and process time by reducing overall transportation time and subsequently process time. This concept also endeavored to reduce the equipment cost from the original, and the magnitude of reduction can be seen in the cost table below, Table 3.1.

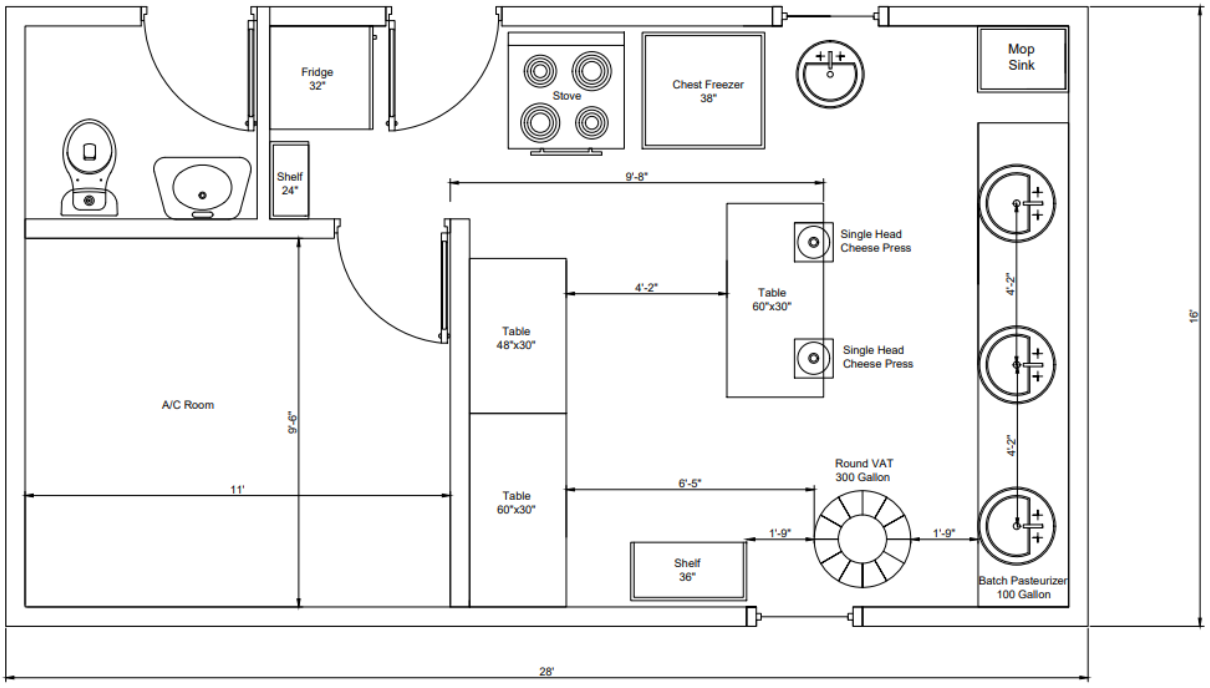

Figure 3: Layout of Concept 2

Table 3.1: Cost of Facility Items for Concept 2

Qty	Item	Price ($)
1	300 gal cheese VAT [1]	$20,950
3	100 gal open top batch pasteurizer [2]	$16,575
2	Single Head Vertical A-Frame Cheese Press [3]	$3,500
1	48”x 30” table [4]	$788
2	60”x 30” table [5]	$857
1	38” Chest Freezer [6]	$1,699
1	24” Shelf [7]	$266

1	36” Shelf [8]	$234
1	32” Fridge [9]	$1,840
1	Stove [10]	$4,099
120	Bucket [11]	$906
2	Annual Worker Salary [12]	$33,150
	TOTAL:	$155,521

Per this concept, it can be seen that the cheese VAT size has been increased from 150 gal to 300 gal. In addition, the pasteurizer sizes have increased from 50 gal to 100 gal. The cheese press has not changed in this concept compared to the original. The stove, originally being in the lower left section of the right side space, is now on the opposite end of the room. The pasteurizers will contain the milk that is then stored in buckets and the process is done simultaneously with 2 workers. The buckets (2.5 gal volume) containing the pasteurized milk are then transported into the VATs. The bucket size is kept at 2.5 gal (27lbs) since a larger bucket size would equate to a larger weight being infeasible for workers and introduces the risk of injury. There has been a reduction in shelf space from having a 36” and 24” shelf, to only having a 24” shelf. This is because a larger table space was introduced for working on the cheese with the cheese presses to allow a larger amount of cheese to be compressed at a time. Considering the overall design, it has been arranged in a layout such that transportation from one station to another can be done with ease (i.e. see location of the VAT in comparison to pasteurizer along with cheese press). This will reduce the amount of walking distance required from station to station following the process. After all this is done, the compressed cheese is taken into the A/C room for storage.

This work process requires two workers. Each worker must transport all 100 gallons of pasteurized milk from a pasteurizer and an additional 50 gallons from the remaining pasteurizer to the VAT. After this is complete, they monitor the churning process. The workers are responsible for adding the flavour to the cheese by mixing various cultures, rennet, and seasoning during the standard 30 minutes it takes to churn. As the cheese forms curds, the workers hand compress the cheese curds at the table and place them in buckets. After this, both workers compress the curds even further by using the cheese press and storing the final product in the A/C room to age. This process is very similar to the original process, but the difference is the larger pasteurizes, VAT, and a layout change.

Concept 2 Layout Process:

Table 3.2: Flow Process Chart of Concept 2

Process	Distance (m)	Time (min)	Symbol	Description
Milk enters pasteurizers	-	8.33 min		300 Gallons (100 gallons per pasteurizer)
Fill bucket with pasteurized milk	-	68.18 min		Bucket is filled up to 2.5 gallons, each worker must fill 60 buckets
Transport bucket to VAT	1’9” - 10’1”	4.59 + 10 min		2 workers are required to do 60 trips from pasteurizer to VAT
Churn the milk		40 min		Worker will start churning process
Inspect milk		-		Worker will inspect the VAT process and inspect the cheese curd
Transport ingredients from shelf to the VAT	1’9”	-		Worker will bring ingredients from the shelf to mix into the milk
Mixes the ingredient		-		Worker will mix the needed ingredients into cheese mixture
Inspect ingredients are in		-		Worker inspects that the necessary ingredients are being mixed
Transport ingredients back to the shelf	1’9”	-		Worker puts ingredients back in the shelf
Inspect milk		-		Worker will inspect the VAT process and inspected the cheese curds after completed
Fill bucket with curds		13.63 min		Workers fill buckets with 150 lbs of curds
Empty curds at table	6’5”	2.92 + 10 min		Workers will do 60 trips back and forth to empty the curds onto the table

Compress the curd		113.64 min		Workers will hand compress 150lbs of curds into larger form
Fill up compressed curd in a bucket		13.63 min		Workers will fill 150 lbs of compressed curds into bucket
Move compressed curd to Cheese Press	4’2”	1.90 + 10 min		Workers will transport all the buckets to the cheese press table within 60 trips
Press the cheese in the bucket		120 min		Each worker uses cheese press used to further compress 60 buckets of cheese curds in the bucket
Transport pressed cheese to A/C room	9’8”	4.40 + 10 min		Workers moves 60 buckets of the pressed cheese curds to the A/C room
Store pressed cheese	-	-		Worker places the pressed cheese to age in the A/C room

Total Time: 431.22 Minutes
Work Day: 12 Hours
Number of Processes: 1
Lbs of Cheese Produced: 300lbs/day

Table 3.3: Pros and Cons table for Concept 2

Pros of new design	Con of new design
● Relatively cheaper ● Less distance between workstations ● Shelves are more easily accessible ● Longer table to work on ● Higher pasteurizer volume ● Higher VAT volume	● Requires more trips of carrying buckets ● Output is projected to only be moderately larger

*Note: this is in comparison to the original

Concept 3

This concept focuses on a more linear design where employees move from one side of the factory to the next with as little backtracking as possible to keep transportation costs down. It also cuts out the bottleneck where employees transfer milk from the pasteurizer to the VATs by using a pump and tube system. The biggest change in this design is the implementation of three smaller VATs, which make it so each employee can work on a singular VAT. Also using this approach, the amount of cheese produced per day can be finely tuned depending on the demand by only using one VAT if needed.

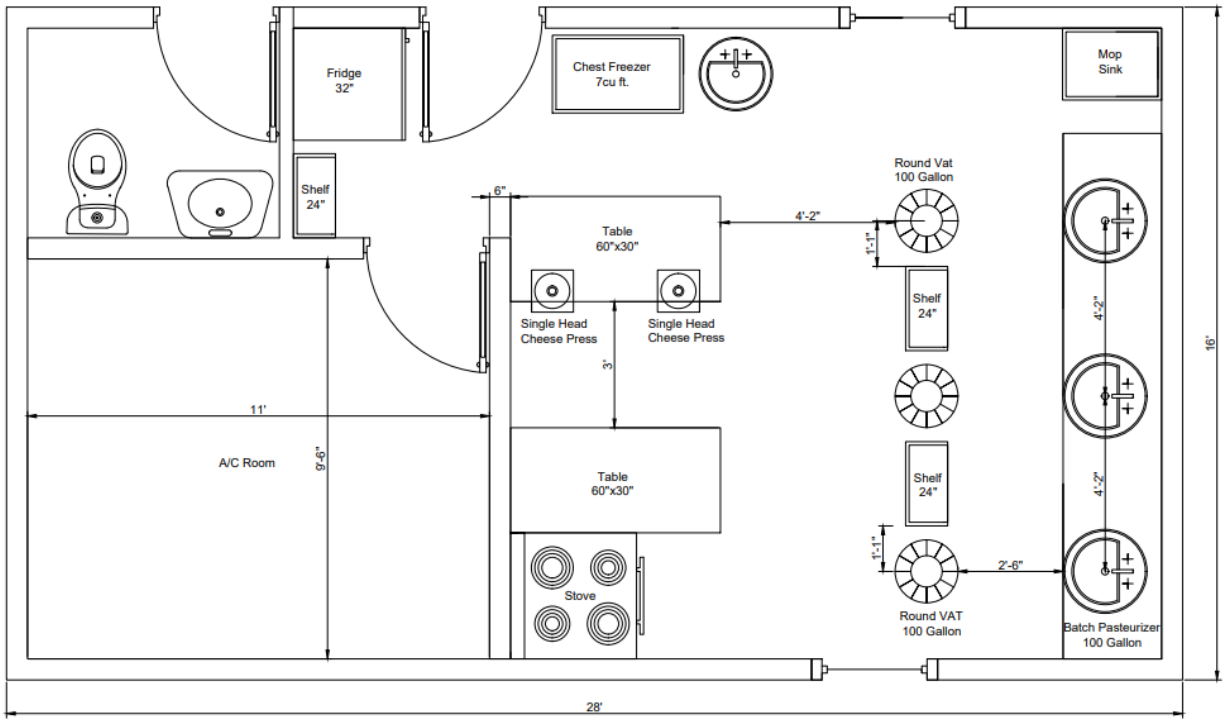

Figure 4: Layout of Concept 3

Table 4.1: Cost of Facility Items for Concept 3

Qty	Item	Price ($)
3	50 gal cheese VAT [1]	$24,275
3	50 gal open top batch pasteurizer [2]	$26,275
2	Single Head Vertical A-Frame Cheese Press [3]	$3,500
2	60”x 30” table [5]	$857
3	24” shelf [7]	$266
1	32” Fridge [9]	$1,840

1	Stove [10]	$4,099
3	Woodstock D4202 2-Inch by 10-Feet Clear Hose [13]	$75
3	Aquascape Ultra Pump 550 GPH [14]	$336
1	7cu ft. Chest freezer [15]	$299
120	Bucket [11]	$906
3	Annual Worker Salary [12]	$33,150
	TOTAL:	$268,989

This process implements three small VATs. The workers use a Tubing system connected to the VATs so the pasteurized milk automatically goes from the pasteurizer to the VATs. This assists in automating the process of the milk going into the VATs. Another difference in this process is the implementation of smaller seasoning shelves Right next to the VATs so workers do not need to travel far to get the seasoning and other ingredients required to make the cheese. The main assembly of the cheese has not changed from the original process, which means there aren't any more steps involved that change the recipe of the cheese. The process also only employs one table to move the initial cheese curds on instead of the original designs two tables.

Compared to the original, this design is much more modular in the sense that one employee has their own path that they follow. This process consists of 3 workers, each in charge of moving pasteurized milk to their respective VAT, monitoring and adding required ingredients, transporting curds from their VAT to a table, hand compressing 100lbs of curds respectively, and finally bringing the compressed curds over to the cheese press in buckets. At this step, two workers use the cheese press to further compress the cheese while the other worker resets the workplace for another batch of cheese making. After compressing the cheese, all three workers move the pressed cheese and store it in the storage room.

Concept 3 Layout Process:

1) Pasteurized milk is extracted from the pasteurizer to the VATs using tubes.
2) Grab rennet, culture, and seasoning, to add to the milk in the VAT from the tables next to the VATs.
3) After curds are formed in the VAT, transfer them over to a table.
4) After hand compressing the curds, put it in the cheese press.
5) Move the pressed cheese to the A/C room to age.

Table 4.2: Flow Process Chart of Concept 3

Process	Distance (ft-inch)	Time (min)	Symbol	Description
Milk enters pasteurizers	-	8.33 min		300 Gallons (100 gallons per pasteurizer)
Open valve and pump for the tube.	-	0.83 mins		Start the pump to allow the milk to flow from the pasteurizer to the VAT.
Let pasteurized milk enter VAT	-	12 mins		500 gallons/hour pump fills up 100 gallon VAT in 12 mins
Churn the milk	-	30 mins		VAT will start churning process
Inspect milk	-	-		Worker will inspect the VAT process and inspect the cheese curd
Transport ingredients from shelf to the VAT	1’1”	-		Worker will bring ingredients from the shelf to mix into the milk
Mixes the ingredient	-	-		Worker will mix the needed ingredients into cheese mixture
Inspect ingredients are in	-	-		Worker inspects that the necessary ingredients are being mixed
Transport ingredients back to the shelf	1’1”	-		Worker puts ingredients back in the shelf
Inspect milk	-	-		Worker will inspect the VAT process and inspected the cheese curds after completed
Fill bucket with curds	-	9.09 mins		Worker will fill buckets with 100lbs of of curds
Empty curds at table	4’2” - 11’5”	3.47 + 6.67 mins		Workers will do 40 trips back and forth to empty the curds onto the table
Compress the curd	-	75.76 mins		Worker will hand compress 100 lbs of the curds into larger form

Fill up compressed curd in a bucket	-	4.54 mins		Worker will fill 100lbs of compressed curds into bucket
Move compressed curd to Cheese Press	3’	0.911 + 6.67 mins		Workers will transport the buckets to the cheese press table within 40 trips
Press the cheese in the bucket	-	40 mins		Two workers use a cheese press to further compress 60 buckets of cheese curds in the bucket each
Transport pressed cheese to A/C room	5’6”	1.67 + 6.67 mins		Worker move 40 buckets of the pressed cheese curds to A/C
Store pressed cheese	-	-		Worker places the pressed cheese to age in the A/C room

Total Time: 206.61 Minutes
Work Day: 12 Hours
Number of Processes: 3
Lbs of Cheese Produced: 900lbs/day

Table 4.3: Pros and Cons table for Concept 3

Pros of new design	Con of new design
● Much less back tracking. ● Faster and easier VAT fill up due to the automated system. ● Less transportation time ● Shelves are more easily accessible ● Higher pasteurizer volume ● Higher VAT volume	● More workers ● Expensive to implement ● More trips required when transporting buckets ● Only one table to work with when hand molding cheese curds. ● Limited space

*Note: this is in comparison to the original

ANALYSIS

Table 5: Cost vs Production Analysis

Concept	**Cost**	**Production Rate per day**	**Annual Production Rate[3]**	**Cost/lb**
Original	$159,700	450lbs/day	89,550lbs/year	$1.78/lb
Concept 1	$320,331	1000lbs/day	199,000lbs/year	$1.61/lb
Concept 2	$155,521	300lbs/day	59,700lbs/year	$2.61/lb
Concept 3	$268,989	900lbs/day	179,100lbs/year	$1.50/lb

Table 5 above shows the cost and production rates of the various concepts created. It was determined that concept 2's facility cost is by far the cheapest, however, to produce 1lb of cheese in this layout would be 62% more expensive than in the original design. Furthermore, the production rate is 66% of what the original design. Concept 1 produces the most cheese per given time at a production rate of 2.2 times the original and is also 9.55% cheaper than the original design. If the goal of the factory is to produce a high quantity of cheese, this concept may be the most desirable even though it isn't the best alternative cost wise. The best concept cost wise is concept 3, as it is 15.7% cheaper than the original design while doubling the production.

Break-Even Analysis

When looking at the cost of concept 3, the initial investment seems like a large sum, but when the annual and daily production rate are taken into account during a breakeven analysis, it is determined that 162 days are needed in order to recover from excess equipment costs in relation to the original (See appendix for calculation). This concept also displays the lowest cost/lb, which allows the concept to generate more in savings compared to the other options. After the initial 162 day period, the initial investment of $109,289 is recovered and the facility will experience daily savings which may contribute to further facility investments.

Material Flow Process Analysis

The flow of a system is defined as the movement of materials, energy, information and people throughout this system. This cheese factory displays a regular flow, as it can be defined in three categories of subject, resources, and communications. The subject of the flow in this process would be the cheese that is processed throughout the system. The resources that are needed to bring about this flow would be the milk that is transported into the facility to accomplish the required flow as without the milk there is no base to begin the cheese making process. Lastly, the communication aspect of this process would be the workers coordinating the procedures in the flow, as this step-by-step flow requires a linear process which means the workers must be able to know when each procedure is completed before continuing to the next task.

[3] 4 day work weeks minus statutory holidays in Ontario (199 work days)

To describe the system of the flow, we can use the label of the system being a Material Flow System, which is a flow that occurs within the facility. The goal in a material flow system is always to minimize the total flow, as it ultimately reduces the time and cost of the process. Ways to reduce the time and cost flow that we implemented in this report was by planning for the delivery of materials into the facility by being prepared to start the first batch of cheese immediately to ensure that no time is put to waste by eliminating any intermediate steps of wait time. Minimizing the repetitive flows that occur between two consecutive points is another step that was taken to ensure that as few movements was made as possible. This was shown in our new concepts by moving the shelves that had the ingredients closer to the tables that utilized them to reduce the amount of trips needed to get the ingredients. Another step taken to minimize repetitive flows was the implementation of a tube that would replace the process of the workers carrying buckets of pasteurized cheese from the pasteurizer to the VATs to instead tubes taking the pasteurized cheese to the VAT. This would ultimately eliminate the procedure of the workers having to walk multiple times between two consecutive points, as the automatic tube would be performing this step. Lastly, to reduce time, combining flows and operations were implemented into our new concepts to eliminate unnecessary intermediate tasks during this process. To apply this theory, we combined the procedure of taking the cheese from the VAT in buckets to the table and churning the cheese. Furthermore, to combine these steps, the cheese can now be churned inside a newly added 10 foot VAT so that there is no need for the workers to transport the cheese from the VAT to a table and do the churning at the table. Ultimately, the new implementations to the new concepts were all completed to reduce the total flow time and cost in the entire cheese making process.

Line Flow

As discussed, when implementing work simplification to minimize the total flow, time as well as cost is also reduced. The way cost is implied in this equation is due to backtracking. Backtracking cost is determined by the amount of repetitive movements that are performed in a system which costs money for the company that could otherwise be used for other processes and to speed up and increase the output of the products. To determine the backtracking cost of the original design, the flow patterns utilized must first be discovered. As seen in the layout drawing, this flow would be a flow within the product and process departments. When inspecting the original design and the process of the flow, it can be seen that the current system had a W-Flow. As this original design does not exactly flow as a W, there are many backtracking cases with the total distance travelled. To equate the cost of backtracking, the directed flow path can be seen with this model:

A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-
B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-A-B-D-B-D-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C
-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-B-C-E-C-
E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C-E-C
-E-C-E-C-E-C-E-C-E-C-E-C-E-F

As seen in this flow path model, there are over 90 repetitions of movement that occurs for one process of cheese production. This is a large number of repetitions that can be innovated, as we have done in our concepts. This ultimately reduced this model significantly with the different placements of machines and tables which would in turn reduce the repetitions of the process B-D. The addition of a tube also eliminates the repetition of movement in process A-B. Lastly the combination of joining the operations of

manually churning the cheese at table C is eliminated and this eliminates the repetition of the process from B-C. Once we innovated this process with the addition of these new changes in our concepts, the model is estimated to be represented as such:

A-B-D-B-D-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-
B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-B-E-F

This new model proves that the innovation of our process has ultimately reduced the amount of repetitions from over 90 to less than 40, resulting in over a 50% improvement from the original design.

DISCUSSION

In picking the best concept, neither a pairwise exchange model nor From-To chart will be used. This is because the From-To chart nor pairwise exchange model would not be applicable to the cheese making process under investigation due to the layouts presented being non-negotiable. All processes are set in stone and cannot be interchanged when denoted as departments (i.e. you must go from pasteurizer to VAT, you cannot go from A/C to VAT). Furthermore, the material flow diagram would not be usable as well since the order in which each material is being transferred is important.

When determining the possible layouts, the cost of items used in the facility along with the production rate, time to produce, and distance required to travel were considered. It was believed that keeping these when making the layouts would allow for better alternatives to be produced. The designs main focus were not the employees physical and mental loading. Further changes needed to the workstation may become evident when simulating it for the workers. However, this aspect of the redesign would be out of the scope of the project and was not further researched.

Design Combination

Upon re-evaluation of the present design concepts, the team has considered some different design combinations, but will not be analyzed to the extent of the previous four. This section is devoted to presenting/illustrating potential design concepts that may be feasible in the future after investigating performances of the current alternatives. The idea is to take the best features of each design and discuss combinations.

It has been seen that concept 1 has exponentially increased the amount of cheese output. This is due to the increase in VAT size. It has also been noted that concept 3 has significantly reduced the amount of transportation time by introducing interconnecting tubes mainly from the pasteurizer to the VAT. Furthermore, in concept 2, the distance between the VAT and pasteurizers has decreased the amount of travel time for the milk to arrive at the VAT. Combining these features into a single design theoretically sounds ideal, but is not recommended to implement before the initial individual concepts are assessed further for their performance and stats. Should the individual concepts be feasible and successful during their respective testing stages, this concept will be subsequently tested and implemented if yielding better results.

Physical Strain

Factory work requires a lot of physical work from employees, so it is important to look at the physical strains that workers experience and the ergonomics of the workplace. There are also legal parameters which always need to be followed, so the workplace thoroughly needs to be examined. Another reason physical strains need to be examined is to improve worker happiness and ensure less employee turnover to ultimately lower training costs. The maximum carrying weight for all the floorplans examined is 10 kg, which equates to a 2.5 gallon bucket of milk. Throughout each concept, there are actions conducted that vary in severity, but the execution of the tasks stays constant nonetheless. Actions resulting in physical strain of the operator will be underlined in this section.

The process of carrying a 2.5 gal bucket from the pasteurizer to the VAT required multiple trips in every process and can be strenuous on the operators. The act of compressing the curds is another example of physical strain on the human body. A 2.5 gallon bucket of milk weighs 9.4635kg. The worker must carry this weight repeatedly while using a hook grip, which will undoubtedly provide stress in the hand region as well as the shoulder area over multiple replications of this type of action. This original process requires 30 repetitions of using the bucket to fill up the VAT from the pasteurizer. The first alternative concept requires 100 trips to fill up the 250 gallon VAT, the second alternative concept requires 60 trips, and the final concept requires zero as it uses an automated system. This task would be extremely tiring for the workers, especially if only one worker is assigned to do it. It would result in lower back pain because you need to bend over to pick up the bucket and then lift it up to pour the milk in. The rest of the process for each design is much easier to do due to the fact that only a 10th of the milk actually turns into cheese curds, therefore requires less carrying.

Another area of interest is the physical strain that occurs when molding the cheese curds by hand. This requires a lot of pressure to be exerted by the worker and can get tiring if done repeatedly. The original and alternative designs do not change this part of the process as it is necessary to mold by hand before taking the molded cheese curd to the presser to get the final shape.

Therefore, alternative 1 is the worst process in terms of ergonomics and physical strain while alternative 3 is the best because pumps and tubes do the bulk of the work instead of employees. The original design would be ranked third best in terms of ergonomics. This is because even though the second design has more carrying involved, it is over a lesser distance, which is easier to do. The original design requires workers to walk an average of 166 inches while the second alternative has much less of a distance.

CONCLUSION

The purpose of this report was to select a product manufacturing plant and produce recommendations to increase the production of the product, whilst also minimizing the cost of operation. As such, a cheese manufacturing facility was selected and the plant was investigated to determine the amount of time it takes to produce cheese, as well as the material handling and transportation costs associated with it.

The current facility (original design) was operated by two workers who performed all tasks of pasteurizing the milk, churning, adding flavours, processing, transferring, etc. by themselves. The layout was capable of executing the process 3 times and producing a total of 450lb of cheese. The three alternative layouts produced were capable of producing 1000lb, 300lb and 900lb of cheese, respectively. Whilst the layout that produced 1000lb satisfied the requirement of producing more than the original, the layout that produced 900lb had a lower cost per pound of cheese, making it the optimal solution. The cost per pound of Concept 1, which produced 1000 lb of cheese was found to be $1.61/lb, as compared to the $1.50/lb for Concept 3 which produced 900lb. Based on analysis, though the implementation of Concept 3 was determined to cost an excess of $109,289 as compared to the original design, it was determined after 162 days, the facility would break even on its investment and save money thereon.

In conclusion, Concept 3 was deemed as the most optimal concept for the original cheese factory layout. With the implementation of different cost and time beneficial improvements, the flow of the process introduced a new workstyle for workers with reduced movement, reduced pressure, and reduced stress on the body and mind. We believe that with the new process, both workers and the company will be able to work in a feasible work environment where everyone is comfortable and maximum productivity is achieved.

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APPENDIX

Assumptions

Assumptions were made to calculate various times for each process:

Milk Enters pasteurizer - The quantity of milk was divided amongst the workers working on this step (in most cases one pasteurizer worth of milk per worker). The quantity of milk in gallons was divided by 12 as the flow rate of milk into pasteurizer is 12 gallons per minute. [16]

$(gallons\ of\ milk\ /\ \#\ of\ workers)\ \div\ (12\ gallons\ /\ min)\ =\ Time\ it\ takes\ to\ fill\ up\ pasteurizer\ with\ milk$

Fill the bucket with pasteurized milk - The quantity of pasteurized milk is divided amongst the workers working on this step. The quantity in gallons of pasteurized milk per worker is determined. The flow rate of pasteurized milk to the bucket is 2.2 gallons per minute. The quantity of milk is divided by the flow rate to determine the time it takes to fill the buckets with pasteurized milk [17].

$(gallons\ of\ pasteurized\ milk\ /\ \#\ of\ workers)\ \div\ (2.2\ gallons\ /\ min)\ =\ Time\ to\ fill\ bucket\ with\ pasteurized$

Or

$quantity\ of\ buckets\ required\ for\ the\ operation\ \times\ [(2.5\ gallons\ /\ bucket\ of\ milk)\ \div\ (2.2\ gallons\ /\ min)]$

$=\ Time\ to\ fill\ bucket\ with\ pasteurized\ milk$

Churn the milk - This process was determined to take 30 minutes per the study. The size of the VAT does not play a factor as larger VATs are equipped with larger [19].

Fill bucket with Curds - 1 gallon of milk produces 1lb of curds. The amount of curds being put into buckets is evenly distributed between the workers on this step. Each bucket is filled with 2.2kg of curds at an average rate of 5kgs of curds per 5 min or 11lbs of curds per min. This was determined by performing a similar task of filling a bucket with milk curds.

$(lbs\ of\ curd\ /\ quantity\ of\ worker)\ \div\ (11lbs\ /\ min)\ =\ Time\ to\ fill\ buckets\ up\ with\ curd$

Compress Curds - Curds being compressed is often evenly distributed amongst the workers for this step. On average it takes 5 minutes to compress 3 kgs or 6.6lbs of curds [19].

$(lbs\ of\ curd\ /\ quantity\ of\ worker)\ \div\ (6.6lbs\ /\ 5\ min)\ =\ Time\ to\ compress\ curds$

Press the cheese in the bucket - The use of cheese press is divided amongst the workers, ensuring that there are not more workers on this step than there are cheese presses. To use the cheese press, it takes 10 minutes to press 12.5 gallons of cheese curds or 2 minutes per bucket [20].

$(quantity\ of\ buckets\ /\ quantity\ of\ worker)\ \div\ 2\ minutes\ /\ bucket\ =\ Time\ it\ takes\ workers\ to\ use\ cheese\ pre$

Transportations - A study revealed average walking speed is 3 mph or 4.39 ft/s. For the layouts used in this project, measurements were taken in feet. The longest distance an individual has to walk was used to determine the transportation time. This was done by determining the amount of trips required and multiplying that by two as they must go there and come back. This was then divided by the average walking speed to get the time in feet per seconds and divided once more to get the resultant time in feet per minute [18].

$$[(furthest\ distance\ required\ to\ travel\ \times\ quantity\ of\ trips\ required\ \times 2)\ \div\ (4.39\ ft/s)]\ \div\ 60\ seconds/m$$
$$=\ Total\ time\ to\ travel\ for\ the\ current\ step$$

Use of Pump to transport milk to the VAT - It was determined that the pump used in this project redesign has a flow rate of 500gallons/hour. This is the same as 8.33 gallons per minute.

$$Quantity\ of\ milk\ in\ pasteurizer\ \div\ 8.33\ gallons/minute\ =\ Time\ to\ transport\ milk\ to\ VAT\ using\ a\ pump$$

Calculation for break even analysis

268,989-159,700 = 109289 excess cost
109289/1.50 = 72859.3333333 pounds needed to be produced to break even
72859.3333333/450 divided by excess produced every day
161.90962963 number of days required ~ 162 days