

The impact of scientific management principles on food hub

by

Dean Jose

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Program of Study Committee:
Richard T Stone, Major Professor
Caroline Krejci
Stephen Vardeman

The student author and the program of study committee are solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

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DEDICATION

I dedicate my thesis to my parents and my sister for their continual support throughout my life and always believing in me. I thank them for always

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ABSTRACT

Food hubs has seen substantial growth in past few decades but the overall operational efficiency and effectiveness is a concern for the managers of these facilities. The physical layout and infrastructure of the facility along with training to the operators is one of the critical part of improvements that will improve the efficiency of these facilities. Regional food hubs even though different from large-scale food hubs, effectively need both operational efficiency and effectiveness. Currently, the food hub is reliant on volunteer labor without any specific training materials to help them acclimatize to their respective job. The lack of training provided to the volunteers causes volunteer frustration and operational errors. The ad-hoc labeling system used in the food hubs to hold the material there is another area for concern.

This thesis proposed a scientific management approach to management of operations as compared to the ad-hoc methods followed currently. This thesis analyzed the current workflow method, infrastructure layout of the facilities and the operating procedure followed by the workers and compared the efficiency with the addition of scientific management techniques like training and standard operating procedure for workers along with improved layout of the facility.

In order to check for the current efficiency, Task Analysis and Time study techniques were used. A scaled down simulation of the regional food hub was set up in the lab and a control group performs the task as it is performed in the food hub currently. The experimental groups performed the task in the modified method using scientific management principles like training, standard work procedure and process improvement. The four-group experiment

helped the experimenter compare the efficiency of the current and the proposed method and find out which factor is making more of an impact on the identified KPI's like time to stack, time to pack, number of errors while stacking, number of errors while packing and team interaction.

The experiment designed was a 2*2 factorial design, consisting of 60 participants divided into four treatment groups. The treatment groups had all combinations of the two independent variables 'Training' and 'Process Improvement'. Each treatment group had five teams with three members each. The above-mentioned KPI's were studied. The results shows that for time to stack and pack, both training and process improvement significantly reduce time. For Number of error while stacking, both training and process improvement are significant whereas for time to pack, only process improvement significantly reduce the number of errors. Both Training and Process Improvement is significant in improving the Team Interaction score.

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

General Introduction

“The structure of agriculture in the United States is moving towards two relatively separate spheres: large, corporately coordinated, agricultural commodity production units; and dispersed, local, and smaller-scale farms relying on direct markets” (Lyson, Stevenson, & Welsh, 2008).

In the case of United States, 99.2% of all food purchased is through traditional wholesale channels such as restaurants, grocery stores, and institutions (Martinez, et, al). It was a tough market for small-scale markets in the future. However, over the last decade, consumers have found a market for specific goods in the small local markets. Specifically, there is an increased demand for locally produced food and this has seen the rise of direct markets. A focus of the local food system movement early on nationally was organically grown produce. Over time, trends have evolved to include an emphasis on environmentally sustainable production methods without necessarily being certified as organic. National research on food hubs conducted in 2013, described in the following section, explored the approach of food hubs related to procurement of locally produced foods and their use of specific criteria (requirement for) versus preferences for certified and non-certified organic, sustainably produced and other categories of food products.

Thus there is a very clear increase in demand of regionally produced for over the last decade and this rise is mainly due to its social, economic and environmental benefits.

Local/Regional food

The word local has been ambiguously used over the years. According to the definition adopted by the U.S. Congress in the 2008 Food, Conservation, and Energy Act, the distance anything can be transported and still be called ‘locally or regionally produced agricultural food product’ is less than 400 miles from its origin, or within the State in which it is produced. As mentioned above, the demand for local/regional food has grown tremendously in the United States over the last decade. Since 2007-2014, the growth in farmer’s market is 180%, growth in Regional food hubs is 280% and growth in School districts with farm to school programs is around 430% (Low et al, 2015). In addition, the growth of Direct to consumer sales grew by a multiple of 3 from 1992-2007. The reason why the consumers prefer local food is not only because of environmental factors but also because of social, health and economic factors. (Tropp, 2008) Local food according to customers have higher quality, gives them a chance to learn about the farming practices, support local farmers and small-scale business and economically productive use of land. 66% of the people strongly believe it supports local economies, 60% believe they get a wider variety of products, 45% of the people believe that it provides a healthier alternative, 19% believe that local food enhances carbon footprint and 19% believe that it will lead to an increase in natural or organic production (AT Kearny, 2013). The study also found that 38% of the people are willing to pay 5% or more, whereas 24% of the people are willing to pay 10% or more for locally grown food. In addition, people in all segments of the economic strata are willing to pay more for locally grown food with 57% of the low-income families and 95% of the Single urban families willing to pay more.

Food hub

As people in each community move more towards local food, the community took an initiative to organize the diverse local food production and distribution solution and thus leading to the formation of a community based local food system. Thus the novel concept of ‘Food hubs’ emerged. Food hubs are defined as “financially viable businesses that demonstrate a significant commitment to place through aggregation and marketing of regional food” (Fischer et al, 2105a). This definition is a narrower version of the USDA definition that sees food hubs as mechanisms for working with local producers and community to create a diverse collection of local food while having a positive economic, social and environmental impact within their communities (Barnham et al., 2012). The food hub thus provides a point, which could act as a single point where producers can bring their goods and expect a better cut of profit. In addition, food hubs provided that point where consumers could come and buy local food.

Regional Food hub

The regional food hub is defined as “a business or organization that actively manages the aggregation, distribution, and marketing of source-identified food products primarily from local and regional producers to strengthen their ability to satisfy wholesale, retail, and institutional demand”. (Barnham et al., 2012). Thus, they act as the key driver towards creating large, reliable, consistent supply of local food. The main characteristics of a regional food hub according to (Barnham et al., 2012) are that they coordinate the aggregation and sale of local goods, the producers are involved in the business side of operations and are just not people who supply goods and makes sure that the producers get a good price for their produce using market differentiation techniques. Thus, they aim to be a positive impact on social, economic and environmental factors, not just the financial side.

The overall operation of a food hub is very similar to a conventional food supply chains. The food hubs since they act as the aggregator and distribution channel for the goods should make sure they have a very good supply chain system in place. Most of the food hubs have made investment in the food distribution infrastructure. They generally have a building that acts as a warehouse and a distribution center (Barnham et.al. 2012). The major difference between the food hub and a conventional store is that, the conventional store mainly works for profit and this profit is not shared equally with the producers who are more often than not exploited. The food hubs on the other hand, makes sure they keep it fair for the producers and focuses on the well-being of all stakeholders. The wholesale buyers who want to have local products in the store find food hubs an easy place to get the products rather than approaching individual producers (Barnham et.al. 2012). The regional food hubs can generally be classified into Farm to business/institution model, farm to consumer model and hybrid model. The regional food hubs are better than other direct to consumer markets like farmer market and farm stands because they have a consistent supply of food items. The food cooperatives in this research study is based on the Farm-to-consumer model (Barnham et.al. 2012). This is where the food hubs are responsible for marketing, aggregating, packaging and distributing products directly to the consumers. The food hubs generally have a 2-week selling cycle during which the producers are supposed to bring in the quantities ordered by the customers. The food hubs act as distribution centers taking in the supplies bought by the producers, placing them in the specific inventory locations, processing them as need be, picking them according to the orders and repackaging them according to customer orders. Since the regional hubs are mainly organized and run by non-professionals, there are many operational challenges faced.

Factors affecting operational efficiency/Challenges faced in food hubs

Even if there are various benefits of a food hub, there are many challenges faced. The top 5 challenges faced by food hubs are, balancing supply and demand (37%), managing growth (19%), access to capital (14%), finding appropriate technology (5%) and lack of ownership of infrastructure (4%). Even though food hubs are growing in the United States with over 95% of the food hubs experiencing an increase in demand for their products and services (Purcell E, 2014), the food hubs earn only 4% profit with an average of -2%. A typical food hub operates with a net margin of -2.99%. (Purcell E, 2014). This clearly suggests that even if food hubs are a very good and growing initiative, there needs to be work done all aspects for it to achieve its real potential.

Operational challenges are another big factor for the food hubs. Around 45% of the food hubs managers mentioned that increasing staff, securing more product supply, increasing truck/delivery capacity and increasing warehouse/storage space as an operational barrier. The major reason why increasing staff is a challenge to the growth of food hubs because of the lack of training material or standard procedures available to the volunteers. Also, according to (Bunham, 2012), the average employee in a food hub is 5 among which the number of volunteers are around 3. Thus lack of effective management skills appears to be a major obstacle in the development of food hub. (Fischer et al, 2013) Lack of training programs to the managers as well as the volunteers who work at the food hub is another obstacle addressed in the survey. Based on these findings, this research study is conducted to see the positive effect of providing training and application of scientific management to the regional food hubs. The layout of the facility and the inventory storage locations (i.e., refrigerators, freezers, and shelves) needs to be reassessed as the food hubs' operations grow and the needs of the business change.

Scientific management

The current management style followed in the food hub is ad-hoc style management. Ad-hoc style management was one in which the workers and the managers did not follow a specific set of procedure and the manager was isolated from the workmen. In addition, the workers could use any methods they think would suit the job and there was no standard procedure followed.

(Chandima, 2009). In the current process followed by the food hub which is mainly volunteer based (Fischer et al, 2013), the new volunteers who come in to work does not have a specific procedure set to follow and end up working just to complete the work told. This leads to customer dissatisfaction, which is a major barrier to the growth of food hub (AT Kearny). Scientific management believes that workers would have higher productivity if they were assigned specific tasks. Scientific management majorly encompasses;

1. Shift in decision making from employers to managers.
2. Develop a standard method for performing each job
3. Train workers in the standard method established.
4. Help workers by good planning and avoiding interruptions.

Based on these principles, the importance of training and the individual work done by each worker is very clear and that is the basis upon which the scientific management theory is built on. (Gaugler, E., 1995)

Motivation for research

The three factors that motivate this research are:

1. Need for training currently given to the volunteers and workers at the food hub
2. Lack of any studies on the workflow analysis on the operational side of food hub

3. Need of introduction of scientific management principles in food hub to improve the effectiveness and efficiency.

The growth of food hubs over the last decade clearly shows that there should be more study done on the operational side of food hubs. There has been a lot of studies focusing on the supply chain aspect of food hubs and how it can be optimized to improve the efficiency of a food hub (Mittal & Krejci, 2015; Craven et al., 2016; Mittal et al., 2017). The need of effective management skills appears to be one of main causes of the inefficiency of food hubs. (Fischer et al, 2013) Training to the managers and workers on common functionalities of all food hubs and also training specific to a particular food hub is another factor that the National food hub survey suggests.

The introduction of scientific management principles in the industry has seen the various industries like the auto industry has seen it thrive in the 20th and 21st century (Gaugler, E., 1995). There is a distinct lack of research done on the operational side of food hub and this is the gap my research is trying to bridge by introducing the Scientific Management and work organization principles in the food hub.

Hypotheses

H1: The Experimental group will take less time to stack than the control group.

H2: The Experimental group will take less time to pack than the control group.

H3: The Experimental group will have less number of errors in items stacked than the control group.

H4: The Experimental group will have less number of errors in items packed than the control group.

H5: The overall Team Interaction score of the experimental group will be higher than the control group.

Literature review

This chapter will look at all the literature that focuses on the work done on the food hubs and the areas of improvement that has been proposed based on previous studies and how scientific management principles could aid in filling this gap.

Local food has seen a significant growth in the last decade and that has translated to a growing body of research devoted to the topic. Studying and knowing the previous research enables us to build upon the research that is already done on this topic and exploring those areas that have been left out. The answer as to why there is the sudden growth in local food system has been answered in the previous research with many studies pointing to the environmental, health and economic benefits of moving towards local food hubs. Many studies have also shown the benefit of moving towards local food for the community. (Harris et.al, 2012; Winne, M., & Donahue, K. 2013; Johnson, R et.al, 2012; Bauman A, et.al, 2014)

According to the National food survey, the major challenges to the growth of a food hub are, managing growth, balancing supply and demand, access to capital, operational difficulties, price stabilization and finding reliable staff (Fischer et al, 2013). Also, the major barriers to growth according to the survey was increasing staff, securing more product supply, increasing truck capacity, increasing warehouse space, securing capital and consumer education.

According to this survey, increasing staff was the barrier to growth that the most food hubs noted. Of these, 19 hubs estimated the amount of money it would take to increase their staff to an appropriate level. Report from the various food hubs also suggest that increasing the revenue would not be enough to pay the staff and that other methods should be introduced in order to

increase the productivity of the current staff. The hubs had estimated costs that were around \$10,000 to \$250,000 with an average of \$67,000 whereas the sales are in the range of \$17,000 to \$45,000,000 per annum with an average of around \$3,000,000. (Fischer et al, 2013) Thus, it is clear that just by increasing the cash flow, the volunteer attrition or work satisfaction will not be affected and other ways of improving the volunteer interaction and satisfaction has to be looked into. Standardization and documentation, people management, material flow and quality control can be used to improve the efficiency and effectiveness. (Mittal et al., 2016). One possibility is train the staff and introduce standard work procedure. (Fischer et al, 2013). Training is defined as ‘A planned process to modify attitude, knowledge or skill behavior through a learning experience to achieve effective performance in any activity or range of activities. Its purpose, in the work situation, is to develop the abilities of the individual and to satisfy current and future manpower needs of the organization’ (Finegold, D., & Soskice, D. 1988)

Training plays an important role in the achievement of an organization goal by working towards the interest of the workforce and the organization itself. (Towers, B, 1996). Training has a positive impact on the return on investment. Training tries to impart necessary knowledge, skills and attitude to perform job related tasks and thus aids in improving job performance in direct way. (Truelove, 1995). The ideal practice is to supplement training with hands-on experience (Hughey, A. W., & Mussnug, K. J. 1997). They also state the idea of a Training manager, who in the case of food hubs could be the manager who is a full-time employee and how knows how the food hubs work. The time spent on training depends on the size of the institution and in the case of food hubs, need to be not a lot since the operation is not so complex. (Hughey, A. W., & Mussnug, K. J. 1997) The National Food-hub Survey, 2013 also mentions that improving the efficiency or performance of the employees is another way to improve operational efficiency of a

food hub. Training and development is a critical factor in the improvement of the employee efficiency (Ahmad, I., & ud Din, S. 2009). Training can be defined in many ways for example, training is defined as the planned and systematic modification of behavior through learning events, activities and programs which result in the participants achieving the levels of knowledge, skills, competencies and abilities to carry out their work effectively (Nassazi, A., 2013)

Training is given to employees mainly so that they acquire knowledge and perform it the best of their abilities. Scientific training is one of the most important principles of Scientific Management. Taylor states that each company should train the workers scientifically rather than passively leaving them to train themselves. It aims to unearth and cultivate workmen's endowment, let them have the best performance in their work and obtain the highest efficiency (Freeman, 1996). It can be seen that "finding reliable seasonal and/or part-time staff" was one of their top three challenges faced by food hubs (Fischer et al, 2013). One way to make the current volunteers reliable is to give them initial training. It can also be seen that "dependence on volunteer labor" is a major concern for the food hubs. The average ratio of full-time employees to regular volunteers to occasional volunteers was 1 to 6.4 to 8. One of the major concerns of the food has been the high volunteer attrition rate. It can be seen that one of the factors that has always affected volunteer retention is satisfaction (Chelladurai & Ogasawara, 2003; Hayhurst, Saylor, & Stuenkel, 2005; Jamison, 2003; Carla A. Costa, Laurence Chalip, B. Christine Green, 2006; Perkins & Benoit, 2004) Satisfied and happy employees are more likely to stay with an organization. The two keys components that volunteer job experience depends on are: (1) training and (2) task execution. Thus, volunteer experience depends on the job satisfaction and training they receive which helps them do the job well (Wisner, Stringfellow, Youngdahl, &

Parker, 2005; Elstad, 1996). It is also seen that volunteer job satisfaction plays a direct role in improved job commitment (Vandenberg & Lance, 1992; Bateman & Strasser, 1984;) Thus, training should be set up in a way that there is interaction among the volunteers. This will enable the volunteers to improve their social connection and thus foster a community where they would want to come again and thus reduce attrition rates and at the same time improving job satisfaction.

Another factor that is a part of scientific management Principle is introduction of standard operating procedure (SOP) to improve the efficiency. Scientific Management implies that supervision must be achieved through a clear chain of commands and thus implies that SOP is a critical part of the philosophy. Standard operating procedures say that it must provide instructions in a manner that is easy for the new operator to easily understand the process and do it effectively and consistently. (Tuck, M K., et. Al, 2008) Thus, they should be concise systematic instruction to do a job effectively. Subject matter experts who know the process inside out should make SOP's and they should have the willingness to consult the employees and consider their inputs.

CHAPTER 2

METHODOLOGY

Iowa food co-operative

Iowa Food Cooperative is a multi-farm, community supported agriculture cooperative organized in 2008. The aim of the Cooperative was to create a system to be a focal point for the distribution of local food while meeting the demand for locally produced and benefitting the producers, customers and workers. Every producer, customer and workers are all part of the board and they are all equal stakeholders in the cooperative. Thus the cooperative also helps to build a connect between the customers and the producers. Thus it is a multi-stakeholder cooperative. The Sandhills farm to Table cooperative was one of the first of this type of equally owned of enterprises. The members can order products bi-weekly, depending on the season and the producers will bring in the produce on the Wednesdays and Thursdays. The customers can come in and get their order on Thursdays and various distribution centers pack the goods and take it to the respective distribution centers on Thursdays. The main products are divided into 3 sections. Frozen, Refrigerated and dry goods. The co-op also sells bulk produce in standard case lots and specialty produce, such as tomatoes, salad mix, etc. Along with fresh produce, the cooperative also sells shelf-stable items, such as jams, packaged flour, and bread. Dairy products including eggs is also available. The cooperative has more than 1000 consumer-subscribers. This subscription model helps the producers to know ahead of time the quantity of products needed for that cycle and gives them to time to finalize products available to be sold in additional channels. The members generally subscribe for a season, thus the cooperative receives a monetary commitment, creating a more stable market for both member classes. The cooperative

totally relies on a strong supply of good quality goods by the local producers. Value-added products are priced according to their local retail price.

Work flow

The major activity in the food hub can be divided into 3 sections.

1. Aggregation
2. Stacking
3. Packing

The general operation in the Food hub happens on a Wednesday and Thursday.

A pictorial representation of the facility layout is shown in Figure 1.

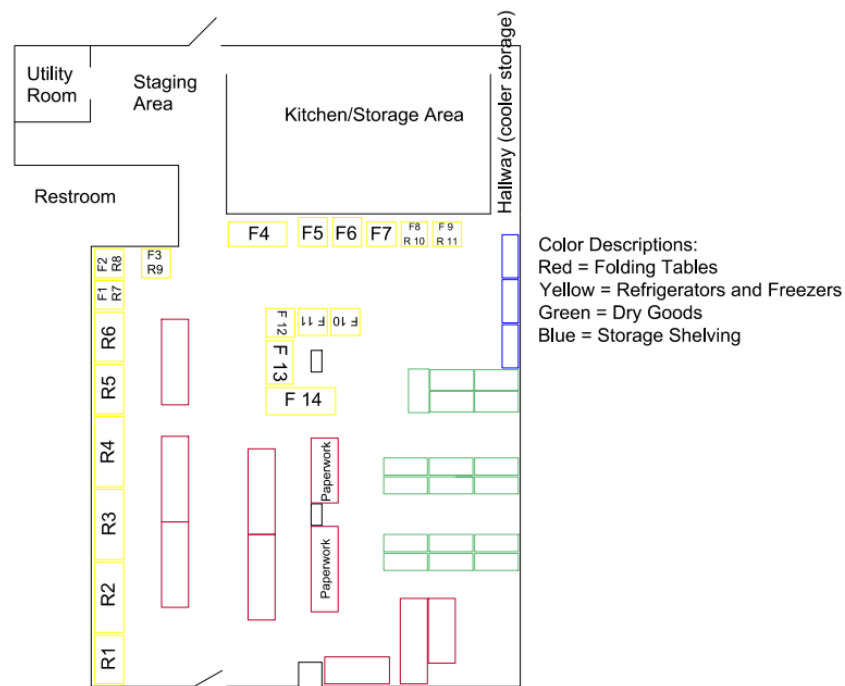


Figure 1: Cad representation of the facility layout (Mittal, 2016)

Process chart - Day 1

1. Producer comes in with items they are supposed to bring The food items all have a tag a shown in fig 2 which tells us what the food item is, who is the customer, the customer number, the producer name and the quantity.

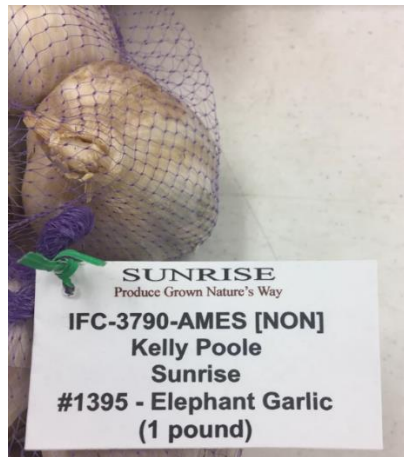


Figure 2: Item tag on all items bought by the producer

2. One of the workers checks in the Producer based on the producer list invoice. The list contains the different items, quantities, weights as shown in Figure 3.

Producer List for November 6, 2014 for Harvest Moon Farms

Sorted by Product
NOTE: Sections are sorted with the items purchased first at the top.

Click for invoice sorted by customer
Click for invoice sorted by storage/customer
Click for invoice with multi-sort/merge-update
Click for labels (one per product/customer)
Click for labels (one per storage/customer)

MemID	Member	Quantity	Weight	Price	Stock?	Total	Edit
✓ Aronia Concentrate (Product ID# 5673)							
# 1854	Deanna Selmer	1 Bottle		\$13.95/Bottle	In	\$ 13.95	Update
					Out		
# 2382	Jay Cornwell	1 Bottle		\$13.95/Bottle	In	\$ 13.95	Update
					Out		
Product Quantity: 6							
Product subtotal: \$27.90							
✓ Radishes (Product ID# 5845)							
# 1139	Aaron Haley-Lehman	1 Pound		\$3.00/pound	In	\$ 3.00	Update
					Out		
# 1320	susan selts	1 Pound		\$3.00/pound	In	\$ 3.00	Update
					Out		
# 3432	Ray Meyler	1 Pound		\$3.00/pound	In	\$ 3.00	Update
					Out		
# 2426	Bobbie Fuller	1 Pound		\$3.00/pound	In	\$ 3.00	Update
					Out		
# 1389	Lisa Bean	1 Pound		\$3.00/pound	In	\$ 3.00	Update
					Out		
# 3745	Sheila Treu	1 Pound		\$3.00/pound	In	\$ 3.00	Update
					Out		
# 3497	Maggie Beier	1 Pound		\$3.00/pound	In	\$ 3.00	Update
					Out		
Product Quantity: 5							
Product subtotal: \$21.00							
						Product Total	\$ 48.90
						15% Coop Fee	\$ -7.34
						Total Extra Charges	\$ 0.00
						Adjustments	\$ 0.00
						TOTAL with Coop Fee	41.56

Figure 3: Producer invoice

3. Once the particular producer is checked in and the workers confirm they have all the goods, the producer collects the check from the previous week and leaves.
4. The items bought in by the producer is treated differently based on what is the item.

There are mainly 3 categories

- a. Normal food items - Non refrigerated items
 - b. Refrigerated food items
 - c. Frozen food items
5. The way in which each type is treated is as follows
 - Dry goods - All kept in a tray and then assembled based on Customer number and place of delivery as shown in Figure 4.



Figure 4: Dry good shelves

- Refrigerated goods - All the items are kept in the refrigerators just according to their place of delivery as shown in Figure 5. Also, once they are kept, a tag with

the respective producers' name is stuck on the door (the tagging is done prior to the stacking) making it easy for the volunteers to pack.



Figure 5: Refrigerators

- Frozen food - Kept in refrigerators at the back. Arranged according to customer number, place of delivery as shown in Figure 6.

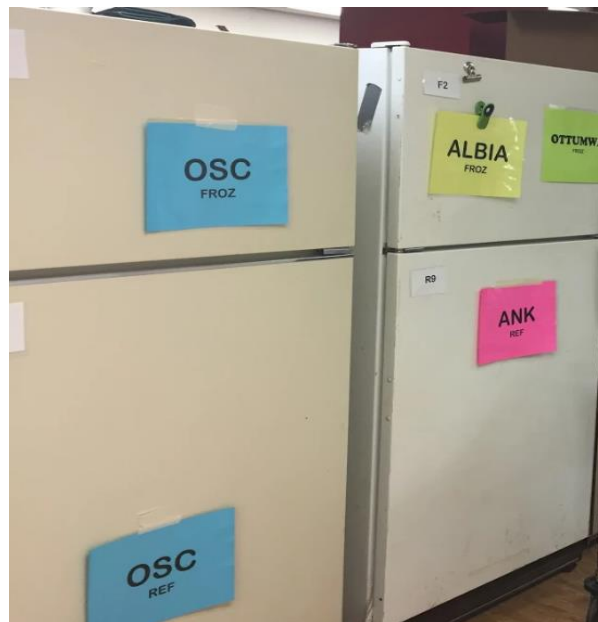


Figure 6: Freezers for frozen goods

6. Volunteers come in by now and start putting tags on the pantry as shown in Figure 3 .The process they follow to put the tags on the pantry is:

- The volunteers were given lists sorted according to the place of delivery. The list as shown in Figure 7 contains all items going to the particular place sorted according to the customer name and number.

#319	☐	REF	Global Greens: Jipat	Cylindra Beets	(1) - bag
5552	☐	REF	Global Greens: Namas	Leeks	(1) - bunch
8597	☐	REF	Global Greens: Namas	Fresh Ginger	(1) - bag
6537	☐	REF	Heritage Hill Farm,	Green Onion Bunches, 5-7 per bunch	(2) - bags
8618	☐	REF	Heritage Hill Farm,	Romaine Lettuce 1/2 lb bag	(1) - bag
4289	☐	REF	Lee's Greens, LLC	Arugula	(1) - bag
4301	☐	REF	Lee's Greens, LLC	spinach	(1) - bag
8080	☐	REF	Middle Way Farm	Kale, Green Curly	(1) - bunch
4719	☐	REF	Organic Greens LLC	Sunflower Greens, Organic, 5 oz	(1) - bag
(3429) IFC-3429-OTT - David Camphouse					
3181	☐	FROZ	Holdeman Poultry	Capon Party Wings \$2.50 per lb.	(1) - package
6757	☐	FROZ	Lucky George Farm	Spicy Merguez Sausage	(1) - package
8628	☐	NON	Early Morning Harves	Cucumber	(2) - items
1414	☐	NON	Sunrise	German Xtra-Hardy Garlic	(3) - bulbs
438	☐	REF	Berry Patch Farm	Snack size Honey crisp apples SALE	(1) - 5 lb bag
6548	☐	REF	Global Greens - Eati	Dinosaur Kale	(1) - bag
8000	☐	REF	Global Greens - Eati	Babybeats	(1) - bag
7953	☐	REF	Middle Way Farm	Arugula	(1) - 6 oz. bag
5288	☐	REF	WW Homestead Dairy	Cheddar Cheese - Chipotle Morita (8oz bl	(1) - 8 ounce bloc
(3559) IFC-3559-OTT - Julieanne Gentz					
5165	☐	REF	Beaver Creek Produce	Butterhead Lettuce	(1) - item
6634	☐	REF	Country View Dairy	Original: 4-Pack of 6 oz Black Cherry	(1) - 4-pack
6645	☐	REF	Country View Dairy	Original: 4-pack of 6 oz Strawberry	(1) - 4-pack
5928	☐	REF	Early Morning Harves	Large brown eggs	(1) - dozen
4468	☐	REF	Iowa Orchard	2nd Grade-HoneyCrisp Apples 1/2 Peck	(1) - peck
4613	☐	REF	WW Homestead Dairy	Butter (Salted)	(1) - pound

Figure 7: Customer invoice

- The volunteers then take the list to the respective delivery place location on the pantry and see if the name tags having the respective customer name who has a Non-refrigerated food item in the list is already put up on the pantry. If the tag is already there, then put a tick mark against that customer name on the list. If the tag is not there, circle the respective customers' name. If there is an extra tag whose customer is not on the current list, remove it and keep it on its back side.
- Once the tags needed are known, the volunteer checks the stacks of tags as shown in Figure 8 kept on a movable cart. The tags are kept sorted according to the

customer number. Volunteer checks for the respective tag that is needed and takes it from the stack. In case the customer number is new, then a new tag is made.



Figure 8: Stack of magnetic tags

- These tags are then taken and arranged in ascending order of the customer name onto the pantry shelves as shown in Figure 3.

Process chart - Day 2

1. The producers stop bringing in food at 11am. The volunteers start packing the goods at 12:00PM.
2. There will be clipboards on which the lists are attached according to the delivery place and they are color coded for the ease of volunteers as shown in Figure 9.

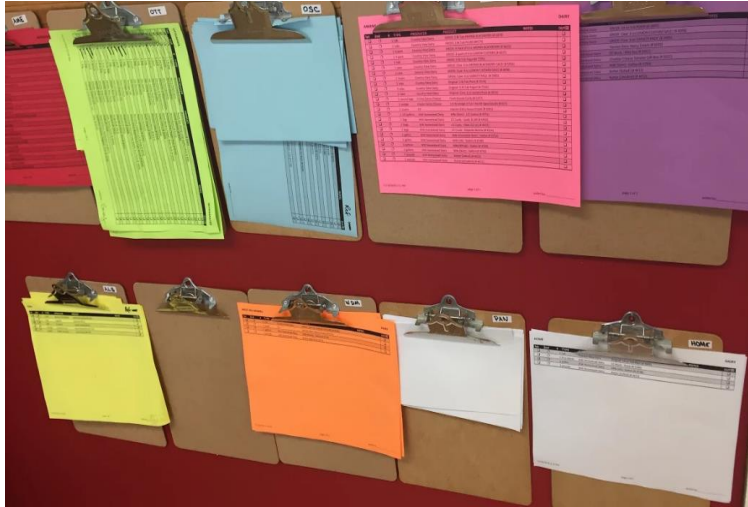


Figure 9: Color coded list used for packing

3. There is no special sequence as to which the whole packing is done. Volunteers are free to choose whatever list they like and start there.
4. The lists are divided into 3 categories
 - Frozen – It is basically the whole list of items as shown in Figure 7 for a particular place sorted according to customer number and number with FROZ marked on the top.
 - Dry goods - It is the whole list of items as shown in Figure 7 for a particular place sorted according to customer number and number with DRY marked on the top.
 - Refrigerated - The refrigerated goods list is color coded according to the place and is not sorted based on the customer number or name since the items all look alike and it is too tough to sort based on name as shown in Figure 10.

OTTUMWA						REFRIGERATED	
1st	2nd	#	TYPE	PRODUCER	PRODUCT	NOTES	OUTS
☒	☒	5	bag	Beaver Creek Produce	Butterhead Lettuce (R 5355)		☒
☒	☒	1	5 lb bag	Berry Patch Farm	Snack size Honey crisp apples 5AL (R 418)		☒
☒	☒	1	bunch	DE's Farmagraphics	round radishes (R 8055)		☒
☒	☒	1	package	DE's Farmagraphics	Butterhead (R 8113)		☒
☒	☒	1	pack	Elements of Rejuvenation	Arabis Chik Pepper Pack (R 8324)		☒
☒	☒	1	pack	Elements of Rejuvenation	Sweet Banana Pepper Multi Pack (R 8355)		☒
☒	☒	1	bunch	Garden on Garden	Tanga Celery (R 8283)		☒
☒	☒	1	bag	GG - Eating Well Farm	Butterhead (R 8055)		☒
☒	☒	1	bag	GG - Eating Well Farm	Onion Kilo (R 8049)		☒
☒	☒	1	bag	GG - Hamlet	Celery Root (R 8119)		☒
☒	☒	1	bag	GG - Hamlet	French Finger (R 8052)		☒
☒	☒	1	bunch	GG - Hamlet	Leeks (R 5552)		☒
☒	☒	1	head	GG - Hamlet	Napa Cabbage (R 8124)		☒
☒	☒	1	bag	Heritage Hill	Romaine Lettuce 1/2 lb bag (R 8618)		☒
☒	☒	1	bag	Heritage Hill	Green Onion Bunches, 5-7 per bunch (R 6537)		☒
☒	☒	1	pack	Iowa Orchard	2nd Grade Honeycrisp Apples 1/2 Pack (R 4458)		☒
☒	☒	1	bag	Lee's Greens, LLC	Arugula (R 8289)		☒
☒	☒	1	bag	Lee's Greens, LLC	spinach (R 4303)		☒
☒	☒	1	5 oz. bag	Middle Way Farm	Maschun Lettuce Mix (R 8027)		☒
☒	☒	1	6 oz. bag	Middle Way Farm	Arugula (R 7953)		☒
☒	☒	1	8 oz bag	Middle Way Farm	Spinach (R 7953)		☒
☒	☒	1	bunch	Middle Way Farm	Kale, Green Curly (R 8080)		☒
☒	☒	1	bunch	Middle Way Farm	Leeks (R 7333)		☒
☒	☒	1	head	Middle Way Farm	Head Lettuce, Butterhead (R 8057)		☒
☒	☒	1	bag	Organic Greens LLC	Sunflower Greens, Organic, 5 oz (R 4739)		☒
☒	☒	1	Bag	Salama Greenhouse, Inc.	Kale (R 4556)		☒

Figure 10: Refrigerated goods list

5. The packing method is different for the different items

- Frozen goods - They are packed into coolers with dry ice at the bottom. The cooler will have the Place name written on top and also will have the list attached to it with the producer names so that it will be easy for the distributors.
- Refrigerated goods - They are packed into coolers with no dry ice at the bottom. The coolers have the name of the Place of delivery. Also, it is not packed according to the customer name.
- Dry goods - They are packed into dry box according to the place of delivery. And they are arranged according to the customer name and number. The list of customer number is stuck on the box making it easier for the distributors.

6. Once it is packed, the respective distributors come and load them onto the respective transportation options available.

The overall process flow chart divided into 3 main categories is shown in the Figures 11, 12 and 13. Figure 11 showing the initial check in process, Figure 12 showing the stacking process and Figure 13 showing the packing stage.

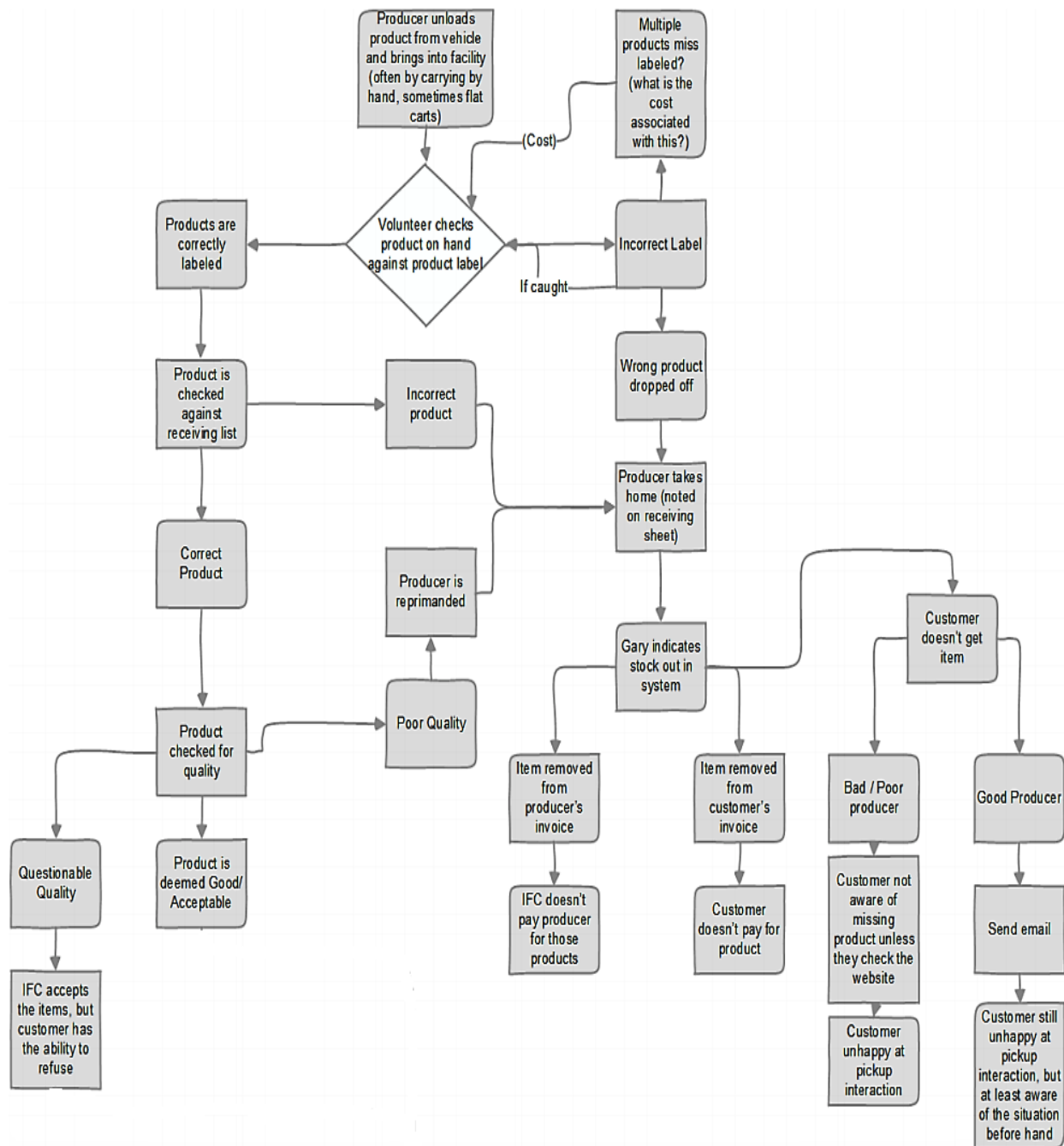


Figure 11: Producer check in flowchart

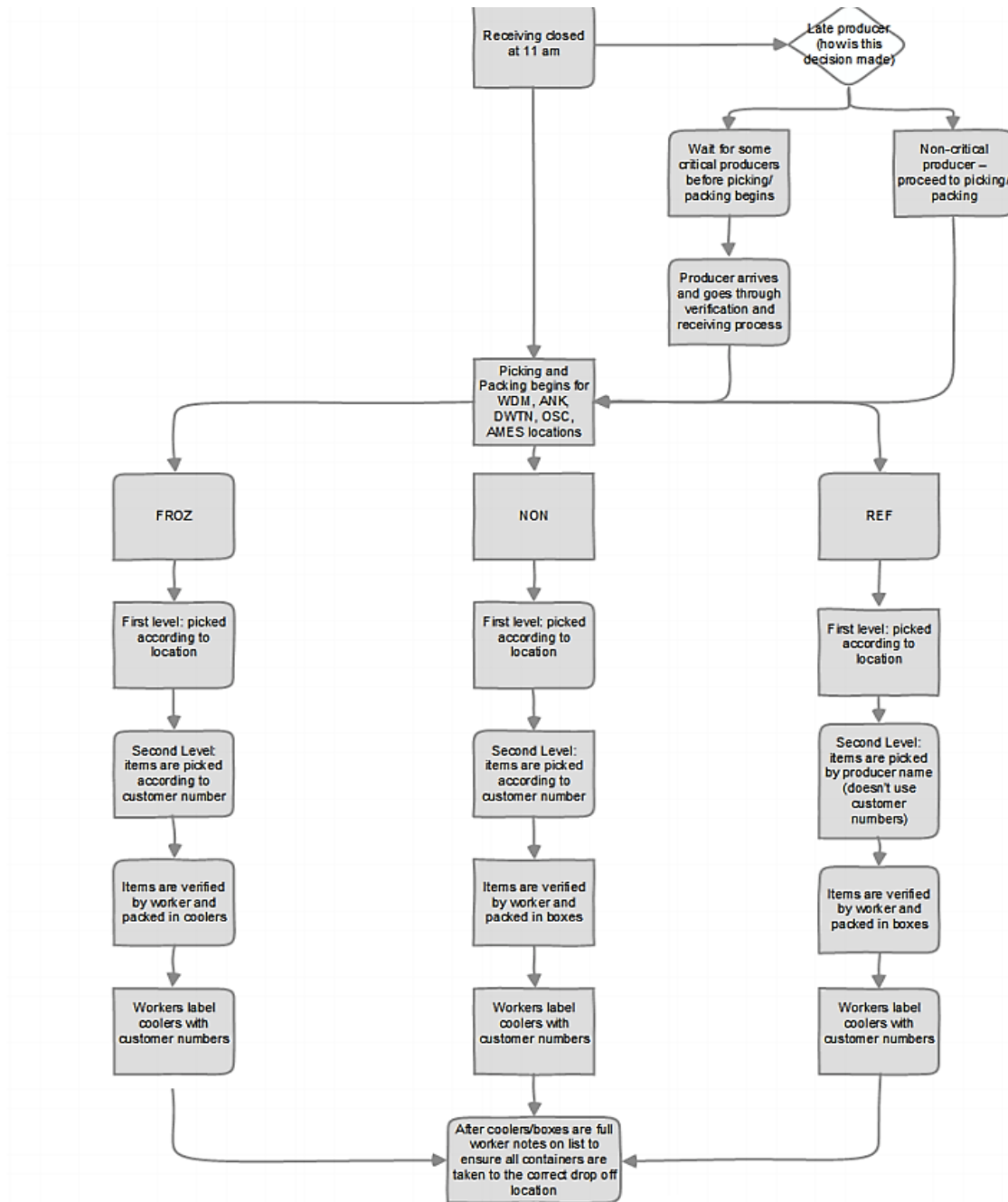


Figure 12: Processes involved in stacking stage

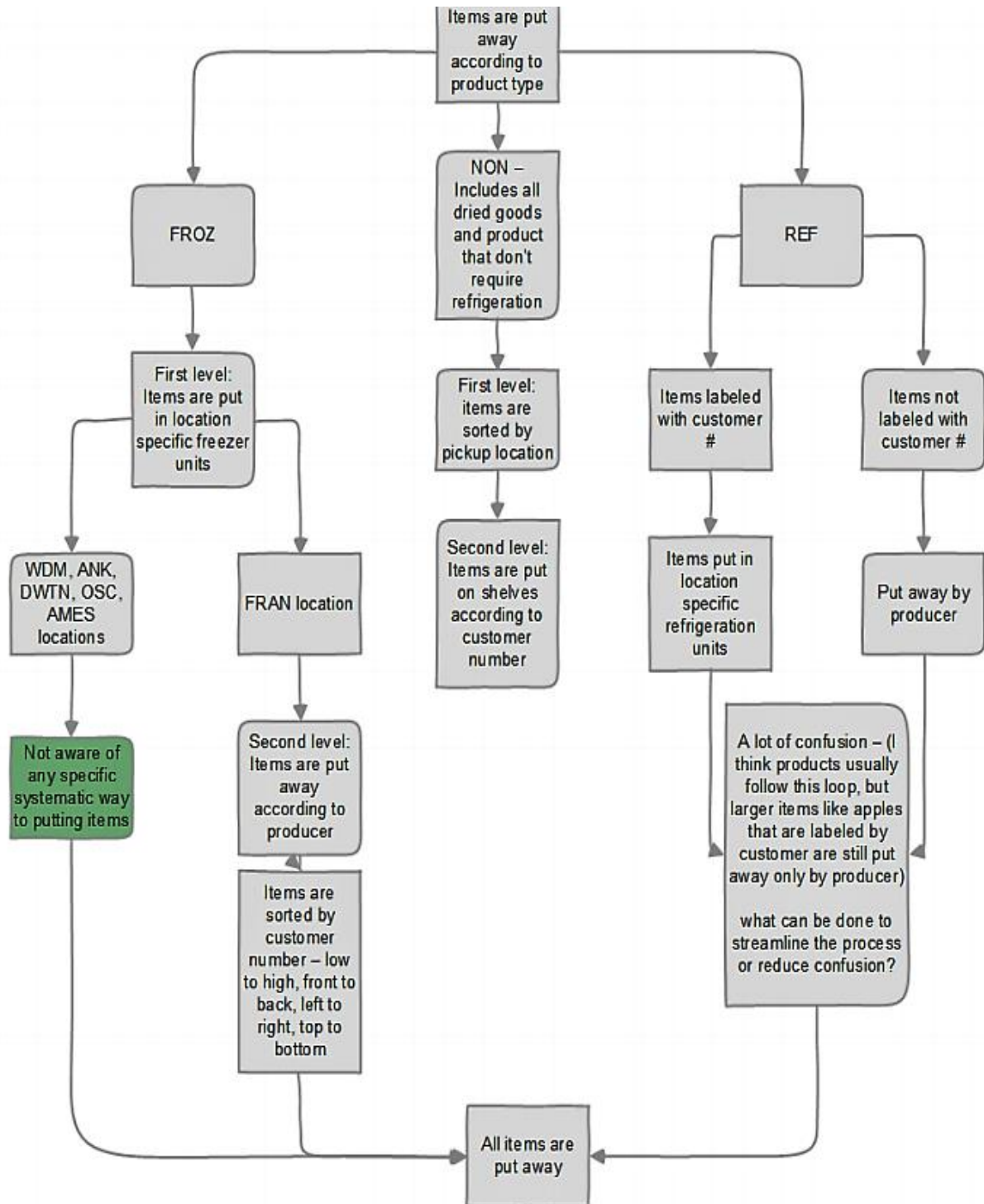


Figure 13: Packing stage

Participant Selection

There were 60 participants selected for the study where each experiment in the study required 3 participants. The 60 participants included in the study were students enrolled at Iowa State University. The participants called for the study had no previous experience in working in a food hub since we needed to validate the effect of first time volunteers. Participants needed for the study was called in 3 ways. Using Flyers (APPENDIX C) containing brief of the study details was the 1st method and they were put in Black Engineering building. Second method involved announcement about the study to IE 271 class taken by Dr. Stone (Co PI). Students in his class were given the option of taking part in the study to obtain extra credits. Taking part in the study, whether the students finished the study or not, would earn them extra credits which accounted to 3% of their final grade in the class. If the students from IE 271 chose not to take part in the study, they were provided with an alternative homework assignment, which will provide them with the same credits upon submission. An informed consent form template was obtained from Iowa State University website and filled out with all the details as required by the Internal Review Board (IRB). The consent form (APPENDIX B) was provided to each participant prior to taking part in the study. The participants were asked to read and understand the consent form and sign upon agreement of conditions of the study. If anyone had any concerns, they were allowed to withdraw at any point of time.

The exclusion criteria followed for participant selection is that anyone under 18 years old had be excluded because the volunteers at the food hub are all above 18 and that had to be the population group that will be included in the study. The participants' ID will be checked before the recording. Individuals must be over 105 pounds and not use a heart pacemaker or an automatic defibrillator. This is because the task does involve lifting of objects around 5 pounds.

Materials

In order to replicate the activities in a food hub, the most appropriate method was to create a small-scale food hub facility in the lab at Iowa State University with an appropriate scale down of different materials there. In the scaled down version of the food hub, there will be two shelves for dry goods, one closed shelf acting as a refrigerator for the refrigerated goods. Two closed plastic shelves, one acting as a refrigerator and one acting as a freezer for frozen goods. The rest of the food hub operation was simulated using the various customer, producer lists used by the volunteers to stack and pack the food items, three white boards, 2 tables to collect the items bought by the Co-PI. The fake food items used will be 65 refrigerated goods, 104 NON-goods and 29 frozen goods.

Variables

Table 1: List of independent and dependent variables

Independent Variables	Dependent Variables	Units
Process Improvement	Time taken to stack all the products	seconds
Training	Time taken to pack all the products	seconds
	Total number of errors in items stacked	No unit
	Total number of errors in items packed	No unit
	Team Interaction score	No unit

Data Collection

This section will describe the methods used for measuring each of the above-mentioned dependent variable. The time taken to complete stacking the products will be noted and the time taken for the participants to pack the goods will be noted by the PI. The accuracy with which the products are stacked and packed into the boxes will be calculated based on the number of errors made per group. The PI and the Co-PI will check the shelves, refrigerators and freezers once they are packed and also check the individual boxes packed to see if all the items in the customer invoice is packed into the boxes. The data between the control groups and the treatment groups will then be compared to see the effect training and the other changes have on the operational efficiency both time wise and error rate wise.

Experimental Design

The experimental design is a full factorial based design with 2 levels of Training and 2 levels of Process improvement (With and without). Thus the independent variables in the study is Training and Process Improvement. The dependent variables which are the main KPI's that are used to access the operational efficiency of a food hub are, time taken to stack (TS), time taken to pack (TP), number of errors during stacking (ES), number of errors during packing (TP) and team interaction score (TI). Thus based on the full factorial design, 4 treatment groups are tested in this study. The treatment groups being;

Treatment Group 1 (T1): This is the control group, where the participants are doing exactly what is done in the food hub at the moment. Thus, this acts as a baseline group. This group did the study without any process improvement or training. There were five teams of three members each as part of Treatment Group 1.

Treatment Group 2 (T2): This is the group where the participants were given both training and they did the study in an improved process. There were five groups of three members each were part of Treatment Group 2.

Treatment Group 3 (T3): This is the group where the participants did the task with the process improvement but without any training. Five groups of three member each were part of Treatment Group 3.

Treatment Group 4 (T4): This is the group where the participants did the task in the old setting, without any process improvement but were given training. Five groups of three member each were part of Treatment Group 4.

Table 2: Treatment Groups and their respective conditions

	Treatment Group 1	Treatment Group 2	Treatment Group 3	Treatment Group 4
Condition	No training + No Process improvement	Training + Process improvement	No Training + Process improvement	Training + No Process improvement

Experimental Procedure

The study started with the participants signing the Informed consent form, filling out a discomfort survey and given an overall idea about the food hub, the research motivation and the work done by the volunteers at the food hub. Participants in T2 and T4 were given training on what exactly needed to be done. The PI and the Co-PI gave a demo on what needs to be done as part of training. The participants in these groups were also given standard work procedure which clearly gave instructions per participant as shown in Figures 14, 15, 16, 17 and 18. Verbal

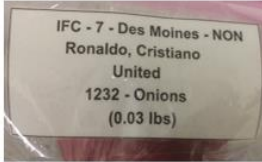
instructions were given to participants in all the groups since that is the way it is currently done in food hubs and the participants were asked to let the PI know in case they had any questions regarding the process. The number of producers to be used in the study was determined based on the observational data collected prior to the study. The number thus determined for a scaled down study was eight. The number of goods per producer was determined based on the observational data done prior to the study too.

Operator 1 – Check in

1) Goods will arrive in boxes with labels. The labels and their meanings are shown in steps 2-4.



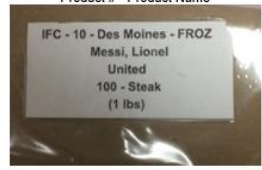
2) IFC - Customer # - Location – NON
Customer Name
Producer Name
Product # - Product Name



3) Producer
Product ID – Product



4) IFC - Customer # - Location – FROZ
Customer Name
Producer Name
Product # - Product Name



5) Take the producers invoice and check if the quantity and Product ID match what is on the labels in the box.



6) If products match producers invoice, set products into their respective locations.



If there aren't enough of certain products, take a note of the product ID and quantity missing.

If there is too much of a product, put the product back in the box it came in.

Operator 2 – Set Up

1) Take the Customer List by Location and check to see if there are NON goods under the Type of Item (REF, FROZ, NON) column.

Check box	Customer Number	Customer Name	Place	Type of Item (REF, FROZ, NON)	Item Code	Item Name	Number of Items	Producer
	102	David	Des Moines	Ref	1001	Tomato	2	United
				Ref	2101	Cucumber	1	Cherokee
				Ref	555	Mixed (1 nos)	1	United
				Ref	666	Potato	2	United
				Ref	1232	Onions	2	United
				Ref	145	Black bean	2	United
				Ref	100	Steak	1	United
	87	Scholar, Paul	Des Moines	Ref	1001	Tomato	1	United
				Ref	540	Corned	1	United

2) If there are, put a check mark in the checkmark column. If not, go to the next customer.

Check box	Customer Number	Customer Name	Place	Type of Item (REF, FROZ, NON)	Item Code	Item Name	Number of Items	Producer
✓	102	David	Des Moines	Ref	1001	Tomato	2	United
				Ref	2101	Cucumber	1	Cherokee
				Ref	555	Mixed (1 nos)	1	United
				Ref	666	Potato	2	United
				Ref	1232	Onions	2	United
				Ref	145	Black bean	2	United
				Ref	100	Steak	1	United
	87	Scholar, Paul	Des Moines	Ref	1001	Tomato	1	United
				Ref	540	Corned	1	United

3) Take the Customer List by Location sheet to the respective dry goods shelf. Then, in ascending order, write the customer numbers on the white board tags next to the aisle number. Also, add the number of NON items from the Number of Items column and place this number in the bottom right corner of the whiteboard tag.



Figure 14: SOP for check in

Figure 15: SOP for setting up dry good shelves

Operator 2 – Stacking Goods

1) Take the NON goods from the checked in pile and place them on the shelves by their respective customer number locations



2) Below is how to read the tags of the NON goods.
 IFC - Customer # - Location - NON
 Customer Name
 Producer Name
 Product # - Product Name

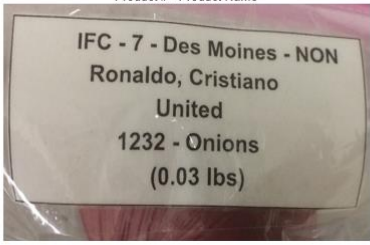


Figure 16: SOP for stacking NON goods

Operator 3 – Set Up

1) Take the Producer Invoice List and check if the producer has REF goods under Product Type. If yes, attach the producers name tag to the outside of the fridge. Then go to the next producer. If no, go to the next producer.

PRODUCER INVOICE LIST

Producer Name: ARSENAL

Prod ID	Product Type	Product	Quantity
1001	Ref	Tomato	3
2101	Ref	Cucumber	1
555	Ref	Bell Peppers Mixed (3lbs)	2
4	Ref	Cabbage	2
545	Ref	Carrot (3lbs)	1
686	NON	Potato	6
7	NON	Garlic (3lbs)	2
1232	NON	Onion	11
123	NON	Lingui Fins (3lbs)	2
14	NON	Pinto Beans (10lb)	2
9	FROZ	Peppers (3lbs)	2
100	FROZ	Steak	1



2) Take the Customer List by Location and check to see if there are FROZ goods under the Type of Item column. If yes attach the respective location to the outside of the freezer. If no, go to the next location.

CUSTOMER LIST BY LOCATION - DES MOINES

Check Box	Customer Number	Customer Name	Place	Type of Item (REF, FROZ, NON)	Item code
	102	Beckham, David	Des Moines	Ref	1001
				Ref	2101
				Ref	555
				NON	686
				NON	1232
				NON	145
				Froz	100
	87	Scholar, Paul	Des Moines	Ref	1001
				Ref	545



Figure 17: SOP for setting up refrigerators

Operator 3 – Stacking Goods

1) Take the REF goods from the checked in pile and place them in their respective fridge locations by producer.



2) Take the FROZ goods from the checked in pile and place them in their respective place by location in the freezer.



3) Steps 3 (REF) and 4 (FROZ) show how to read the tags.

Producer
Product ID – Product



1) IFC - Customer # - Location – FROZ
 Customer Name
 Producer Name
 Product # - Product Name



Figure 18: SOP for stacking refrigerated goods

The general process followed in the study as per what happens in a food hub was; one participant checked the producers in, making sure all the items were there. Simultaneously, the second participant sets up the shelves for the dry goods while the third participant sets up the refrigerators/freezers for the respective goods. Once the set up was complete, the second and third participant move on to stacking the goods. Time taken to stack the dry/refrigerated/frozen goods per producer was noted by the PI. It was determined from the observational data collected prior to the study that each producer will be introduced at an interval of 5mins each. In case the participants finished the stacking before the pre-determined 5mins, the volunteers were asked to double check the location of each product. Once the goods for all eight producers are stacked, the PI counted the number of errors for the stacking process by checking the goods for each customer.

The next process is the packing process for which verbal instructions were given for all the groups and specific instructions regarding what needs to be done was given for the treatment groups T2 and T4. T2 and T4 participants were also given Standard Operating Procedure as shown in Figures 19, 20 and 21 which clearly demarcates work according to participant. . The items were supposed to be packed into containers with respect to the location for dry/refrigerated/frozen goods respectively with a written tag signifying what type of goods and where the goods are supposed to be delivered in the respective container. The participants also had to label the dry goods and frozen containers noting down the respective customers in each container. The refrigerated goods container just needed to be labeled with the respective delivery location name. The packaged containers were checked to see whether there is any errors and the total number of errors per place was noted down.

Packing Goods – Dry Goods
1) Take the empty box to the dry goods location indicated on the Customer List by Location.
2) From the NON goods shelves, pick the quantities indicated on the Customer List by Location sheet from their respective locations and put them into the box.
3) Re-check the Customer List by Location to confirm all products are in the box.
4) When all products from the NON Goods List are in the box, close the box and label it by location. Write down all customer numbers that are in the box on the label.

Figure 19: SOP for packing NON goods

Packing Goods – Frozen
1) Take the empty box to the freezer.
2) From the freezer, pick the quantities indicated on the Customer List by Location sheet from their respective locations and put them into the box.
3) Re-check the Customer List by Location to confirm all products are in the box.
4) When all products from the FROZ Goods List are in the box, label the box by location. Write down all customer numbers that are in the box on the label.

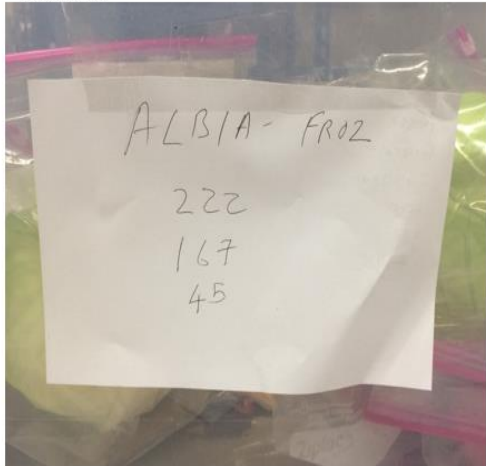


Figure 20: SOP for packing refrigerated goods

ALBIA - REF GOODS LIST			
Quantity	Producer	Product	Check
2	Athletico	Tomato	
1	Madrid	Carrot (3 nos)	
1	Barca	Bell Peppers Mixed (3nos)	
1	Athletico	Tomato	
1	Milan	Carrot (3 nos)	
2	Madrid	Cucumber	
2	Barca	Bell Peppers Mixed (3nos)	
2	Milan	Cabbage	
1	Athletico	Carrot (3 nos)	

3) When all products from the REF Goods List are in the box label it by location.

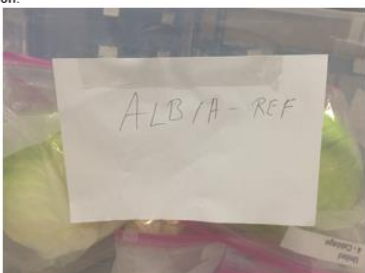


Figure 21: SOP for packing frozen goods

The study ended with the participants all given a team interaction scorecard where they were asked to rate their team-members based on five criteria (Loughry, M. et.al, 2014). The five criteria's being,

- Contributed to teams work?
- How was interaction among team members?
- Kept the team on track?
- Had expected quality of work?
- Had relevant knowledge, skills and abilities?

Participants were asked to fill a discomfort survey (APPENDIX D) and also asked to fill a questionnaire with a few questions (APPENDIX E)

CHAPTER 3

RESULTS AND DISCUSSION

Results

The five KPI's affecting the operational performance was determined to be Time to stack, Time to pack, Numbers of errors while stacking, Number of errors while packing and Team Interaction score. Since we have a full factorial 2*2 model, 2 Way ANOVA at 95% confidence interval was performed on the data to check if the changes made created a significant difference or not. To determine whether the data is normal, the Box Cox method was used and transformation was done as necessary to make the data normal.

Time to stack

The time to stack was found by calculating the total time taken to stack all the different type of goods (dry, refrigerated and frozen) per producer. The individual times were added up and a total time was calculated per group. Figure 22 shows the average time per treatment group. It can be seen that the average time to stack is lesser for Treatment groups T2 and T3 is less than Treatment groups T1 and T4. It was also noted that the initial dry goods set up time taken for the Treatment groups with the Process Improvements (T2 and T3) was around 10% lesser than the time taken by Treatment groups T1 and T4. This is a significant improvement since this is generally the process that takes maximum time in a Food hub.

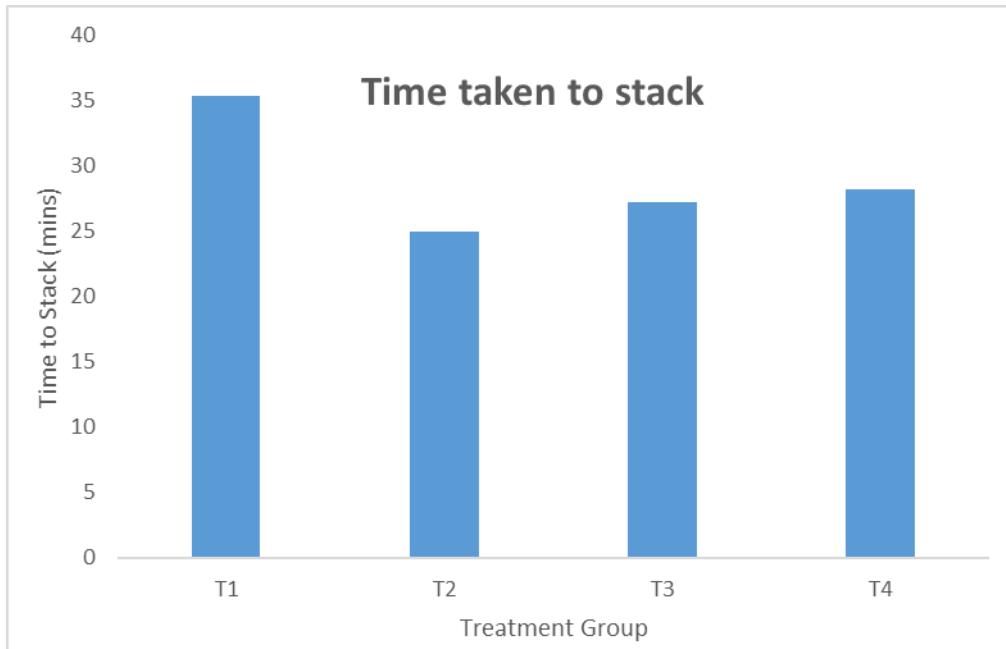


Figure 22: Average time taken to stack per treatment group

Since the data set is less than 30, a Box Cox test for normality was done and the results were determined to be normal as seen in Figure 23.

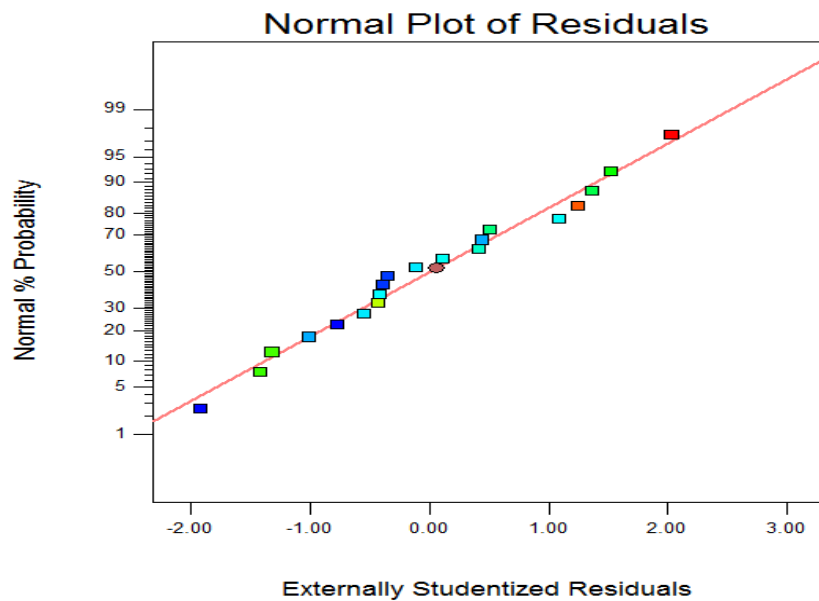


Figure 23: Normality plot for time to stack

Since the data was normal, a 2 way ANOVA was done. The results as shown in Figure 24 clearly shows a p value less than 0.0001 for the model on the whole, p value of 0.0001 for the Process Improvement, a p value of 0.0007 for Training and a p value of 0.0439 for both together which shows that there is an interaction between the two variables. Thus, we can see that the main effects and the interaction of the independent variables are both significant as any p value < 0.05 is deemed significant.

Response 1 Time to stack					
ANOVA for selected factorial model					
Analysis of variance table [Partial sum of squares - Type III]					
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	300.99	3	100.33	16.19	< 0.0001 significant
A-Process In	161.60	1	161.60	26.08	0.0001
B-Training	109.75	1	109.75	17.71	0.0007
AB	29.65	1	29.65	4.79	0.0439

Figure 24: Summary of ANOVA results for the independent variables for time to stack

Figure 25 shows that the both the Process Improvement and Training Factors negatively affect the time to stack. In addition, it is clear that the interaction effect of these two factors is playing a role in reducing the time to stack. Moving from without training to with training caused larger reduction in time to stack under the without process improvement condition compared to with process improvement condition. From the slope of the two plots, it can also be seen that Process Improvement plays a bigger role in the 'Without training' condition as compared to the 'With Training' condition. Based on the above statements, it can be concluded that 'With Process Improvement' and 'With Training' will lead to the lowest time to stack.

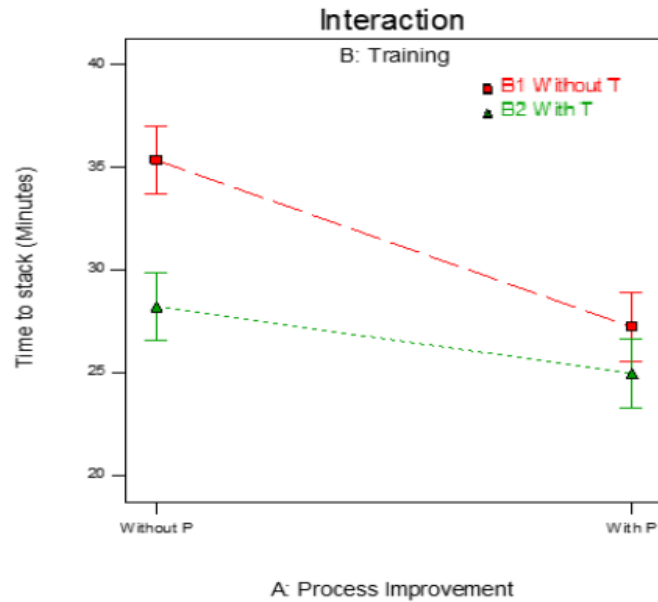


Figure 25: Interaction plot for variables Training and Process Improvement – time to stack

Time taken to pack

The time to pack was calculated by calculating the total time taken to pack all the different type of goods (dry, refrigerated and frozen) per location into the containers. The individual times per location was added up and a total time was calculated per treatment group. Figure 26 shows the average time taken to pack per treatment group. It is clear to see that the groups with training T2 and T4 have the lesser average time compared to the control group T1 and T3.

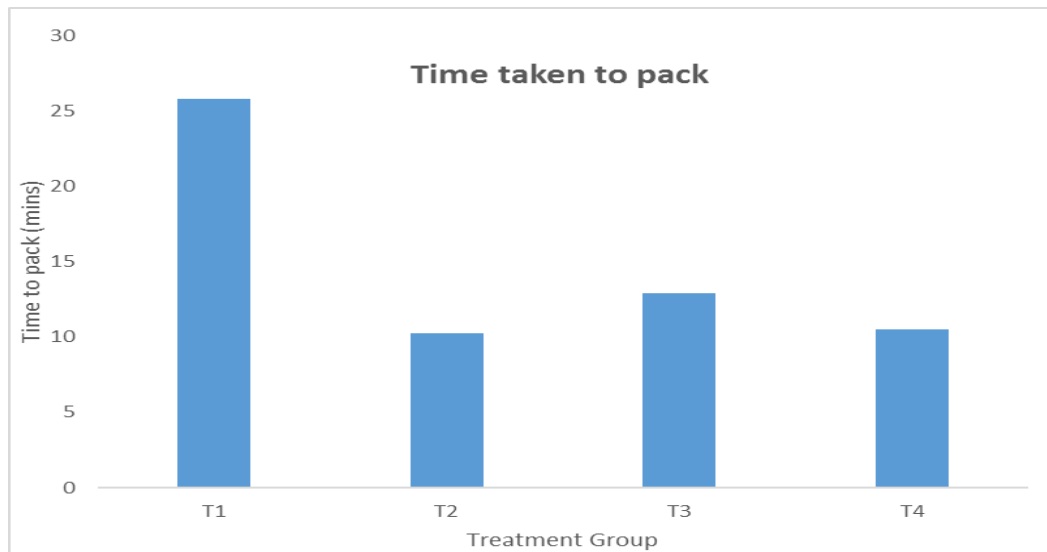


Figure 26: Average time taken to pack per treatment group

Since the data set is less than 30, a Box Cox test for normality was done and the results were determined to be normal as seen in Figure 27.

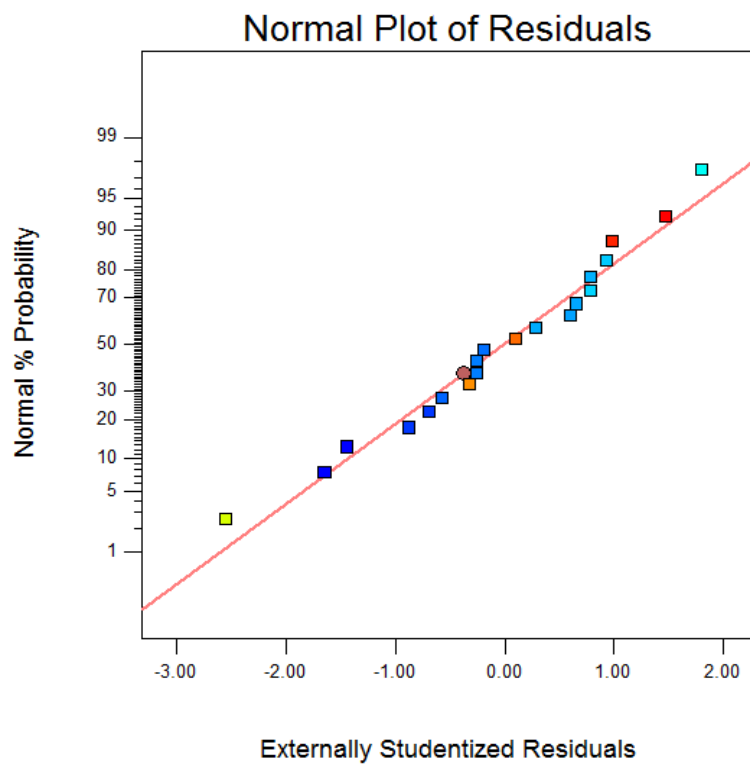


Figure 27: Normality plot for time to pack

A 2-way ANOVA was done on the data and the results as shown in Figure 28 clearly shows a p value less than 0.0001 for the model on the whole, just for training and just for process improvement. Also, a p value less than 0.0001 for both Training and Process Improvement together which shows that there is an interaction between the two variables. Thus we can see that the main effects and the interaction of the independent variables are both significant.

Response 3 Time to pack					
ANOVA for selected factorial model					
Analysis of variance table [Partial sum of squares - Type III]					
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	876.02	3	292.01	91.17	< 0.0001 significant
A-Process In	288.04	1	288.04	89.94	< 0.0001
B-Training	320.80	1	320.80	100.16	< 0.0001
AB	267.18	1	267.18	83.42	< 0.0001

Figure 28: Summary of ANOVA results for the independent variables for time to pack

Figure 29 shows that training majorly negatively affect the time to pack. In addition, it is clear that the interaction effect of these two factors plays a role. Moving from without training to with training caused a larger reduction in time to pack under the without process improvement condition compared to with process improvement condition. From the slope of the two plots, it can also be seen that Process Improvement plays a bigger role in the 'Without training' condition as compared to the 'With Training' condition. Based on the above statements, it can be concluded that 'Training' leads to the lower time to pack irrespective of Process Improvement.

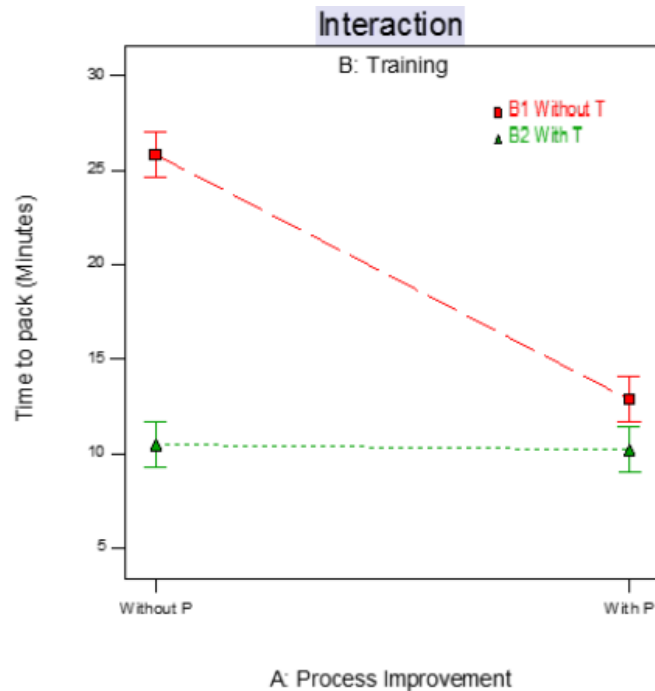


Figure 29: Interaction plot for variables Training and Process Improvement – time to pack

Number of errors while stacking

The number of errors while stacking was found by calculating the number of errors per location per type of goods. Total number of errors were found by adding up individual number of errors.

Figure 30 shows the average number of errors per treatment group. It is clear to see that the groups with process improvement (T2 and T3) have the lower average number of errors as compared to Treatment groups T1 and T4. Another factor that was seen from the study was that the around 90% of the errors in stacking came due misplaced dry goods and the additional check included in the Process Improvement Treatment groups T2 and T3 has caused a decrease in the average number of errors due to stacking.

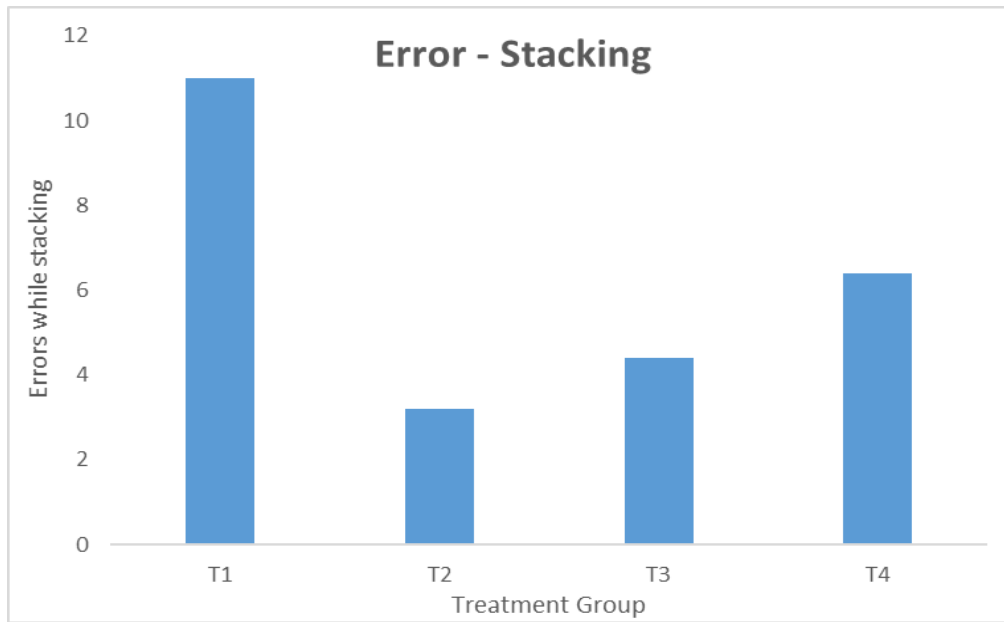


Figure 30: Average number of errors during stacking per treatment group

Since the data set is less than 30, a Box Cox test for normality was done and the results were determined to be normal as seen in Figure 31.

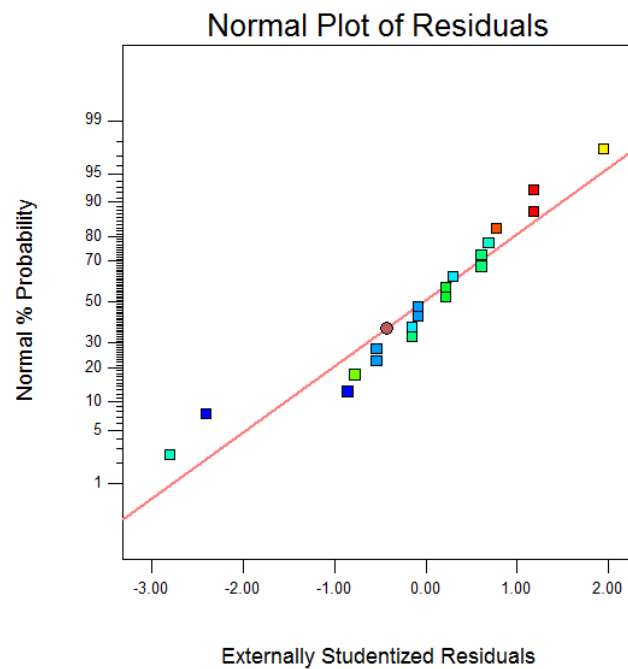


Figure 31: Normality plot for number of errors while stacking

A 2-way ANOVA was done on the data and the results as shown in Figure 32 clearly shows a p value of 0.0029 for the model on the whole. The p value for just Process Improvement is 0.0015 and the p value for Training is 0.0378. The p value for interaction is 0.2030. Thus we can see that the main effects are significant but the interaction in itself is not significant and this can be seen in the interaction plot in Figure 33.

Response 2		Number of Error - Stack				
ANOVA for selected factorial model						
Analysis of variance table [Partial sum of squares - Type III]						
	Sum of		Mean	F	p-value	
Source	Squares	df	Square	Value	Prob > F	
Model	176.55	3	58.85	7.18	0.0029	significant
A-Process In	120.05	1	120.05	14.64	0.0015	
B-Training	42.05	1	42.05	5.13	0.0378	
AB	14.45	1	14.45	1.76	0.2030	

Figure 32: Summary of ANOVA results for the independent variables for number of errors while stacking

Figure 33 shows that the both the Process Improvement and Training Factors negatively affect the number of errors during stacking. Moving from without-training to with-training caused larger reduction in number of errors while stacking under the without process improvement condition compared to with process improvement condition. From the slope of the two plots, it can also be seen that Process Improvement plays a bigger role in the 'Without training' condition as compared to the 'With Training' condition. It can be seen from the graph that the 'With Training' and 'With Process Improvement' condition has the lowest number of errors.

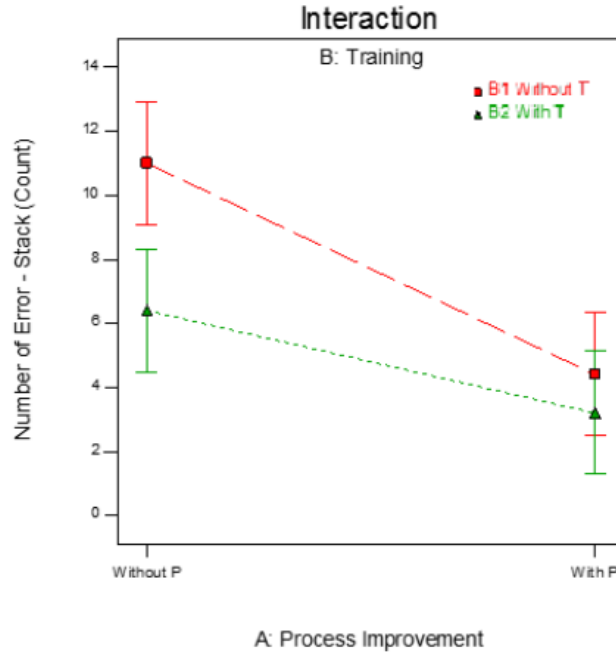


Figure 33: Interaction plot for variables Training and Process Improvement – number of errors while stacking

Number of errors while packing

The number of errors while packing was found by calculating the number of errors per location/type of goods and the total number of errors was found by adding up individual numbers. Figure 34 shows the average number of errors per treatment groups. It can be clearly seen that Treatment groups T2 and T3 have the least average error as compared to Treatment groups T1 and T4. Again, as discussed in the previous section, the majority of the errors during packing was due to the wrongly stacked dry goods and the double check measure added as part of Process Improvement has reduced the number of errors while packing significantly.

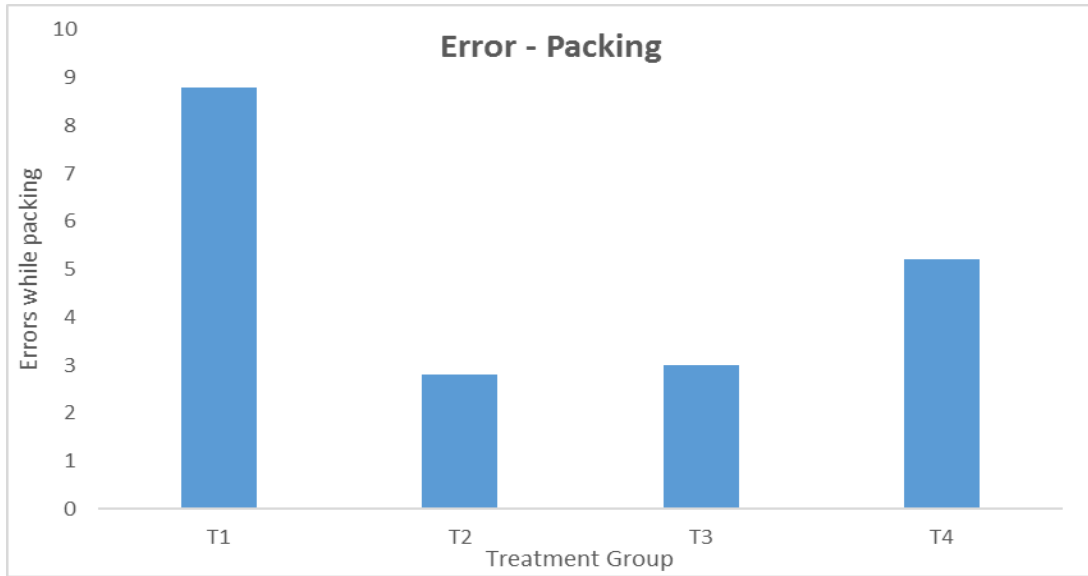


Figure 34: Average number of errors while packing per treatment group

Since the data set is less than 30, a test for normality using the Box Cox method is done on the data and it was seen that the data was not normal. A square root transformation was done on the data and the resulting set of data was found to be normal as seen in the Figure 35.

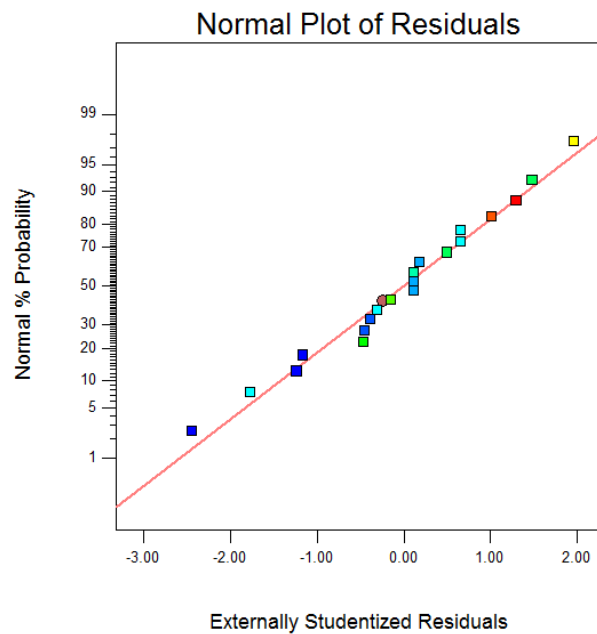


Figure 35: Normality plot for number of errors while packing

A 2-way ANOVA was done on the data and the results as shown in Figure 36 clearly shows a p value of 0.0029 for the model on the whole. The p value for just Process Improvement is 0.0050 and the p value for Training is 0.1176. The p value for interaction is 0.2183. Thus we can see that the main effect from Process Improvement is the only one that has a significant impact on the numbers of errors due to packing. Training in itself and the interaction is not significant in this case.

Response 4 Number of errors - Pack					
Transform: Square Root Constant: 0					
ANOVA for selected factorial model					
Analysis of variance table [Partial sum of squares - Type III]					
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	5.35	3	1.78	4.74	0.0150 significant
<i>A-Process In</i>	3.98	1	3.98	10.57	0.0050
<i>B-Training</i>	0.75	1	0.75	2.00	0.1766
<i>AB</i>	0.62	1	0.62	1.64	0.2183

Figure 36: Summary of ANOVA results for the independent variables for number of errors while packing

From Figure 37, it was observed that Process Improvement and training factors negatively affect the number of errors while packing. Statistically, moving from without training to with training does not reduce the number of errors while packing under the without process improvement condition compared to with process improvement condition. From the slope of the two plots, it can also be seen that Process Improvement plays a bigger role in the ‘Without training’ condition as compared to the ‘With Training’ condition. It can also be concluded that in the ‘With Process Improvement’ groups, training does not play a big role in reducing the number of errors as the average number of error is almost the same.

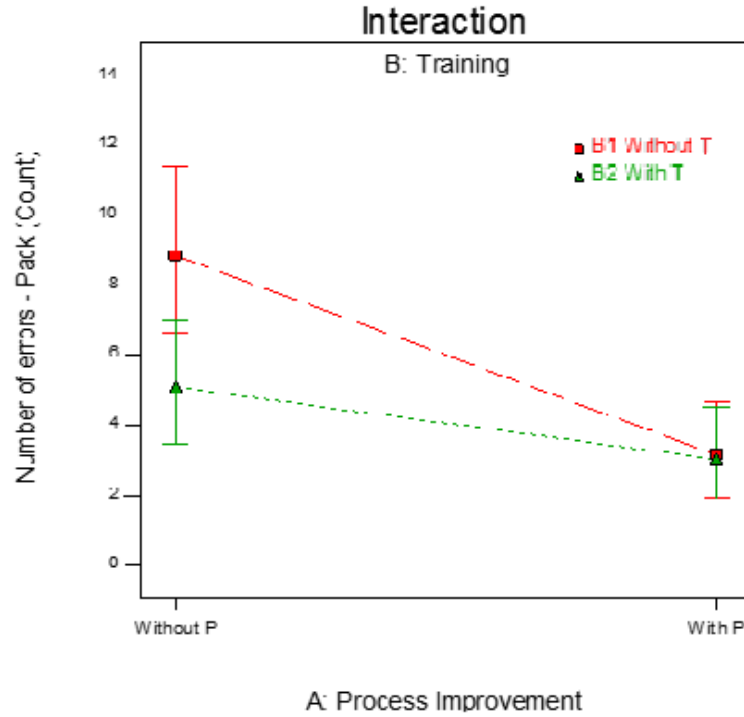


Figure 37: Interaction plot for variables Training and Process Improvement – number of errors while packing

Team Interaction

The team interaction score per group was calculated by adding up individual scores as per the team interaction score chart. Figure 38 shows the average Team Interaction score per Treatment group. It can be seen from the figure below that the team interaction score is higher for the Treatment groups T2, T3 and T4.

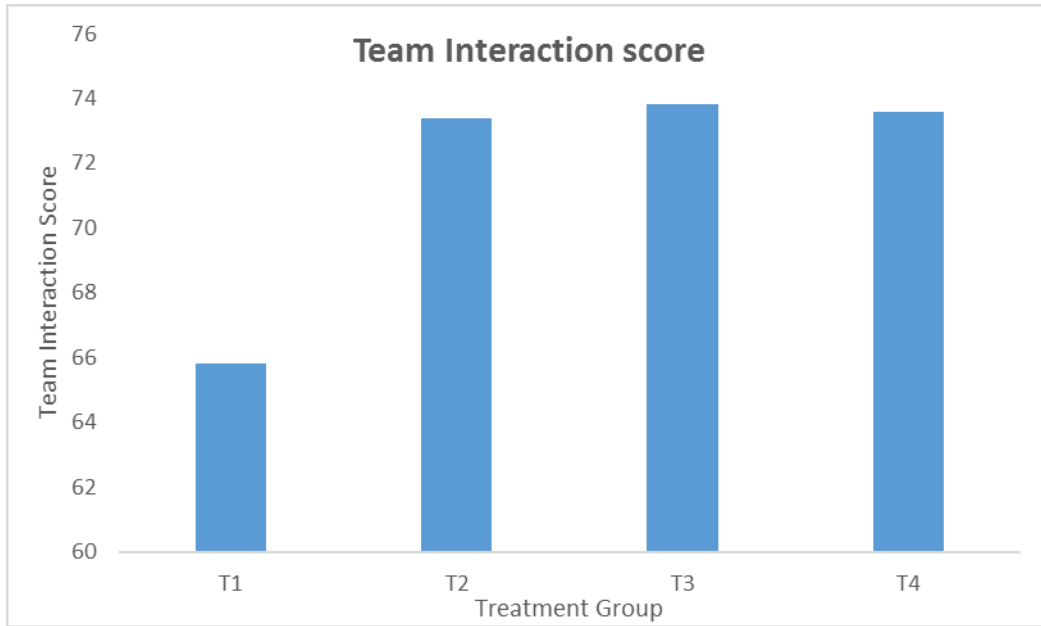


Figure 38: Average team interaction score per treatment group

Since the data set is less than 30, a test for normality using the box-cox method is done on the data and it was seen that the data was normal as shown in the figure below.

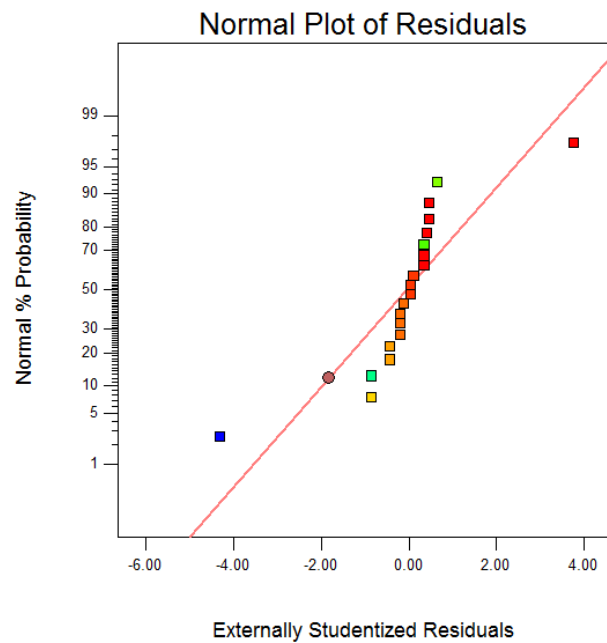


Figure 39: Normality plot for time to stack

A 2-way ANOVA was done on the data and the results as shown in Figure 40 clearly shows a p value of 0.0081 for the model on the whole. The p value for just Process Improvement is 0.0312 and the p value for Training is 0.0395. The p value for interaction is 0.0245. Thus it is seen that the main effects Training and process improvement as well as the interaction is all important.

Response 5 Team Interaction					
ANOVA for selected factorial model					
Analysis of variance table [Partial sum of squares - Type III]					
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	228.55	3	76.18	5.59	0.0081 significant
A-Process In	76.05	1	76.05	5.58	0.0312
B-Training	68.45	1	68.45	5.02	0.0395
AB	84.05	1	84.05	6.17	0.0245

Figure 40: Summary of ANOVA results for the independent variables for team interaction score

Figure 41 shows that the training majorly affects the team interaction score. In addition, it is clear that the interaction effect of these two factors plays a role. Moving from without-training to with-training caused larger reduction in team interaction score under the without process improvement condition compared to with process improvement condition. From the slope of the two plots, it can also be seen that Process Improvement plays a bigger role in the 'Without training' condition as compared to the 'With Training' condition. It can also be seen from the straight line for 'With Training' that once training is provided, it does not make a difference whether there is process improvement or not.

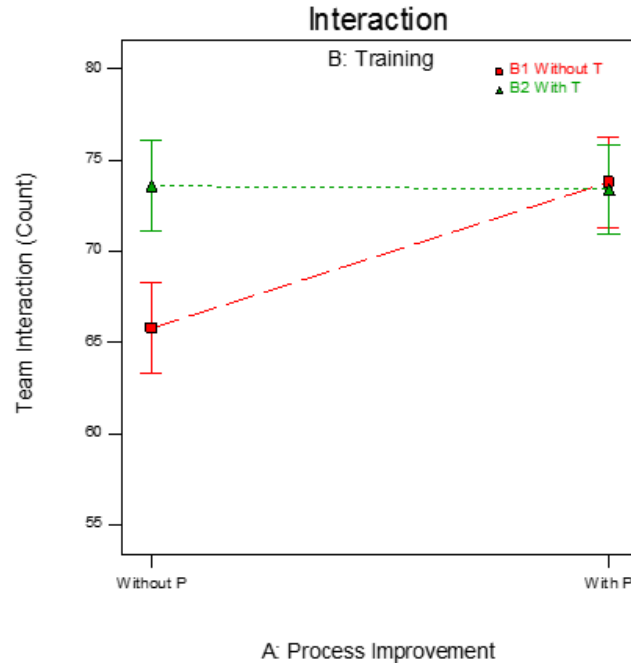


Figure 41: Interaction plot for variables Training and Process Improvement – time to stack

General Discussion

From the experiment results, the effectiveness of the introducing Scientific Management Principles in food hub to improve the operational efficiency was assessed using various KPI's like time to stack, time to pack, number of errors while stacking, number of errors while packing and the team interaction score. As you go through the results, it is clear to see that there is an overall improvement.

If we consider each of the KPI's individually, the effect of Process Improvement, Training and their interaction is different on each. If we take the case of time to stack, we can see that Training, Process Improvement and interaction are all significant. It was observed that the best option is to go with a combination of Training and Process improvement to get the best efficiency in terms of time to stack. If we take the case of time to pack, it was seen that Training, Process Improvement and interaction are all significant. It was observed that the best results

were observed when Training and Process Improvement were combined. In the case of number of errors to stack, it was seen that Process improvement and Training are both significant but the interaction is not significant. Another factor that was observed that almost 90% of the errors during the stacking process was made in the dry goods stacking process and the improved process that has the additional check made to catch the error, reduced the number of error significantly. When the Number of errors to pack data is analyzed, it was noted that Process improvement is significant in reducing the errors whereas Training alone and their interaction was not significant. When the Team interaction score data was analyzed, it can be seen that Training, Process Improvement and Interaction are all significant, but it was difficult to conclude which factor alone made a bigger impact. Training does play a pivotal role in improving the Team interaction score. The biggest factor in the team interaction study that was the Quality of work showed an increase in its mean value of 3.4 to 5 for the Training treatment groups (T2 and T4).

Furthermore, in the questionnaire that was answered by the participants, an overwhelming 100% of participants in T1 and T3 felt that standard work procedure and training at the beginning of the study would have helped improve the overall efficiency. 92% of the participants for T1 and T4 felt that the stacking process was confusing and only 3% of the participants in T2 and T3 felt it confusing after the process improvements. Also, another factor that was seen was that the initial set up time for stacking the dry goods came down by around 10% for the Treatment groups with the process improvement. This is a major improvement because in the large scale food hub, this is the first process that is done and the completion of this governs the time taken by the other process and thus can make a significant improvement in the overall process. The new process also negates the use of magnetic tags and thus offers a financial advantage too.

It can be concluded that a combination of both Training and Process Improvement is the way to move forward if the objective is an overall operational efficiency improvement. Thus it can be concluded that introduction of Scientific management principles does improve the efficiency of a food-hub.

CHAPTER 4

CONCLUSION

This paper attempts to highlight the importance of introducing scientific management principles in the food hub operation. It can be clearly seen from the observational study and the experimental results that the current ad-hoc process has a high scope of improvement. It can be concluded that Training and Process Improvement when introduced together offers an improvement in the overall efficiency of the food hub in terms of its key KPI's like time to stack, time to pack, number of errors while stacking, number of errors while packing and the overall team interaction.

Food hubs are a key player when it comes to a bridging the gap between sustainability and social economy. In short, food hubs are creating a symbiotic culture between social and environmental objective in the way food is produced, accessed and consumed. Food hubs thus play an important role in scaling up the sustainable regional and local food systems. Thus, food hubs with their mode of functioning is a direct contributor to sustainable agriculture, which is a method of farming that minimizes environmental damage and depletion of resources. For the food hubs to be grow, the operational efficiency and volunteer participation has to increase with a decrease in volunteer attrition which is what we see with the introduction of scientific management principles.

In summary, scientific management principles does have a positive impact on the operational efficiency of food hubs.

Future work

In this study, five KPI's were analyzed and it is clear that introducing the proposed changes brings about an improvement in the efficiency. As a part of future work, detailed KPI's can be analyzed and each activity can be taken in isolation and studied. Standardizing the whole process by standardizing the process to stack and pack the different type of goods could be studied. This would help in making a standard process and will make training the volunteers easier. Using a higher sample size and changing up the different team sizes will give more reliable data. Another factor that could be considered is a test for familiarity by making the same group who did test in one particular condition do the test once more in the same condition and analyze how much that improves performance as compared to introducing Training and Process Improvement. Ergonomic improvements could be made and tested in addition to the other improvements.

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APPENDIX A IRB APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 201
Ames, Iowa 50014
Tel: 515-294-4760

Date: 2/9/2017

To: Dean Jose
4710 Steinbeck St., Apt. 307
Ames, IA 50014

CC: Dr. Richard T Stone
3004 Black Engineering
Jaipravin Vijayarangan
4710 Steinbeck St., Apt. 307

From: Office for Responsible Research

Title: Scientific evaluation and redesign of food hub operations

IRB ID: 16-535

Approval Date: 2/7/2017

Date for Continuing Review: 12/9/2018

Submission Type: Modification

Review Type: Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- Use only the approved study materials in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.
- Retain signed informed consent documents for 3 years after the close of the study, when documented consent is required.
- Obtain IRB approval prior to implementing any changes to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.
- Stop all research activity if IRB approval lapses, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- Complete a new continuing review form at least three to four weeks prior to the date for continuing review as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. Approval from other entities may also be needed. For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. IRB approval in no way implies or guarantees that permission from these other entities will be granted.

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 202 Kingland, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B INFORMED CONSENT FORM

ISU IRB # 1	16-535
Approved Date:	7 February 2017
Expiration Date:	19 December 2018

INFORMED CONSENT DOCUMENT

Title of Study: Scientific evaluation and redesign of food hub operations

Investigators: Dean Jose, Dr. Richard Stone, Dr. Caroline Krejci, Dr. Michael Dorneich, Dr. Richard Stone, Zhonglun Wang

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Please discuss any questions you have about the study or about this form with the project staff before deciding to participate.

Introduction

The objective of this study is to simulate the current jobs in food hubs and conduct a classical ergonomics analysis on the jobs in a normal shift at the food hub, analyze the efficiency of the jobs currently done and analyze how good the proposed methods for improvement are.

You are being invited to participate in this study because you are over the age of 18, weigh at least 105 pounds, and do not use a heart pacemaker or an automatic defibrillator.

Description of Procedures

If you agree to participate, you will be asked to sign this consent form. You are requested to wear athletic clothes and shoes to the experiment. Tank tops are not allowed. After signing, height and weight measurements will be collected. You will be asked to complete a discomfort survey that asks you about your perceived level of discomfort for specific parts of your body. You will then be equipped with a heart rate monitor. Heart rate data will be collected for the remainder of the experiment. Before beginning the trial, you will be asked to sit and remain silent for 5-10 minutes so resting data can be collected.

The participants will be given instructions about the study and participants are encouraged to ask any questions regarding the study.

The Audio and video recording will begin at this point right before the actual task starts. The task and how it is done will be recorded for further investigation later during the analysis phase in case any extra clarification is needed regarding the data collected. The audio recording is mainly to analyze team interaction among the participants in both the treatment groups.

Part 1 - 1 hour - Arranging the deliveries in to the designated areas in the shelves (The shelves will be named accordingly). The PI and/or the Co-PI will make 20 deliveries of different food items and set it in a designated area. The weight of the food items would not exceed 5 pounds. From this area, the participants have to take these and keep it on the designated shelves.

This will continue for an hour after which the food item delivery will stop.

Part 2 - At the completion of part 1, the participants have to take these food items from the shelves and keep it in the packets for each customer (Packets will be named and the items needed for the customer will be noted on the packet like current practice)

Participant will complete the discomfort survey again. Participant will remain standing while taking this discomfort survey. Sensors will be removed. The participants will be given a team interaction score sheet where they will score their teammates on five attributes. [Attachment 6] Participant will participate in an informal interview [Attachment 5].

Your participation will last around 3 hours. The questionnaire, height and weight measurements, and discomfort survey should take a total of 5-10 minutes. Getting equipped with the heart rate monitor as well as collecting baseline data should take 15 minutes. Part 1 of the study should take 1 hour and the 2nd part should be done within 30 minutes. Removing the sensors, taking the discomfort survey and completing the informal interview should take around 15 minutes.

Risks or Discomforts

While participating in this study you may experience the following risks or discomforts: picking up loads of around 5 pounds, frustration of performing the tasks. You will be monitored throughout the experiment and if you experience too much physical or mental discomfort, you will be allowed to terminate the trial at any time and the facilitator will immediately stop the trial. If any participant is feeling anxious because of the EMG electric pulses, you are free to let me know and will be allowed to discontinue from the trial.

Benefits

If you decide to participate in this study, there will be no direct benefit to you. It is hoped that the information gained in this study will benefit society by advancing the knowledge of backpack features, usage, and design.

Costs and Compensation

You will not have any costs from participating in this study. If you are a student in Dr. Stone's IE 271, you will receive up to 5% extra credits points for participation in the study. Should you choose to withdraw from the study at any time, you will still receive full credit. There will be no effects on students' grades or standing with the course instructors beyond extra credit. If you are not a student in IE 271, no compensation will be offered.

Alternatives to Participation

Students in IE 271 may alternatively choose to complete an auxiliary homework based extra credit assignment worth the same amount of points.

Participant Rights

Participating in this study is completely voluntary. You may choose not to take part in the study or to stop participating at any time, for any reason, without penalty or negative consequences. You can skip any questions that you do not wish to answer. Your choice of whether or not to participate will have no impact on you as a student/employee in any way.

If you have any questions *about the rights of research subjects or research-related injury*, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

Confidentiality

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy study records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken: all participants will be assigned a research identification number. Identifying information will be collected, retained, and kept confidential. Your information will be kept in a locked filing cabinet and/or a password protected computer file. In the case of the video being used in the presentation or in the thesis, the faces will be blurred.

Questions

You are encouraged to ask questions at any time during this study. For further information *about the study*, contact the principal investigator, Dean Jose, at deanjose@iastate.edu or the supervising faculty member, Dr. Richard Stone, at rstone@iastate.edu.

Consent and Authorization Provisions

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document, and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant's Name (printed) _____

Participant's Signature

Date

Participants needed!

Iowa State University is currently conducting a study regard ergonomic assessment in the food hub, it will help the food hub to build a better ergonomic environment to prevent injuries.

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available.

Participation will be voluntary and you may quit the study at any time if you do not wish to finish the study. There will be no compensation provided for this study. All identifying details such as names, video and audio information will be kept confidential and will not be used in publication.

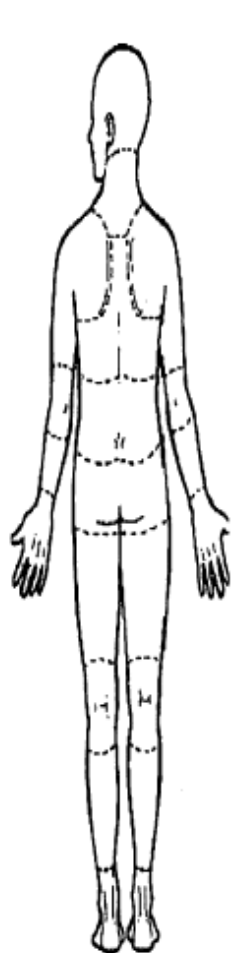
Dean Jose, deanjose@iastate.edu

Email: deanjose@iastate.edu

[illegible]

APPENDIX D DISCOMFORT SURVEY

Discomfort Survey



	😊				☹️
Eyes	1	2	3	4	5
Neck	1	2	3	4	5
Shoulder(s)	1	2	3	4	5
Elbow(s)	1	2	3	4	5
Lower Back	1	2	3	4	5
Forearm(s)	1	2	3	4	5
Wrist/Hand(s)	1	2	3	4	5
Thigh(s)	1	2	3	4	5
Knee(s)	1	2	3	4	5
Lower Leg(s)	1	2	3	4	5
Foot/Ankle(s)	1	2	3	4	5

APPENDIX E QUESTIONNAIRE

Post Experimental Interview questions

1. Did you face any discomfort during the survey? If Yes, what were the discomforts?
2. Was it specifically during a certain task?
3. Which task did you think was the most time consuming or confusing?
4. Do you think you could improve any task that you did? Any suggestions to improve this?
5. Do you think that specific instructions at the beginning will help you/helped you with the activity?
6. Do you think placement of the final baskets influenced the time and effort you had to put in?