Increasing Food Sharing in a PreK-8 School Cafeteria with Six Sigma

Sanukta Mylandla

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INCREASING FOOD SHARING IN A PREK-8 SCHOOL

CAFETERIA WITH SIX SIGMA

An Integrated Project

Submitted to the Faculty

Of

ROSE-HULMAN
INSTITUTE OF TECHNOLOGY

Department of Engineering Management

By

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In Partial Fulfillment of the Requirements for the Degree

Of

Master of Science in Engineering Management

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ABSTRACT

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Increasing Food Sharing in a PreK-8 School Cafeteria with Six Sigma

Thesis Advisor: Dr. Diane Evans

Six Sigma, a statistics-based methodology developed by Motorola in the mid-1980’s to help reduce defects, is a tool commonly applied across various industries to improve their processes by reducing variation. The statistical nature of Six Sigma makes process improvement a quantitative study garnering potential real savings to an organization. This project’s goal was to apply Six Sigma methodology to a PreK-8 school cafeteria in order to measure the daily levels of food waste and convert it into meaningful data to be used to promote food rescue and reuse at local elementary schools.
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ABBREVIATIONS

1. DMAIC – Define, Measure, Analyze, Improve and Control
2. VCSC – Vigo County School Corporation
3. FAO – The Food and Agriculture Organization of the United Nations
4. USDA – United States Department of Agriculture
5. NSLP – National School Lunch Program
6. VOC – Voice of Customer
7. C&E Diagram – Cause and Effect Diagram
8. SIPOC – Supplier-Input-Output-Process-Customer
9. Gage R&R – Variable Gage Repeatability and Reproducibility Analysis
10. MSA – Measurement System Analysis
11. NDC – Number of Distinct Categories
12. RHIT – Rose-Hulman Institute of Technology
13. ANOVA – Analysis of Variance
15. LSL – Lower Specification Limit
16. USL – Upper Specification Limit
17. DPM – Defects per Million
18. C&E Matrix – Cause and Effect Matrix
19. FMEA – Failure Modes and Effect Analysis
20. DOE – Design of Experiments
21. KPIVs – Key Process Input Variables
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1. INTRODUCTION

During Spring Quarter 2017, the “Six Sigma in Practice” class at Rose-Hulman Institute of Technology began a Six Sigma Black Belt project with two main goals: 1) to quantify and reduce the amount of cafeteria food waste generated by school children during their lunch periods; and 2) to rescue and redistribute their unopened, yet discarded, food. In attempting to reduce the food waste, we used the Six Sigma data-driven problem-solving methodology called the DMAIC, where DMAIC represents Define, Measure, Analyze, Improve, and Control.

In order to improve a process, its baseline measurements must be calculated. Thus, to measure food waste, we did the following: 1) had students hand us their trays at the end of each lunch period; 2) scraped their uneaten food into large categorized buckets (milk, vegetables, fruits); 3) weighed the buckets; 4) and logged the weights into a spreadsheet. Any unopened foods/drinks or unpeeled fruits that could be redistributed for reuse were counted and placed on a table by the students to share with others.

During the project’s improvement phase, our class worked with the school’s 5th graders to implement possible solutions to reducing food waste. After improvements were in place, food waste was measured again. After the improvement measures were put in places, the project was handed over to the students of St. Patrick’s. This summarizes the first half of the project.

The next part of this project was carried out solely by me during the academic year of 2017-2018. During this time, the data collected pre and post improvement were analyzed, and converted into meaningful information. I undertook data analysis of the pre-improvement data using statistical tools such as control charts, capability analysis, ANOVA, etc. Following this, a thorough analysis
of the post-improvement data was carried out to determine any improvements in the food waste amounts generated and various potential causes were determined to explain the results obtained. This was topped off by summarizing the project’s outcomes, challenges faced, and lessons learned during the course of the project.

Our original plan was to work with a public school in Terre Haute on this project. However, we were not able to obtain the school district’s superintendent’s permission to do so. He was concerned that the school district could be found liable if students became ill from eating redistributed food, even if it was unused and unopened. The issue of liability was the main reason why the Vigo County School Corporation (VCSC) did not have food rescue programs at its schools.

We then approached St. Patrick School, which is a private PreK-8 school in Terre Haute. We thought a private school would have more latitude than a public school in trying a project like ours. The administration at St. Patrick’s eagerly agreed to do the project with our class and allowed their 5th graders to participate in the process improvement phase of the project.

In this paper, we will first discuss, generally, food waste in schools, the concepts of food security and food insecurity, poverty and how it relates to food insecurity, and how school children can be given better access to food through food rescue programs at schools. We will then discuss in detail how we used the DMAIC methodology of Six Sigma on this project.

Upon completion of our project at St. Patrick’s, we provided the VCSC with a summary of our data that showed the amounts of food wasted at a school cafeteria and how much food, that would have otherwise been discarded, could be redistributed to children in need of food. We hoped that the data would encourage the VCSC to implement a food rescue program in its public schools,
whose students had a greater need for food rescue than St. Patrick’s. In the summer of 2017, “Six Sigma in Practice” professor, Dr. Diane Evans, worked with Vigo County Purdue Extension\textsuperscript{[1]} so it could launch a pilot food rescue program at Farrington Grove Elementary School, a public school in Terre Haute. Vigo County Purdue Extension personnel and Dr. Evans made presentations to the VCSC superintendent regarding the need to have food rescue programs at the public schools and our Six Sigma project at St. Patrick’s, respectively. Pursuant to their recommendations, the VCSC superintendent granted Vigo County Purdue Extension permission to run the pilot program at Farrington Grove Elementary School. The results of that pilot program will be discussed in more detail in the Control section.

\textbf{Figure 1:} St. Patrick School in Terre Haute, Indiana. In Spring 2017, the school had 343 students grades PreK-8.
2. FOOD WASTE IN THE U.S. AND AT SCHOOLS

According to the advocacy group Food Rescue, more than 1 in 5 children in the U.S. is at risk of hunger. Among African-Americans and Latinos, it is 1 in 3. [2] Despite these hunger rates, about 40% of all foods in the U.S. end up in landfills. [3] All of this uneaten food could feed 25 million Americans.

In the U.S., over 20 million school children receive free or reduced-price lunch each school day. A vast majority of these students come from low-income families and rely on school meals that provide up to 50% of their energy intake. [4] Yet, schools throw away approximately $1.2 billion worth of food each year. [4]

As far as Vigo County schools, we were not able find any third-party data or studies regarding food waste in the county’s public or private PreK-8 schools. It appears that our project is the first analytical food waste study to be done at a Vigo County PreK-8 school.
3. FOOD INSECURITY AND POVERTY

According to The Food and Agriculture Organization (FAO) of the United Nations, “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.”[5] The FAO further states, “Food insecurity exists when people do not have adequate physical, social or economic access to food as defined above.”[6] While there are many reasons why people may not have access to food needed to have food security, one of the fundamental reasons is that people do not have the economic means to access such foods.[7] Accordingly, people living in poverty are more likely to experience food insecurity.

Looking at data from various sources, we found that the poverty and food insecurity rates in Vigo County were above the national rates. According to the U.S. Census Bureau, the national poverty rate for 2015 was 13.5%.[8] Feeding America, a nonprofit organization that is made up of a nationwide network of food banks assisting in domestic hunger-relief, reported that, in 2015, the U.S. food insecurity rate was 13.8%, which meant that there was about 42.2 million people in the U.S. that were food insecure.[9]

For Vigo County, the 2015 poverty and food insecurity rates are set forth below:

- 20.5% lived in poverty,[10]
- 23.6% of children (ages 5-17) lived in poverty,[11]
- 17.4%, or 18,840 individuals, were food insecure,[12] and
- 27.4% of those 18,840 who were food insecure, or 5,170, were children (under age 18).[12]
4. FOOD RESCUE THROUGH FOOD SHARING

Based on the data in the previous section, Vigo County has a great need for its families living in poverty to attain food security. With respect to food insecure children, one way to help these children have better access to foods is through food rescue programs at their schools. Food rescue, also called food recovery, is “the practice of retrieving edible food that would otherwise go to waste and distributing it to those in need.”\textsuperscript{[13]} Food rescue not only reduces food waste, it also provides additional food to low-income families who experience food insecurity. Food rescue programs have been established at, among other places, restaurants, grocery stores, farms and schools. \textsuperscript{[14]}

One form of a food rescue program at schools is the establishment of a “share table.” A share table serves as an area where students can put their uneaten and unopened food items to share with other students who want additional food. In June of 2015, Indiana became the first state, through the Indiana Department of Health and Indiana Department of Education, to publish guidelines on share tables and food donations.\textsuperscript{[15]} In a June 2016 memo from the United States Department of Agriculture (USDA) to state nutritional directors on the use of share tables in children’s nutrition programs, the USDA stated, “Using share tables is an innovative strategy to encourage the consumption of nutritious foods and reduce food waste in the National School Lunch Program (NSLP).” \textsuperscript{[16]}

Before we began our project, St. Patrick’s already had a share table in its cafeteria. During lunchtime hours, students were able to freely take food items from the table. Any food left on the
share table at the end of the day was taken to the soup kitchen at St. Patrick’ Church. Items that often

![Share table at St. Patrick’s cafeteria including a small bin with ice for shareable dairy products](image)

Figure 2: Share table at St. Patrick’s cafeteria including a small bin with ice for shareable dairy products

...were placed on the share table included unopened milk cartons, unopened packets of string cheese and chips, and unpeeled fruits (e.g., bananas). Although St. Patrick’s had a share table, we found that a lot of food that could have been rescued and redistributed was still being discarded. This was one of the areas that we felt needed improvement.
5. SIX SIGMA - APPLYING THE DMAIC METHODOLOGY

As mentioned earlier, Six Sigma is a detailed data-driven methodology that uses statistical tools to improve a process. Six Sigma began in the 1980’s by Motorola’s Bill Smith, but became popular in 1990’s by GE’s Jack Welch. [17] The methodology is referred to as DMAIC, which represents the five phases of the methodology: Define, Measure, Analyze, Improve, and Control. See Figure 3.

<table>
<thead>
<tr>
<th>DEFINE</th>
<th>MEASURE</th>
<th>ANALYZE</th>
<th>IMPROVE</th>
<th>CONTROL</th>
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<tr>
<td>DEFINE the process that requires improvement; the process must have a measurable output, or metric, $Y$.</td>
<td>Establish the ability to accurately MEASURE $Y$. Then determine a current process, or baseline, value for $Y$.</td>
<td>Identify, organize, and ANALYZE the key process input, variables $x$’s, that affect $Y$. Then determine the $x$’s that need to be adjusted.</td>
<td>IMPROVE the process by adjusting the $x$’s that affect $Y$. Measure the process value for $Y$ following improvements.</td>
<td>CONTROL the process (e.g., use control charts) to sustain the gains. Then determine next steps for ongoing improvement.</td>
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Figure 3: An outline of the phases of the DMAIC methodology

The DMAIC methodology can be thought of as a roadmap to solve problems and make improvements on processes or products. [18] While the phases may appear to be linear, the phases can be iterated. So, for example, if in the analyze phase project team members determined that more data was needed to properly do the analysis, then the team may have to go back to the measure phase to obtain that data. A project team can go through various iterations in refining their analyses and improvements to maximize the effectiveness of their solutions.
5.1 Define

The Define phase is the foundation of a Six Sigma project. For this phase, the class had to define the following for the project:

- Customers;
- Problem statement;
- Metrics;
- Scope;
- Project goals and objectives; and
- Improvement activities.

5.1.1 The Customers

There are two customers for this project:

1. St. Patrick’s School System, including administrators, teachers, and staff, and
2. St. Patrick’s students.

For the customer St. Patrick’s School System, we are trying to improve the food waste, rescue, and share process. The St. Patrick students are the customers directly involved in the cafeteria lunch process with respect to food waste, rescue, and share.

5.1.2 Defining the Problem

In defining the problem for this project, we first gathered some basic information from St. Patrick’s. Specifically, we had to determine: 1) the students’ lunch routines in the cafeteria; and 2) why the students did not eat certain foods on their trays. We visited St. Patrick’s during the students’ lunch periods and observed how the students got their lunches, ate their food, and threw
away their leftovers. We also interviewed school administrators, cafeteria staff, and students asking them why certain foods were left uneaten on students’ trays.

a. Lunchtime Routines in the Cafeteria

We created a layout of the cafeteria and determined how the students got their lunches, where they ate, and where they discarded their waste. The cafeteria layout and flow of the students through the cafeteria lunch line, service area, seating area, and discarding of waste are displayed below in what is called a Spaghetti Diagram (Figure 4).

Figure 4: Spaghetti Diagram of St. Patrick’s cafeteria
Students enter the cafeteria with their classmates and either choose a seat in the seating area if they have brought their own lunch or stand in a line to go into the cafeteria food service area. Once they are allowed to proceed into the food service area (as there is only a limited number of students permitted inside this area at one time), they form another line to be served food on plastic trays held by servers. As students inch their way through the food service line, food is dispensed by the cafeteria servers onto the designated trays as students request which items that they want. As shown in Figure 5’s cafeteria food service area poster, they must choose food from three of the five food groups and at least one fruit or vegetable. After receiving their tray with the served food, they can choose to purchase fun snacks (e.g., chips, cookies) for a minimal cost, and then they pick up their silverware. Upon leaving the food service area, a different cafeteria worker checks their tray for the three food groups and at least one fruit or vegetable. If a student does not have the appropriate food on their trays, they are directed to the food service line.

The seating area is outside of the food service area and has long cafeteria “picnic-like” tables. Students have 20 minutes for lunch. After they are done eating, they take their trays to a table with
a water-filled container for their silverware, a large plastic container for dumping their remaining liquids, a container with a spatula to scrape off food from their trays, and a large grey trash can for the scraped food. This table is displayed in Figure 4. If a student has a pre-packaged food item (e.g., peanut butter & jelly sandwich, potato chips), an unpeeled piece of fruit (e.g., banana, orange), or an unopened milk carton, they can take it to the share table for use by another student. Some students do forget to use the share table, but most of them remember, especially when it comes to dropping off their cartons of unopened milk. Finally, students take their empty trays to a window attached to the food service area for cleaning by a cafeteria server.

b. The Defects

There are two different defects: recoverable and non-recoverable food waste. Recoverable food waste consists of food remaining on a student’s lunch tray that can be re-distributed for use, such as unopened pre-packaged food, unpeeled fruit, or unused milk in cartons. Non-recoverable food waste consists of opened packaged food or peeled edible fruit that cannot be reused once it is served on a student’s lunch tray, such as soup, a serving of vegetables, or an opened milk carton. Although both defects are unwanted, recoverable food waste can at least be repurposed. We would like to “save” additional recoverable food waste in this project by encouraging students to leave pre-packaged food and unopened milk on a share table if they do not want to eat it.

c. Voice of Customer

To determine why cafeteria food was left uneaten and thrown away, we did a Voice of Customer (VOC) and interviewed students and school personnel. VOC methodology allowed us to get feedback from school administrators, cafeteria staff, and students on the cafeteria food waste problem. We recorded the reasons that they gave us and put the reasons in a Cause and Effect
(C&E) Diagram (Figure 5) would provide a systematic way of displaying them. The main branch of the C&E Diagram is the effect of “Food Waste in Cafeteria.” We were able to categorize the reasons for food waste into four main “cause branches”: 1) Personal Preference, 2) Time, 3) Distractions, and 4) Requirements. The remaining causes were grouped under “Other.” Sub-branches and mini-branches further break down the main branches providing more specific and detailed causes. Personal Preference, for example, was further broken down to:  a) Doesn’t want to eat a lot before playing; b) Doesn’t want to get messy; c) Not hungry; d) Doesn’t like food item; or e) Temperature of food. Further, under “Doesn’t like food item,” for example, causes include: i) Quality of food; or ii) Picky eater.

![Figure 6: Cause-and-Effect Diagram for the Effect of Food Waste in the Cafeteria](image)

The main branches are blue, and their sub-branches are green. Additional mini-branches in yellow and then orange further break down the causes.
With all the possible causes laid out in the C&E Diagram, we were able to gain a better understanding of the food waste problem at the school and how we were going to develop improvements to reduce food waste.

**d. Supplier-Input-Output-Process-Customer**

The entire process leading to food waste in the cafeteria, from the suppliers (e.g., the school) to customers (e.g., the school and students), is outlined in the Supplier-Input-Output-Process-Customer (SIPOC) diagram in Figure 7. A SIPOC diagram is a tool used to identify all relevant elements of a process improvement project before the actual work (i.e., data collection, measurements, analysis) begins. The SIPOC give us a fully-contained, high-level view of our process. We can now see what goes in and out of the process, its scope, and how we may be able to make improvements to the process.
Figure 7: SIPOC showing entire process in the cafeteria that leads up to food waste
5.1.3 Problem Statement

The problem that we saw at St. Patrick’s was that too much uneaten cafeteria food was being thrown out by the students at the end of their lunch periods. Entire entree side dishes (e.g., vegetables) or beverages were discarded without being touched, tasted, or even opened (e.g., milk cartons, bananas). Although the school had a share table for unopened food/drinks and unpeeled fruits, these items were still ending up in the trash.

5.1.4 Project Metrics

Successful Six Sigma projects produce measurable outputs, \( Y \)'s, also known as metrics. It is important that a metric be clearly defined. In statistical terms, metrics require detailed operational definitions. In defining a problem in the Six Sigma context, \( Y \) is what we want to improve or optimize. Improving or optimizing a metric could mean:

- Maximizing or minimizing the metric;
- Getting the metric “closer” to some nominal value;
- Reducing variation in two different metrics; or
- Making the metric “robust”, that is making the metric insensitive to uncontrollable variation or noise.

There are three metrics \( Y \) being considered in this project over the entire lunch period:

1. The number of unopened milk cartons and other food items that go to the share table during each entire lunch period;
2. The amount of wasted milk with respect to weight; and
3. The amount of wasted fruits, vegetables, and soups (when available) with respect to weight.

These were collected in the following manner:
• Counting the number of unopened milk cartons taken to the share table throughout the lunch periods,

• Weighing opened milk cartons and discarding the wasted milk into buckets according to milk flavor,

• Separating the food waste on the trays into buckets labeled fruits and vegetables. (Other wasted food and paper waste are thrown in the trash and not weighed.)

• The percentages of milk waste by weight will be calculated as:

\[
\% \text{ milk wasted} = \frac{\text{weight of milk waste in bucket at the end of lunch}}{\text{total weight of milk served}}
\]

The same formula was used to calculate the percentage of fruit and vegetable waste.

5.1.5 Project Goal

The goal of this project was to reduce cafeteria food waste by 25% and increase the number of food items placed on the share table by children in grades PreK-8 during lunch periods at St. Patrick School from March 6, 2017 to May 19, 2017.

Outside of the quantitative aspect of this project, we wanted to achieve the following:

• Raise awareness of the large amounts of food that are wasted each day during the lunch periods at the school.

• Involve the school children in educating their classmates about food waste and food rescue.

• Encourage the school children to put their unused and unopened food items on the share table.

By sharing the food waste amounts with St. Patrick’s, we wanted to give the students, teachers, and staff a firsthand look at the actual amounts of food being wasted at their school. In addition,
by sharing the findings and results of our project with the VSCS, we hoped that the VSCS would bring a similar study or food rescue program in VSCS schools.

5.1.6 Scope of the Project

The Six Sigma in Practice class conducted a food waste study at St. Patrick School from March 6, 2017, to May 19, 2017. As part of the Measure phase, we collected data at St. Patrick’s school cafeteria on March 23, March 24, and from April 4 to April 7, 2017, to determine how much food was being thrown away by its students grades PreK-8 who received school lunches. The foods that we collected data on were vegetables, fruits, and milk. We also counted the number of food items that were being placed on the share table. The food items of interest on the share table included foods that could be rescued or repurposed, such as unopened packaged food, unpeeled fruit, and unopened milk cartons.

A portion of St. Patrick’s lunch periods overlapped with the schedule of the Six Sigma in Practice class; however, some did not. For the ones that did not, different teams took charge of being at St. Patrick’s to carry out data collection. For the data collection days, we created an interactive Google spreadsheet so that all eight teams in the class could select time intervals that fit with their own class schedules and overlapped St. Patrick’s lunch schedule. In this way, we were able to spread the responsibility of data collection to all teams.

After this initial week of data collection, we analyzed the data we collected and brainstormed ways to reduce the amount of food waste generated and increase the amount of food shared. Once we had an improvement plan in place, we carried out a variety of improvement processes at St.
Patrick’s. We collaborated with the 5th grade students and staff of the school in constructing activities to raise awareness of food waste, especially among the PreK – 4th grade students.

After improvement measures were implemented at St. Patrick’s, another week of data collection was carried out at St. Patrick’s from May 9, 2017 to May 12, 2017. This data was analyzed to determine if there were any statistically significant improvements in the amount of food wasted or shared.

5.1.7 Project Objectives

The objectives of this project were as follows:

1) On March 23 and 24, 2017, and April 4-7, 2017, we collected data during the students lunch periods. Lunch at the school cafeteria began at 10:50 a.m. and each grade’s 20-minute lunch schedule is set forth in Table 1.

<table>
<thead>
<tr>
<th>GRADE</th>
<th>LUNCH HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd</td>
<td>10:50 - 11:10</td>
</tr>
<tr>
<td>4th</td>
<td>11:05 - 11:25</td>
</tr>
<tr>
<td>1st &amp; 2nd</td>
<td>11:25 - 11:45</td>
</tr>
<tr>
<td>PreK &amp; K</td>
<td>11:35 - 11:55</td>
</tr>
<tr>
<td>6th</td>
<td>11:57 - 12:17</td>
</tr>
<tr>
<td>7th &amp; 8th</td>
<td>12:17 - 12:37</td>
</tr>
</tbody>
</table>

2) From April 10 to May 1, 2017, our class determined what improvements to the process were going to be made.
3) On May 8, 2017, our class worked with 5th graders at St. Patrick’s to create posters to educate other students in the school about food waste and to encourage the usage of the share table.

4) On May 8, 2017, we, along with the 5th graders, implemented the improvements.

5) From May 9 to May 12, 2017, we went back to the cafeteria and collected data again on how much food was being thrown away during the lunch periods.

6) By May 19, 2017, we analyzed all the data by using statistical tools to determine whether the improvements we implemented had any effects on the amount of food being wasted at the school.

7) By mid-May, the 5th graders were to carry on the project from the start of the Control phase.

8) By the end of May we shared our data and analysis with St. Patrick’s administration.
5.2 Measure

The Measure phase focuses on establishing the ability to measure the output “Y” of the current process. The first step of this phase is to validate the measurement system used to obtain the baseline data. This is done with the help of statistical tools such as Variable Gage Repeatability and Reproducibility analysis (Gage R&R), and Attribute Agreement analysis. The next step is to determine the existing process’ capability against the given baseline data. This is done with statistical graphs, summary statistics, inferential statistics, control charts, and capability analysis. Finally, the project objectives are re-evaluated as part of this phase.

5.2.1 Measurement System Analysis

The first part of the Measure phase to validate the measurement system using Measurement System Analysis (MSA). The goal here is to check that the measurement system that we are using for collecting data is “on target;” i.e., it is not underestimating or overestimating the metric or adding variation to the measurements of the desired metric. There will be variation in a process, and we do not want this variance to be inflated by the measurement equipment or its operators. See Figure 8 for a breakdown of variation by parts and the measurement system. In our project, there are two different scales being used to collect measured data. One large scale is used to weigh the buckets of discarded food and a smaller scale is used to weigh the milk remaining in opened milk cartons.
a. Reproducibility

Reproducibility can be defined as the variation in the average measurement when *different operators* measure the same part. For example, in this project we had multiple teams from the Six Sigma in Practice class visit St. Patrick’s during different lunch periods to measure the amount of food waste generated by grade level. For such a situation, the goal is to have different operators obtain the same value when measuring the same item. For example, if operator A measures a milk carton’s weight to be 5 ounces, operator B should obtain a weight of 5 ounces for the same carton.

If reproducibility error between operators is much greater than repeatability error within an operator, then:

- An operator may need additional training,
- the measurement system may need improvement to maintain consistency,
- the operational definition of the measurement may not be clearly defined, or
- the measurement system may be difficult to read correctly.
b. Repeatability

Repeatability is defined as the variation in the average measurement when the *same operator* measures the same part multiple times.\[21\] The same person taking measurements on the same item should get the same result on their 1\textsuperscript{st}, 2\textsuperscript{nd}, 3\textsuperscript{rd}, etc. trials. For example, as part of this project, if operator A measures a milk carton to weigh 5 ounces, then they should get the same value when measuring the same carton multiple times. In such a situation, if there is poor repeatability, this may reflect internal gage problems; i.e., something is wrong with the measuring equipment. In such situations, it is beneficial to make a trainee practice on a gage until little to no repeatability variation exists.

If repeatability error within an operator is much greater than reproducibility error between operators, then:

- Gage maintenance may be needed,
- Gaging location or clamping may not be consistent, or
- There may be excessive within part variation

c. Resolution

If a measurement system is resolute, this means that the measurement equipment has the capability to differentiate between similar parts to the extent necessary to make a decision about part differences. Resolution can be thought of as the smallest unit that a measurement system can detect. Rounding to the nearest inch or pound can cause resolution issues.\[22\] Suppose an operator wants to detect a one-tenth of an ounce difference in milk carton weights, clearly, variation in the carton weights can be detected. For example, there is a one-tenth difference between 5.0, 5.1, 5.2,
5.3, and 5.4 ounces, if a scale weighs them all as 5 ounces, then the measurement system is not picking up their differences to the extent necessary. If the measurement system does not have sufficient resolution, then it is likely to have an unacceptable level of precision when conducting a Variable Gage Repeatability and Reproducibility (Gage R&R) study. It is always worthwhile to check the measurement system’s resolution first, such as checking the “Rule of Tens,” before spending time and money completing a full Gage R&R analysis. The “Rule of Tens” states that the resolution of your measurement system should fit at least ten times into the process variation that you are measuring. If the resolution is more than one-tenth of the process variation, then the resolution should be improved before precision or accuracy is checked.

5.2.2 Variable Gage Repeatability and Reproducibility (Gage R&R)

The data that we collect on a metric is one of two types: variable or attribute. Variable data, referred to as measurement data, is quantitative. This data is generally “continuous” in nature, meaning that it is defined over intervals of real numbers; e.g., time, height, distance, length, percentages. Attribute data, referred to as categorical data, is data that can be separated into different categories or bins. The categories are determined by the nature of the attribute. Binary data has two categories, such as either pass or fail. Ordinal data has two or more ordered categories, such as small, medium, large. Nominal has two or more unordered categories. For example, suppose a restaurant has three options as entrees, fish, meat, and pasta. This is an example of nominal data.

For this project, we measured the amount of generated food waste by weighing the discarded food. Food waste was collected into separate buckets, and at the end of every lunch period, the weight of each bucket was recorded. These weights are measurement, or variable data.
As part of Measurement System Analysis, a Gage R&R study was performed on the school’s spring scale that was used to weigh food waste in buckets during the trial week of data collection. A picture of this scale is shown in Figure 9.

Before we began collecting data at St. Patrick’s, we asked them if we could borrow their scale for data collection. We were under the assumption that the cafeteria had a reliable digital scale since they measured entrée weights daily. Unfortunately, their scale was old and had a data collection dial face that was hard to read. In addition, its dial often wavered between two weights. For this reason, we performed a Gage R&R on the scale to determine if we needed to buy a modern digital scale because of possible measurement system error by operators.

Variable Gage R&R is a statistical tool that measures the amount of variation in a measurement system arising from the measurement device and/or the operators taking the measurements. [23] As discussed earlier, repeatability is defined as a measure of variability in the measurement system.
that is most often caused by the measurement device. Reproducibility is the variability in the measurement system caused by differences in measurement techniques between operators.

The study was run with three operators who weighed five buckets, a total of three times each. Each bucket was measured by each of the three operators, a total of three times each. This exercise was done to determine if there was reproducibility variation, and perhaps even some variation in repeatability, in how the operators were reading this scale. If this Gage R&R study indeed showed variation, we decided we would need to purchase new scales to eliminate this measurement error from our process. The Gage R&R chart from this study is shown in Figure 10.

Figure 10: Gage Run Chart for data collected using old spring scale
The Gage R&R run chart is used to indicate that there is variation in both repeatability and reproducibility. Each color refers to the operator’s three attempts of measuring the same bucket. The numbers 1, 2…5 refer to the bucket numbers, with 5 buckets in total being weighed. This chart shows that there is variation in the measurement of a bucket taken by the same operator, as well as there is variation in the measurements taken between operators. This shows that there is variation in the repeatability and reproducibility of measurements taken when using the school’s scale.

An Xbar-R chart plots the process mean (Xbar chart) and process range (R chart) over time for variables data. This combination control chart is widely used to examine the stability of processes, and can be used to identify and variations in the existing process. From the Gage R&R Xbar/R method, Figure 10 shows that part to part variation contributes to 99.62% of the total variation, while the remaining 0.38% of the variation is due to repeatability and reproducibility. The number of distinct categories for this study is 22. According to Minitab¹, “the number of distinct categories (NDC) is a metric that is used in Gage R&R studies to identify a measurement system's ability to detect a difference in the measured characteristic. The number of distinct categories represents the number of non-overlapping confidence intervals that span the range of product variation. The number of distinct categories also represents the number of groups within your process data that your measurement system can discern.

The number of categories that are calculated depends on the ratio of the variability in the measured parts and the variability in the measurement system”. [²⁴]

How do we know if our number of distinct categories is large enough?
According to Minitab:[25]

- When the number of categories is less than 2, the measurement system is of no value for controlling the process, since one part cannot be distinguished from another.

- When the number of categories is 2, the data can be divided into two groups, say high and low.

- When the number of categories is 3, the data can be divided into 3 groups, say low, middle and high.

- A value of 5 or more denotes an acceptable measurement system.

Based on Minitab’s explanation of NDC, a Gage R&R with 22 distinct categories is acceptable. However, there is a serious need of increased accuracy in order to reduce the variation seen in repeatability and reproducibility.
**Gage R&R study – Xbar/R Method:**

<table>
<thead>
<tr>
<th>Source</th>
<th>VarComp</th>
<th>% Contribution (of VarComp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Gage R&amp;R</td>
<td>0.00450</td>
<td>0.38</td>
</tr>
<tr>
<td>Repeatability</td>
<td>0.00290</td>
<td>0.24</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>0.00160</td>
<td>0.13</td>
</tr>
<tr>
<td>Part-to-Part Variation</td>
<td>1.18971</td>
<td>99.62</td>
</tr>
<tr>
<td>Total Variation</td>
<td>1.19422</td>
<td>100</td>
</tr>
</tbody>
</table>

**Number of distinct categories is 22**

Figure 11: Minitab results showing the breakdown of number of distinct categories

Overall, the variance in a measurement system is acceptable under the following conditions: [26]

**Table 2. Conditions under which variance in a measurement system is acceptable**

<table>
<thead>
<tr>
<th>Percentage of process variation</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10%</td>
<td>The measurement system is acceptable.</td>
</tr>
<tr>
<td>Between 10% and 30%</td>
<td>The measurement system is acceptable depending on the application, the cost of the measurement device, cost of repair, or other factors.</td>
</tr>
<tr>
<td>Greater than 30%</td>
<td>The measurement system is not acceptable and should be improved.</td>
</tr>
</tbody>
</table>
The Gage R&R Report for Measurement is shown in Figure 12. An Xbar-chart is a type of control chart used to monitor the process mean when measuring subgroups at regular intervals from a process. Each point on the chart represents the value of a subgroup mean. The Xbar chart is used to indicate the average of all three measurements taken by an operator. The Xbar by Operator is used to indicate that the overall mean of all measurements was 3.947 lbs. Since the operators measured the overall weights of the buckets, which were much heavier than the weights of milk cartons, the weights were measured in pounds, and not ounces. The R chart is used to indicate the range between all three measurements taken by an operator. The R chart by operator is used to indicate that the mean of the operators’ ranges was 0.092 lbs. The blips on the R chart by operator show that there was variation from anywhere between 0 and 0.2 in either direction, caused by the scale itself. Since the R chart is used to indicate the range between the three measurements taken by an operator, this means that the measurements taken by an operator had a variation of +/- 0.2 lbs. caused by the measurement system. The Measurement by Bucket Number chart is used to indicate that there is variation in reproducibility. The Bucket Number and Operator Interaction charts show variation in repeatability. Overall, it can be seen that the Gage R&R study concludes that the measurement system is acceptable, however, since the Gage R&R study shows
signs of minor variation in repeatability and reproducibility, the consensus was to swap the school’s scale with a more accurate and reliable digital scale.

Figure 12: Gage R&R report showing that the main variation was part-to-part with small variations in both repeatability and reproducibility

Though the Gage R&R study allowed us to conclude that the measurement system is acceptable, there was still concern on whether or not it was appropriate for the study. There are stark differences in the conditions under which measurements were taken using these scales during the Gage R&R study, and during actual data collection. When running this Gage R&R, we only included 3 operators. During the Measure phase, however, there were numerous people taking measurements using the school’s scale. Also, when performing this study, operators had unlimited time to read the school’s scale and report their measurements. During actual data collection, the
cafeteria ran at a quick pace, and often data recorders had less than a second to take measurements. This could have led to errors that were not caught in the Gage R&R because they were not run under the same conditions. Although the Gage R&R study says that our data with the school’s scale is acceptable, under actual data collection conditions we found the data to not be accurate enough. This lead to us switching the school’s scales with digital scales that were far more accurate and reliable. A picture of the new digital scale that replaced the school’s scale can be seen below in Figure 13.

Figure 13: New digital weighing scale used to weigh buckets of food

5.2.3 Food Waste Measurement

The next part of the measurement phase involved the actual measuring of food waste generated over a two week span, from March 23 to March 24, 2017, and from April 4 to April 7, 2017 at St. Patrick’s. The Six Sigma in Practice class set up a Google spreadsheet so that teams from the class could schedule times to be at St. Patrick’s during the school’s lunch periods to collect data. There were eight teams in total as part of the Six Sigma class. On some occasions, the Six Sigma class
schedule overlapped some of St. Patrick’s lunch periods, but not others. For the other periods, a pre-determined schedule was set-up so that different teams could sign up and take responsibility for collecting data then.

At the end of each lunch period, St. Patrick’s students dropped off their food trays at the measurement tables, tables that were arranged near the tray disposal window in the cafeteria. We placed buckets labelled distinctly as fruits, veggies, white milk, strawberry milk, and chocolate milk at the end of the measurement tables. A small water bucket was set up for us to soak students’ silverware. Next to the measurement tables were trash cans where empty cartons and packaging were discarded. This set up can be seen in Figure 14.
The Six Sigma students would scoop any remaining food into the distinctly labelled buckets using spatulas. Any remaining milk in the milk cartons was poured into the appropriate buckets depending on whether it was vanilla, chocolate or strawberry. Any unopened packaged food or milk carton was then added to the share table if the student forgot to do it themselves. A photo of a food tray with an unopened milk carton that was disposed by a St. Patrick’s student is shown in Figure 14. We encountered many cases where students would dispose unopened milk cartons in the trash can, making this a key area for improvement. A photo of the share table with an ice tray filled with unopened milk cartons is shown in Figure 16. The empty trays were then stacked and subsequently dropped off at the tray disposal window for pick up by a cafeteria server. This entire process is depicted in the data collection process map in Figure 16. This process was done for 5 days, March 23 to 24, and April 4 to April 7, 2017, however, the data collected on March 23 and 24 had certain discrepancies, so, for statistical analysis, only data from April 4 to April 7, 2017 is considered. The discrepancies came about due to errors in the way the buckets were being weighed,
because of which the data was not taken into consideration. In this manner, the amount of food waste generated was measured over the week, and the data was collected for further analysis.

![Figure 15: Food tray with an unopened milk carton](image)

In the process map shown in Figure 17, it is beneficial to note that “RHIT workers” refers to the Six Sigma students belonging to Rose-Hulman Institute of Technology.
Figure 17: Process Map depicting how data was collected as part of the Measure phase.
An example of a spreadsheet showing data collected on April 7, 2017 is shown in Figure 17.

<table>
<thead>
<tr>
<th>Friday, 4/7/17</th>
<th>Third &amp; Fifth Grade</th>
<th>Fourth Grade</th>
<th>First &amp; Second Grade</th>
<th>Kindergarten</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entree: Fish sandwich</td>
<td>Plain</td>
<td>Chocolate</td>
<td>Strawberry</td>
<td>Plain</td>
</tr>
<tr>
<td>Entree: Macaroni &amp; Cheese</td>
<td>9.24</td>
<td>6.14</td>
<td>7.58</td>
<td>3.6</td>
</tr>
<tr>
<td>Vegetable: Broccoli</td>
<td>6.28</td>
<td>4.44</td>
<td>0.49</td>
<td>3.39</td>
</tr>
<tr>
<td>Fruit: Peaches</td>
<td>6.95</td>
<td>2.77</td>
<td>4.98</td>
<td>1.2</td>
</tr>
<tr>
<td>Total ounces with carton weights</td>
<td>21.94</td>
<td>29.02</td>
<td>48.68</td>
<td>11.15</td>
</tr>
<tr>
<td>Number of shared cartons</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of used cartons</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Total used ounces without carton weights</td>
<td>19.84</td>
<td>25.66</td>
<td>44.48</td>
<td>9.05</td>
</tr>
<tr>
<td>Total used ounces for all flavors without carton weights</td>
<td>89.98</td>
<td>34.87</td>
<td>51</td>
<td>86.1</td>
</tr>
</tbody>
</table>

Figure 18: Spreadsheet showing data collected on 4/7/2017 as part of the Measure phase

Data was collected for every lunch period, and the food wasted was divided into distinct buckets based on the item. For example, on April 7, 2017, the menu for the day was a fish sandwich and macaroni & cheese for entrées, broccolis for vegetables, and peaches for fruit. Additionally, students could choose to take a milk carton which most of them (95% or more) did. The milk flavors were vanilla, chocolate and strawberry. Only vanilla milk was available every day. Figure 18 shows that for the first lunch period which consisted of the 3rd and 5th graders, the amount of milk wasted was recorded based on the type of milk. The total ounces of milk with carton weights...
were measured individually using the small weighing scales and then recorded. The weight of the milk wasted per carton was then calculated by subtracting the weight of an empty carton from the total weight. The overall combined weight of milk wasted (vanilla + strawberry + chocolate) was then recorded, along with a count of the number of unopened milk cartons contributed to the share table. This process was replicated for the other lunch periods, and corresponding grades as well.

<table>
<thead>
<tr>
<th>Third &amp; Fifth Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>En&lt;trée</strong>: Fish sandwich</td>
</tr>
<tr>
<td><strong>En&lt;trée</strong>: Macaroni &amp; Cheese</td>
</tr>
<tr>
<td><strong>Vegetable</strong>: Broccoli</td>
</tr>
<tr>
<td><strong>Fruit</strong>: Peaches</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

| **Total ounces with carton weights** | 21.94 | 29.02 | 48.68 |
| **Number of shared cartons** | 2 | 2 | 0 |
| **Number of used cartons** | 5 | 8 | 10 |
| **Total used ounces without carton weights** | 19.84 | 25.66 | 44.48 |
| **Total used ounces for all flavors without carton weights** | 89.98 |

**Figure 19:** Amount of milk wasted by 3rd and 5th graders on Friday, April 7, 2017 broken down by flavors

Next, the amount of vegetables and fruits wasted was recorded by grade as shown in Figure 20. The total amount of vegetables and fruits wasted was then calculated by summing up the individual
weights per grade. With this data, the amount of vegetables, fruits, and milk wasted per student was calculated. At the end of school’s lunch period, we calculated the count of the total number of students who ate cafeteria food on that particular day. On April 7, 2017 the total count of students was 147 as show in Figure 21.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Collection Time</th>
<th>Plain</th>
<th>Plain: % of Total</th>
<th>Chocolate</th>
<th>Chocolate: % of Total</th>
<th>Strawberry</th>
<th>Strawberry: % of Total</th>
<th>Fruits</th>
<th>Fruits: % of Total</th>
<th>Vegetables</th>
<th>Vegetables: % of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3&amp;5</td>
<td>11:15</td>
<td>19.2</td>
<td>0.239</td>
<td>27.0</td>
<td>0.178</td>
<td>46.18</td>
<td>0.437</td>
<td>53</td>
<td>0.179</td>
<td>24</td>
<td>0.133</td>
</tr>
<tr>
<td>4</td>
<td>11:30</td>
<td>9.4</td>
<td>0.117</td>
<td>10.6</td>
<td>0.070</td>
<td>14.6</td>
<td>0.138</td>
<td>61.4</td>
<td>0.207</td>
<td>30</td>
<td>0.167</td>
</tr>
<tr>
<td>1&amp;2</td>
<td>11:50</td>
<td>12.8</td>
<td>0.160</td>
<td>19.0</td>
<td>0.125</td>
<td>16.8</td>
<td>0.159</td>
<td>59</td>
<td>0.199</td>
<td>27.4</td>
<td>0.152</td>
</tr>
<tr>
<td>K</td>
<td>12:01</td>
<td>29.4</td>
<td>0.367</td>
<td>34.2</td>
<td>0.226</td>
<td>17.8</td>
<td>0.168</td>
<td>45.6</td>
<td>0.154</td>
<td>29.4</td>
<td>0.164</td>
</tr>
<tr>
<td>Pre K</td>
<td>12:05</td>
<td>0.2</td>
<td>0.002</td>
<td>13.4</td>
<td>0.088</td>
<td>2</td>
<td>0.019</td>
<td>25.8</td>
<td>0.087</td>
<td>21.4</td>
<td>0.119</td>
</tr>
<tr>
<td>6</td>
<td>12:20</td>
<td>6</td>
<td>0.075</td>
<td>19.0</td>
<td>0.125</td>
<td>8.4</td>
<td>0.079</td>
<td>22</td>
<td>0.074</td>
<td>13.2</td>
<td>0.073</td>
</tr>
<tr>
<td>7&amp;8</td>
<td>12:45</td>
<td>3.2</td>
<td>0.040</td>
<td>28.4</td>
<td>0.187</td>
<td>0</td>
<td>0.000</td>
<td>29.6</td>
<td>0.100</td>
<td>34.4</td>
<td>0.191</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade</th>
<th>Collection Time</th>
<th>Plain: Amount Wasted per Student</th>
<th>Chocolate: Amount Wasted per Student</th>
<th>Strawberry: Amount Wasted per Student</th>
<th>Fruit: Amount Wasted per Student</th>
<th>Vegetables: Amount Wasted per Student</th>
<th>Total Waste per Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>3&amp;5</td>
<td>11:15</td>
<td>0.711</td>
<td>0.999</td>
<td>1.710</td>
<td>1.963</td>
<td>0.889</td>
<td>6.273</td>
</tr>
<tr>
<td>4</td>
<td>11:30</td>
<td>0.495</td>
<td>0.558</td>
<td>0.768</td>
<td>3.232</td>
<td>1.579</td>
<td>6.632</td>
</tr>
<tr>
<td>1&amp;2</td>
<td>11:50</td>
<td>0.640</td>
<td>0.950</td>
<td>0.840</td>
<td>2.950</td>
<td>1.370</td>
<td>6.750</td>
</tr>
<tr>
<td>K</td>
<td>12:01</td>
<td>1.131</td>
<td>1.315</td>
<td>0.685</td>
<td>1.754</td>
<td>1.131</td>
<td>6.015</td>
</tr>
<tr>
<td>Pre K</td>
<td>12:05</td>
<td>0.017</td>
<td>1.117</td>
<td>0.167</td>
<td>2.150</td>
<td>1.783</td>
<td>5.233</td>
</tr>
<tr>
<td>6</td>
<td>12:20</td>
<td>0.400</td>
<td>1.267</td>
<td>0.560</td>
<td>1.467</td>
<td>0.880</td>
<td>4.573</td>
</tr>
<tr>
<td>7&amp;8</td>
<td>12:45</td>
<td>0.114</td>
<td>1.014</td>
<td>0.000</td>
<td>1.057</td>
<td>1.229</td>
<td>3.414</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># of shared Milks</th>
<th># of used Milks</th>
<th># of students eating a cafeteria lunch by milk count</th>
<th>50% of total students in a given grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>137</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>26</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>28</td>
<td>32</td>
</tr>
</tbody>
</table>

*38% on free or reduced lunch price

Figure 20: Calculations showing amount of food waste per student
Next, Figure 21 shows a table that tracks the total amount of food prepared on that day by the cafeteria staff. It then shows the amount of food that was consumed by the students. A simple subtraction of this amount gives the amount of food that was left unused, which could have been reused and shared, if not taken. The percentage of food wasted was then calculated after removing the amount unused. From the calculations shown in Figure 18, it can be seen that, on 4/7/17, approximately 37% of the fruits served were wasted and 42% of vegetables served were wasted. Assuming that each individual food serving is approximately 4 oz, this amounts to 74 servings of fruit that went to waste and 45 servings of vegetables. These numbers provide a realistic depiction of the amount of food waste generated on a daily basis. These food waste percentages bolster the widespread need for food rescue and food sharing initiatives in schools today.

<table>
<thead>
<tr>
<th>St. Pats Amounts (oz)</th>
<th>Plain Milk</th>
<th>Chocolate Milk</th>
<th>Strawberry Milk</th>
<th>Fruit: Peaches</th>
<th>Fruit: Others ****</th>
<th>Vegetables: Broccoli</th>
<th>Vegetables: Mixed Veg, Peas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Amount</td>
<td>280</td>
<td>648</td>
<td>344</td>
<td>624</td>
<td>240</td>
<td>352</td>
<td>96</td>
</tr>
<tr>
<td>Left over: will be re-used</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>56</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Amount Taken</td>
<td>280</td>
<td>648</td>
<td>344</td>
<td>624</td>
<td>184</td>
<td>328</td>
<td>96</td>
</tr>
<tr>
<td>Food weight in buckets</td>
<td>80.2</td>
<td>151.6</td>
<td>105.78</td>
<td>296.4</td>
<td>179.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage Wasted</td>
<td>0.286</td>
<td>0.234</td>
<td>0.308</td>
<td>0.367</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste in terms of # of cartons of milk (8 oz) or # of single servings (4 oz)</td>
<td>10.025</td>
<td>18.948</td>
<td>13.223</td>
<td>74.100</td>
<td>44.950</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**** Blueberries, Strawberries, Applesauce, Mixed Fruit, Mandarin Oranges (all separate)

Assuming 147 students, the amount of food waste per student is:
5.5 oz per student, or 0.344 lb per student

Figure 21: Food waste generated in terms of number of cartons or servings
A summary of the amount of food waste generated between April 4, 2017 and April 7, 2017 is displayed in Table 3.

Table 3. Summary of food waste generated in terms of cartons or servings between April 4, 2017 and April 7, 2017

<table>
<thead>
<tr>
<th>DATE</th>
<th>MILK WASTED IN TERMS OF # OF CARTONS</th>
<th>FRUITS WASTED IN TERMS OF # OF SERVINGS</th>
<th>VEGETABLES WASTED IN TERMS OF # OF SERVINGS</th>
<th>NUMBER OF MILK CARTONS SHARED</th>
<th>TOTAL NUMBER OF STUDENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/4/17</td>
<td>38</td>
<td>69</td>
<td>62</td>
<td>9</td>
<td>164</td>
</tr>
<tr>
<td>4/5/17</td>
<td>48</td>
<td>34</td>
<td>56</td>
<td>13</td>
<td>178</td>
</tr>
<tr>
<td>4/6/17</td>
<td>45</td>
<td>50</td>
<td>65</td>
<td>13</td>
<td>161</td>
</tr>
<tr>
<td>4/7/17</td>
<td>42</td>
<td>74</td>
<td>45</td>
<td>10</td>
<td>147</td>
</tr>
</tbody>
</table>

5.2.3 Establishing Current Process Capability for Flavored Milks

In this part of the Measure phase, we want to determine the capability of milk waste to be less than a designated upper specification limit. We set this value at 2 ounces which would mean that all students are drinking at least 75% of their 8 ounce milk carton. We chose to investigate milk waste in particular amongst all other wastes to see how well the amount of milk waste met a particular, predefined specification limit. Data was collected over the course of four days from April 4th through 7th during all lunch periods. The average amount of food waste per student during those days is shown below in Table 4.
Table 4. Average food waste per student

<table>
<thead>
<tr>
<th>Day</th>
<th>Food waste (oz)</th>
<th>Food waste (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 4th, 2017</td>
<td>5.0</td>
<td>0.3125</td>
</tr>
<tr>
<td>April 5th, 2017</td>
<td>5.7</td>
<td>0.356</td>
</tr>
<tr>
<td>April 6th, 2017</td>
<td>5.0</td>
<td>0.3125</td>
</tr>
<tr>
<td>April 7th, 2017</td>
<td>5.5</td>
<td>0.344</td>
</tr>
<tr>
<td>Average</td>
<td>5.3</td>
<td>0.331</td>
</tr>
</tbody>
</table>

An explanation to how these values of food waste per student were calculated is described in the previous subsection. The average amount of milk wasted per carton, in ounces, over all four days between different grades levels is shown in Table 5. Milk waste was collected in buckets each day during data collection to determine the total daily amounts of waste for each flavor of milk. The breakdown of percentage of milk wasted by flavor per day is shown in Figure 20.

During the Measure phase, an important point to keep in mind was that milk was an optional part of the meal. It was not mandatory for students to choose a milk carton with their meal, but invariably almost all students picked up one with their meals. Unfortunately, some of them would end up taking a sip and then throwing away an almost full carton, where, a full carton consisted of 8oz. of milk. This is an important part of the process that can be improved upon and is discussed later in the Improvement phase.
Table 5. Average total milk waste per carton by grade periods, in ounces.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Vanilla</th>
<th>Chocolate</th>
<th>Strawberry</th>
<th>Average Milk Wasted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-K</td>
<td>1.40</td>
<td>3.14</td>
<td>1.41</td>
<td>2.04</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>4.33</td>
<td>3.01</td>
<td>2.52</td>
<td>3.29</td>
</tr>
<tr>
<td>1st &amp; 2nd</td>
<td>4.22</td>
<td>2.09</td>
<td>1.95</td>
<td>2.75</td>
</tr>
<tr>
<td>3rd &amp; 5th</td>
<td>3.46</td>
<td>2.72</td>
<td>3.37</td>
<td>3.18</td>
</tr>
<tr>
<td>4th</td>
<td>2.75</td>
<td>1.71</td>
<td>2.86</td>
<td>2.44</td>
</tr>
<tr>
<td>6th</td>
<td>2.85</td>
<td>1.63</td>
<td>2.05</td>
<td>2.18</td>
</tr>
<tr>
<td>7th &amp; 8th</td>
<td>0.97</td>
<td>1.35</td>
<td>1.16</td>
<td>1.16</td>
</tr>
</tbody>
</table>

There appears to be a general trend of younger grades wasting more vanilla milk, as may be expected. This can further be seen in Figure 22. It is worth noting that Pre-K has a small amount of waste for vanilla and strawberry milks, but significantly less of these milks are taken with a smaller class size. It is also important to note that the Pre-K and K grades received help from the school’s staff to ensure that they consumed a decent portion of their meals. Because of this, if we disregard the amount of vanilla milk wasted by Pre-K students, a decreasing trend in the amount of vanilla milk wasted can be observed as the age group increases.
Figure 22: Comparing average milk wasted per carton for different age groups (Max. weight of a carton being 8oz.)

Data can also be compared day to day, showing in Figure 23 that the amount of milk wasted does not follow a particular pattern from day to day.

Figure 23: Average milk wasted per carton for across all four days of data collection.

To see if the trend that white milk on average appears to be wasted the most compared to the other flavors and chocolate the least, an ANOVA was conducted. The assumptions of normality and
constant variance were tested and can be seen in Figure 24. Analysis of variance (ANOVA) tests the hypothesis that the means of two or more populations are equal. An ANOVA assesses the importance of one or more factors, in this case by flavor, by comparing the response variable means at the different factor levels. The null hypothesis states that all population means (average amount of milk wasted) are equal while the alternative hypothesis states that at least one is different. The name "analysis of variance" is based on the approach in which the procedure uses variances to determine whether the means are different. The procedure works by comparing the variance between group means versus the variance within groups as a way of determining whether the groups are all part of one larger population or separate populations with different characteristics. ANOVA is useful for comparing (testing) three or more means (groups) for statistical significance. In statistical hypothesis testing, a result has statistical significance when it is very unlikely to have occurred given the null hypothesis is true. A study's defined significance level, \( \alpha \), is the probability of the study rejecting the null hypothesis, given that it were true; and the \( p \)-value of a result, \( p \), is the probability of obtaining a result at least as extreme, given that the null hypothesis is true. The result is deemed statistically significant, when \( p < \alpha \). The significance level for a study is chosen before data collection, and typically set to 5%, depending on the field of study. Through the entirety of this project, the significance level is set to be 5%, or \( \alpha = 0.05 \). ANOVA is based on the following assumptions:

- **Independence of observations** – This is the assumption of independence within and between observations. For example, the amount of vanilla milk wasted does not depend on the amount
of strawberry or chocolate milk wasted. Similarly, the amount of vanilla milk wasted in a particular carton does not depend on the amount of vanilla milk wasted in another carton.

- **Normality** – Distribution of sample data should be from a normal distribution
- **Equality** (or "homogeneity") of variances, called homoscedasticity — the variance of data in groups should be the same.

In ANOVA, a residual plot is a graph that is used to examine the goodness-of-fit. In our analysis, the residuals are tested. A residual of an observed value is the difference between the observed value and the *estimated* value of the quantity of interest.\[^{31}\] In this case, the quantity of interest is the sample mean.

![Residual Plots for Amount of Milk Wasted per Carton](image)

**Figure 24:** Residual plots of the percent milk wasted for the ANOVA
The normal probability plot is a graphical technique for assessing whether or not the residuals are from a normally distributed population. This plot is used to verify that the assumption that the residuals are from a normal distribution. The data are plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line. Departures from this straight line indicate departures from normality. If the plot is relatively close to a line, then the points may be from the same normal distribution. If the plot does not look like a line, then the points probably do not come from the same normal distribution. Thus, it can be seen from the Normal Probability Plot by referring to the p-value of AD test in Figure 24 that the data appears to hint at its normality.

The residuals versus fits plot is used to verify the assumption that the residuals are randomly distributed and have constant variance. Ideally, the points should fall randomly on both sides of 0, with no recognizable patterns in the points. In the Versus Fits plot, it can be seen that the variance of the residuals are unequal with the fitted values. The variance of the residuals increases with the fitted values. Notice that, as the value of the fits increases, the scatter among the residuals widens. This pattern indicates that the variances of the residuals are unequal (non-constant). The plot also shows a few outliers, however, a quick look at the data collected does not show any obvious signs of measurement errors or data-entry errors which justified running the ANOVA despite these abnormalities. The hypothesis being tested was

$$H_0: \mu_{\text{white}} = \mu_{\text{chocolate}} = \mu_{\text{strawberry}}$$

$$H_1: \text{At least one mean is different}$$

where $\mu$ is the average of each flavor of milk wasted. The ANOVA output can be seen below:
The null hypothesis states that the population means are all equal. If \( p\text{-value} \leq \alpha \): The differences between some of the means are statistically significant; if \( p\text{-value} > \alpha \): The differences between the means are not statistically significant. \(^{33}\) With a \( p\text{-value} \) of 0.151, i.e. \( p\text{-value} > \alpha \), the null hypothesis is not rejected. The residuals versus order plot in the bottom right corner of Figure 24 is used to verify the assumption that the residuals are uncorrelated with each other.

This shows that there is not enough statistical evidence to support a claim that there is a difference in the means of each flavor of milk wasted. The histogram of residuals plot shown in the bottom left corner of Figure 23 is used to determine whether the data are skewed or whether outliers exist in the data. A long tail in one direction is an indication of skewness while a bar that is far away from the other bars is an indication of an outlier. During the residuals vs. fits plot analysis, the data was checked confirming that there were no measurement errors or data entry errors to contribute to any outliers or plot skewness. \(^{34}\) In this manner, residuals are used to check for all assumptions considered while carrying out an ANOVA.

To further investigate the amount of vanilla milk wasted, the ounces of milk wasted across all four days of initial data collection were plotted in individual and moving range control charts in Figure
26. First, a test to check if the data is from a normally distributed population was carried out as can be seen in Figure 27.

![I-MR Chart of White Milk Wasted April 4-7](image_url)

**Figure 26: An I-MR control chart of the vanilla milks wasted**

- **$H_0$: Data is from a normal distributed population**
- **$H_1$: Data is NOT from a normal distributed population**
With a p-value of 0.239, the null hypothesis is not rejected and we can conclude that the data is from a normal distribution.

Going back to the I-MR chart shown in Figure 26, every group of seven represent a day's worth of data, with each data point representing the amount of white milk wasted in a lunch period. There appears to be a cyclical pattern that occurs, suggesting that the amount wasted comparatively in the each lunch period follows a daily trend. This makes sense, as we expect each grade level to be fairly consistent in the amount of milk wasted. To further investigate this trend, an autocorrelation plot was constructed.

The autocorrelation function is one of the tools used to find patterns in the data. While carrying out an ANOVA, it is assumed that the data are independent of (not correlated with) each other. If the independence assumption is violated, some model fitting results might not be reliable.
Specifically, the autocorrelation function tells you the correlation between points separated by various time lags. It is constructed to check if there is any dependency in the data.

![Autocorrelation Function for White Milk Wasted per Carton](image)

**Figure 28: Autocorrelation function for the vanilla milk wasted pre-improvement**

Autocorrelation can be seen for every seven data points. This agrees with the observation above, as every seven data points represent a day of data collection. Each data point is drawn from a specific lunch period. Here each time lag corresponds to each lunch period at St. Patrick’s. These are divided into 7 lags in total. The autocorrelation seen means that the same lunch periods across all of the days are correlated, which makes sense since it is the same grade levels.
A process capability report was produced to compare how much the students drank compared to a set specification limit. Specification limits are predefined to represent the desired performance of the process. Specification limits are often divided into a Lower Specification Limit (LSL) and an Upper Specification Limit (USL). In this case, the acceptable upper limit (USL) was set to 2, which would mean that students are drinking at least 75% of their 8oz. milk carton.

The values of Cp and Cpk are indicators of a process’s capability. Cp is defined as the capability the process can achieve if the process is perfectly centered between the given specification limits.
Cpk is defined as the capability the process is achieving whether or not the mean is centered between the specification limits. The k in Cpk stands for centralizing factor. Cpk is a measure to show how many standard deviations the specification limits are from the center of the process.

\[
Cpk = \frac{USL - LSL}{6 \cdot \hat{\sigma}}
\]

\[
\hat{\sigma} = \frac{MR}{d_2}
\]

Where \( \hat{\sigma} \) refers to the process’s within standard deviation, and not overall standard deviation and where \( d_2 \) is an un-biasing constant. Cpk values near or below zero indicate processes operating off target or with high variation. The correlation between Cpk, sigma levels, and defects per million (DPM) is depicted in Table 7. Process Fallout in Table 7 refers to the number of times the process fails and this is measured in terms of defects per million (DPM).

Thus, ideally, the value of Cpk should be at least 1.0, which would indicate that the students are meeting the upper specification limit of 2oz. In Figure 29, it can be seen that there are no Cp values generated. This is because we did not set a value for the LSL. Since the data was shown to belong to a normal distribution, a normal distribution was used to perform the capability analysis.
Table 6. Correlation between Cpk, Sigma levels, and DPM

<table>
<thead>
<tr>
<th>Cpk</th>
<th>Sigma level (σ)</th>
<th>Area under the probability density function</th>
<th>Process Yield</th>
<th>Process Fallout (in terms of DPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33</td>
<td>1</td>
<td>0.6826894921</td>
<td>68.27%</td>
<td>317311</td>
</tr>
<tr>
<td>0.67</td>
<td>2</td>
<td>0.9544997361</td>
<td>95.45%</td>
<td>45500</td>
</tr>
<tr>
<td>1.00</td>
<td>3</td>
<td>0.9973002039</td>
<td>99.73%</td>
<td>2700</td>
</tr>
<tr>
<td>1.33</td>
<td>4</td>
<td>0.9999366575</td>
<td>99.99%</td>
<td>63</td>
</tr>
<tr>
<td>1.67</td>
<td>5</td>
<td>0.9999994267</td>
<td>99.9999%</td>
<td>1</td>
</tr>
<tr>
<td>2.00</td>
<td>6</td>
<td>0.9999999980</td>
<td>99.9999998%</td>
<td>0.002</td>
</tr>
</tbody>
</table>

The process capability report in Figure 29 shows a Cpk value of -0.17, which means that the students are not currently meeting the specification of drinking at least 75% of their milk. In fact, this negative Cpk value indicates that currently the amount of milk wasted consists of data points that are well above this specification limit of 2. Thus, a negative Cpk of -0.17 indicates that students are wasting more than 25% of the milk in the cartons, i.e. the students are not consuming at least 75% of the milk carton. No lower specification limit is being set for this capability analysis since we would be happy if students drank all of their milk. This explains why Cp has a * instead of a numerical value in Figure 29. In the post improvement phase, the hope is to see a greater percentage of the data below the USL and a Cpk value of at least greater than 0 and closer to 1.
5.3 Analyze

The goal of the analyze phase is to identify, organize, and analyze the critical inputs, x’s, that affect the output Y, and to determine what x’s should be adjusted.

In this phase, key statistical tools used are:

- High level Process Map
- Cause & Effect Matrix (C&E)
- Failure Modes and Effect Analysis (FMEA)
- Design of Experiments

For this project, the statistical tools implemented were Process Maps, C&E matrix, and FMEA. Due to the short duration of this project (10 weeks), a DOE was not carried out. However, in a typical six sigma project with a longer duration, the project would involve methodically investigating several KPIVs through a designed experiment to determine which have the biggest effect on the KPOVs.

The purpose of the Analyze phase is to determine the Key Process Input Variables (KPIVs) that affect the Key Process Output Variables (KPOVs). Some of the KPIVs are initially determined from Voice of Customer (VOQ), and C&E Diagrams used during the Process Define phase. The next step is to narrow down the KPIVs to an important few through quantitative calculations (C&E Matrix, FMEA).

Figure 30 below provides a breakdown of how KPIVs are narrowed down by importance during each phase of the DMAIC process.
During the Analyze phase, a high level process map was not created. However, a spaghetti diagram was designed during the Define phase which gives an accurate overall depiction of what the cafeteria’s student flow looks like. This spaghetti diagram is referred to in Figure 4 in the Define phase along with the process flow description. During the Measure phase, at the end of every lunch period, the weights of the buckets were measured and noted down, along with the number of items added to the share table. This process was repeated for all the lunch periods for a given day, across the span of a week. A similar process was also carried out during Post-Improvement analysis.

During the Analyze phase, we spent time observing this entire process at St. Patrick’s to understand what the key issues contributing to the increasing amounts of food waste generated were. Below is a list of key take home points that were in our control to bring about improvements.
• Majority of the students were not aware that they had to pick between fruits and veggies, and did not have to pick both. This was a common observation where students ended up choosing both only to waste most of it.
• Students were not aware that milk was not mandatory. Majority of the milk cartons that were disposed showed that students wasted more than half of its contents.
• Students disposed unopened pre-packaged; unaware of share table
• Students disposed unopened milk cartons; unaware of share table
• Most students struggled to finish their meals in the given lunch duration especially the younger grades; they needed to be made aware that they were allowed to take more time to finish eating
• Students were in a hurry to finish their lunches and leave together with their friends which could be pressuring on the slow eaters

This information is used in the next section to create a C&E matrix, and FMEA.

5.3.1 Cause & Effect Matrix
The next step in this phase is to then to transfer the key processes from the high level process map to the C&E matrix. A C&E matrix is a handy tool for quantitatively determining which KPIVs should be carried into the improvement phase of the project based on the relationship of KPIVs to KPOVs, where KPOVs depict the customers’ requirement. Key inputs are scored as to their relationship to key outputs. Some inputs are more critical to customer satisfaction than others. Key outputs are scored as to their importance to the customer. Some customer outputs are more important than others. The C&E matrix facilitates a scoring system that brings the highest priority inputs to the forefront, based upon what is important to the customer (or the next step of the process).
The first step is to determine a list of all the potential causes, which is done as part of the C&E matrix. In the C&E matrix seen in Figure 31, a list of all the Key Input Variables (KPIV) are first listed in a single column. A list of all the Key Process Output Variables (KPOV) are then listed in the top row. Each KPOV is then rated on a scale of 1-to-10 based on importance to customer. Next, each KPIV’s relationship to each KPOV is rated on a scale of 1-to-10. This form of rating is subjective in nature.

Each KPIV is labelled “C”, “U”, or “S”. C means “controllable,” U means “uncontrollable,” and S represents “standard operating procedure.” Controllable refers to processes or inputs that we have the ability to control to cause improvements. For example, food waste and nutrition education, incentives and rewards, are examples of inputs that we have control over. Uncontrollable refers to key inputs that are not in our control, and that we cannot alter or improve upon. For example, appearance of food, student’s mood, student’s health are examples of uncontrollable process inputs.
**Steps to create a C&E Matrix:**

- Identify key customer requirements based on the VOC
- Rank order and assign a priority factor (determined by the individual carrying out the FMEA) to each output on 1 to 10 scale
- Identify all process steps and KPIV from the high level process map
- Evaluate correlation of each input to each output based on their perceived importance to the customer
- Cross-multiply correlation values with priority factors and sum for each input

<table>
<thead>
<tr>
<th>Key Process Input Variables</th>
<th>Socializing with Friends</th>
<th>Eating Enough</th>
<th>Food in Cafeteria Is Tasty</th>
<th>Showing off (Principals, teachers, visitors)</th>
<th>Wasting Food</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cafeteria Menu (U)</td>
<td>1</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td>224</td>
</tr>
<tr>
<td>Food Appearance/Temp. (U)</td>
<td>0</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td>216</td>
</tr>
<tr>
<td>“Bad” Food (burned, overcooked)</td>
<td>0</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td>216</td>
</tr>
<tr>
<td>Student’s Health (U)</td>
<td>3</td>
<td>9</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>144</td>
</tr>
<tr>
<td>Need to Socialize (U)</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>132</td>
</tr>
<tr>
<td>Student’s Mood (U)</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>112</td>
</tr>
<tr>
<td>Student’s Personality (U)</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>104</td>
</tr>
<tr>
<td>Portion Size (U/C)</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>102</td>
</tr>
<tr>
<td>Distracted/Unfocused in Line (C)</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>72</td>
</tr>
<tr>
<td>Influence of Classmates/Other Grades</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>64</td>
</tr>
<tr>
<td>Pre-peeled vs. Whole Fruit</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>52</td>
</tr>
<tr>
<td>Student Brings Lunch (U)</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Student’s Grade Level (U)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>48</td>
</tr>
<tr>
<td>Student’s Events of the Day (U)</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>44</td>
</tr>
<tr>
<td>Free or Reduced Price Lunch (U)</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>42</td>
</tr>
<tr>
<td>Noise in Line (U/C)</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>Food Waste &amp; Nutrition Education</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Rewards &amp; Incentives ©</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Ability of Staff to Hear Students</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

Figure 31: Scoring of KPIVs and KPOVs in terms of importance to end customer
Understanding the correlation scores:

- Low score: KPIV changes have a small effect on KPOV
- High score: KPIV changes can greatly affect the KPOV
- Correlation scores are frequently a subjective judgment call based upon team input
- Usually no more than 4 or 5 levels, such as 0, 1, 3, 9 or 1, 3, 5, 7, 10
- Assignment of scoring takes the most time; to avoid this, spell out the criteria for each score

Example:

0: no correlation
1: process input remotely affects the customer requirement
3: process input has a moderate effect on the customer requirement
9: process input has a direct and strong effect on the customer requirement

The direct “customer” of the C&E matrix is the potential failure modes and effects analysis (FMEA). Thus, the next step of the Analyze phase involves carrying out an FMEA.

5.3.2 Failure Modes and Effects Analysis

The purpose of an FMEA is to further reduce the number of key process input variables (KPIVs or x’s) with team-based tools. Using the C&E matrix, some inputs have already been eliminated. Additionally, FMEA was carried out to further reduce the number of key inputs.
There are three types of FMEA: System; Design; Process. For this project, a Process FMEA was carried out. ‘Failure Modes’ are any errors or defects in a process, design, or item, especially those that affect the customer. They can either be potential or actual. ‘Effects Analysis’ refers to studying the consequences of process failures.

The FMEA approach can be explained as below:

- Identify ways the product or process can fail, and
- Eliminate or reduce the risk of failure

**a. FMEA Inputs:**

FMEA inputs usually come from one of the following:

- Process Map
- C&E Matrix
- Process history
- Process technical procedures
For this project, the inputs for the FMEA came from the overall process map, and C&E matrix.

b. FMEA Outputs:

FMEA outputs usually come from one of the following:

- List of actions to prevent causes or to detect failure modes
- History of actions taken

c. FMEA terminology and their definitions:

i. Failure Mode:

- The way a specific process KPIV fails
- If the KPIV is not corrected or removed, it will cause the effect to occur

Example: Tasteless food prepared by the cafeteria staff, if not corrected, will continue to cause increasing amounts of food waste generated

ii. Effects

- Impact on customers’ needs or requirements
- Usually, effects are considered in terms of the external customer focus, but it can also refer to an internal downstream process within the organization

Example: The lack of education on food waste of the students of St. Patrick’s directly impacts the amount of food waste generated.

iii. Cause:

- Sources of process variation that cause the failure mode to occur
• Identification of causes starts with failure modes associated with the highest severity ratings

Example: Bad food, be it stale, burned, or tasteless food is an example of process variation that causes the students to discard their food before barely consuming it.

iv. Risk Priority Number (RPN):

The Risk Priority Number is the output of the FMEA. It is the product of the three quantitative ratings:

• If the failure occurs, what is the severity of the effect?
• How likely is the cause behind the failure to occur?
• Does the process have the ability to detect the failure before reaching the customer?

RISK PRIORITY NUMBER (RPN) = Severity x Occurrence x Detection

v. Severity (S):

• Severity of Effect (1 = Not Severe, 10 = Very Severe)
• A rating of the impact or effect of a particular failure mode on the output or customer

vi. Occurrence (O):

• Occurrence of Cause (1 = Not Likely, 10 = Very Likely)
• A rating of how frequently a given cause occurs and creates failure modes

vii. Detection (D):

• Detection (Capability of Current Controls) (1 = Likely to Detect, 10 = Not Likely at all to Detect)
• Ability of current control scheme to detect or prevent the causes before creating the failure mode, or the failure modes before causing the effects

d. Steps Involved in the FMEA:

1. Identify Failure Modes. What are some things that could go wrong at each step?
2. Identify Failure Mode Effects. What happens to our output ‘Y’ when this failure occurs?
3. Determine Severity values. How badly does this affect our Y on a scale of 1 to 10?
4. List Potential Causes
5. Determine Occurrence Values. How often do we think this occurs, on a scale of 1 to 10?
6. Identify Prevention and Detection Controls; i.e., list Current Controls. How can we tell when this occurs?
7. Determine Detection Values. What is our risk of not detecting the failure on a scale of 1 to 10?
8. Calculate RPNs for each Cause
9. Determine Actions, Execute, Repeat

By following the FMEA process laid out in the previous pages, a failure mode and effect analysis was carried out to determine the key causes of increasing amounts of food waste generated. The FMEA generated is shown in the following figures.

Figure 35 shows the various failure modes, their effects, and the severity of such failure modes on the end customer, that is, on the students. Each failure mode, and its effect has a corresponding potential cause, which has a rating for occurrence. For example, based on our analysis at St. Patrick’s, and information gathered from carrying out a VOC, the failure modes with the highest
severity ratings are cases where the food was stale, burned, under/over seasoned, or under/overcooked. Based on occurrence, the failure mode with the greatest occurrence is if the students disliked the food menu planned for the day. If the students didn’t like the menu, there was a very high chance that majority of the food would go into the trash.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Bad&quot; Food (burned, overcooked)</td>
<td>Students may not want to eat the food</td>
<td>6</td>
<td>Recipe is misproportioned; employees misread recipe; different seasoning preferences</td>
<td>4</td>
<td>Follow Recipe</td>
<td>N/A</td>
<td>6</td>
<td>##</td>
<td>Add salt and pepper shakers to table ketchup</td>
</tr>
<tr>
<td>Food Appearance/Temp. (U)</td>
<td>Students may take the food and not even try it</td>
<td>4</td>
<td>Employees rushed; food is naturally an unappetizing color</td>
<td>4</td>
<td>N/A</td>
<td>Visual inspection</td>
<td>6</td>
<td>95</td>
<td>Encourage student to try the foods they don’t think looks good</td>
</tr>
<tr>
<td>Food Appearance/Temp. (U)</td>
<td>Students may run out of time to eat</td>
<td>5</td>
<td>Food warmers are too hot</td>
<td>5</td>
<td>Temperature measured</td>
<td>Temperature measured</td>
<td>3</td>
<td>75</td>
<td>Ensure food has cooled to “edible”</td>
</tr>
<tr>
<td>Student’s Health (U)</td>
<td>Student orders a lunch &amp; cannot eat it</td>
<td>7</td>
<td>Student is ill; breakfast</td>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
<td>5</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Student’s Health (U)</td>
<td>Student orders a lunch &amp; cannot eat it</td>
<td>7</td>
<td>Student is ill; puberty</td>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
<td>5</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Student’s Health (U)</td>
<td>Student orders a lunch &amp; cannot eat it</td>
<td>7</td>
<td>Student is ill; breakfast</td>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
<td>5</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Cafeteria Menu (U)</td>
<td>Students are more likely to waste the food</td>
<td>2</td>
<td>Unpopular products in scheduling rotation - student input not considered</td>
<td>5</td>
<td>N/A</td>
<td>Count how many student order lunch</td>
<td>6</td>
<td>80</td>
<td>Use the number of daily orders to determine the future menu.</td>
</tr>
</tbody>
</table>

Figure 33: FMEA showing Failure Modes, Effects, Severity, Causes, and Occurrences

Figure 34 shows the Current Process Controls for Prevention and Detection, along with the RPN calculated and the Recommended Actions to eliminate or control the causes behind the failure modes. Based on detection, failure modes that were easy to detect were if the food was stale or overcooked. These failure causes could be easily prevented by storing the food in proper conditions, and by following the recipe properly. Based on the Risk Priority Number, under
seasoned or over seasoned food took the top spot. For such a failure mode, the recommended action was to set up a condiments table with salt & pepper shakers, and other condiments like mustard, ketchup, etc. so that students could season their food based on personal preferences.

<table>
<thead>
<tr>
<th>Current Process Controls - Prevention</th>
<th>Current Process Controls - Detection</th>
<th>DET</th>
<th>RPN</th>
<th>Actions Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow Recipe</td>
<td>N/A</td>
<td>6</td>
<td>192</td>
<td>Add salt and pepper shakers to table w/ketchup</td>
</tr>
<tr>
<td>N/A</td>
<td>Visual inspection</td>
<td>6</td>
<td>96</td>
<td>Encourage student to try the foods they don't think looks good</td>
</tr>
<tr>
<td>Temperature measured</td>
<td>Temperature measured</td>
<td>3</td>
<td>75</td>
<td>Ensure food has cooled to &quot;edible&quot;</td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>5</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>5</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>5</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>Count how many student order lunch</td>
<td>6</td>
<td>60</td>
<td>Use the number of daily orders to determine the future menu.</td>
</tr>
<tr>
<td>Follow Recipe</td>
<td>N/A</td>
<td>7</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Store food in proper</td>
<td>N/A</td>
<td>7</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Follow Recipe</td>
<td>Visual inspection</td>
<td>3</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Temperature measured</td>
<td>Temperature measured</td>
<td>3</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

Figure 34: FMEA showing Prevention and Detection Process Controls, RPN, and Recommended Actions

The rating scale used to calculate RPN, Severity, Occurrence, and Detection for different failure modes contributing to the generation of food waste at St. Patrick’s is shown in Figure 35.
Figure 35: RPN Scale for Severity, Occurrence, and Detection

The FMEA thus helps in developing recommended actions that can be implemented in the improvement phase based on risk priority. In this manner, with the help of a C&E matrix, and FMEA, a list of all the potential causes was first generated, and then these potential causes were screened. Next, the key input variables were narrowed down and selected by using RPN, Severity, and Occurrences as metrics. The greater the severity, RPN, and occurrences of a particular failure mode, the greater the chance of selecting it as a KPIV. Usually, the selection of KPIVs is done by carrying out a DOE (Design of Experiments), however, due to the short duration of this project (10 weeks), a DOE was not carried out. In a typical Six Sigma project with a longer duration, the project would involve methodically investigating several KPIV through a designed experiment to determine which have the biggest effect on the KPOV.
5.4 Improve

The main objective of this phase is to improve the process to eliminate root causes, and to implement solutions to reduce variation. The key improvement tools used during this phase are:

- To-Be Process Map
- Brainstorming

In this phase, we brainstormed multiple ways to improve the current process. A major part of the improvement phase was to create awareness amongst the students. The success of this project largely depends on the students’ awareness and determination to ensure food is saved and shared instead of wasted. To promote such widespread awareness throughout St. Patrick’s, we organized activities by collaborating with the students, as described below.

5.4.1 Rearranging the Cafeteria Layout

We rearranged the cafeteria layout to make the share table more centrally located, as well as located next to the disposal area table. This made it easy for students to drop off any unopened prepackaged food, or milk cartons to the share table on their way out of the cafeteria. Six Sigma in Practice students designed posters, as discussed in the next section, one of which is shown in figure 38. The poster was positioned strategically next to the tray disposal area so that students would be reminded to drop off any packaged food that could otherwise be shared with someone else. The poster also had pictures of the type of food items that could be shared, as part of the share table. The condiments table was left to be its own table. The condiments table contributed to the improvement phase, as it allowed students to season their food according to their personal preferences. This helped tackle one of the top causes of failures modes as seen through the C&E
matrix, and FMEA, that was developed during the Analyze phase. By providing them with means to further improve the taste of their food by adding a condiments table, the hope was to see a reduction in the quantity of food being wasted. Since these changes altered the usual cafeteria flow, we helped guide St. Pat’s students on how to go about disposing their food trays, as well as the food remaining on their trays. During this time, we focused on guiding students to the share table if they had any unopened food that could be shared. In this way, we tried to familiarize students of St. Patrick’s with the concept of the food share table. During the Improvement phase, we tried to tackle top failure causes identified in the Analyze phase that were in our control. There were other failure modes such as stale food, burnt food, students not liking the menu, to name a few that were out of our control to bring about any improvements.

Figure 36: Poster showing examples of food items that can be shared
5.4.2 Poster Day

As part of the improvement phase, the Six Sigma in Practice class designed creative and eye-catching posters to decorate the walls of St. Patrick’s cafeteria. The goal of this activity was to design posters that would spread awareness and motivate St. Patrick’s students to actively participate in reducing the amount of food wasted. Below are some of the posters we made.

While carrying out VOC in the Define phase, and developing the high level process map, C&E matrix, and FMEA in the Analyze phase, we noticed many areas of improvement that required us to simply educate the students and make them aware of what their options were. To begin with, it was mandatory for students to pick either a fruit OR a vegetable, but not necessarily both. As we noticed the food selection habits of St. Pat’s students, we realized that most of them tended to pick both veggies, and fruits, only to waste them both. However, the schools rules and regulations restricted us from directly discouraging students from choosing both fruits and veggies. To combat this issue, teams belonging to the Six Sigma in Practice class designed posters that spread awareness of what students mandatorily had to pick as part of their lunch, and the choices that
were optional. Figure 38 shows an example of a poster that lets the students know that they had the choice to pick between fruits and veggies, and not necessarily both if they didn’t feel like it.

Another example of a key contributor to the amount of food waste generated was milk. Students had the choice of choosing between milk and water as a beverage. The school offered three varieties of flavored milk – Chocolate, Vanilla, and Strawberry. Although students were aware that picking a milk carton was optional, our observations showed that majority of the students picked a milk carton along with their meals. From our Measure phase, it is clear that a large amount of waste generated was due to students wasting milk. Since we were not allowed to blatantly discourage students from picking up milk cartons, one of the teams from the Six Sigma in Practice class designed a poster shown in Figure 39 to let students know that if they were not in the mood to actually drink their milk, they should avoid opening the carton and add it to the share table.

Figure 38: Example of poster used as a means to spread awareness amongst the students of St. Patrick’s
instead. This poster was made because a lot of students would as an afterthought, hurriedly open
the carton, take a sip and then discard it, while trying to rush out of the cafeteria at the end of their
lunch period.

![Poster motivating students to not waste milk](image)

Figure 39: Poster motivating students to not waste milk
In an effort to engage St. Patrick’s students as much as possible, we organized a Poster Day with the 5th grade class where we helped them decorate posters to adorn the cafeteria walls. The students came up with their own fun slogans, and artwork to promote food saving and sharing. Figure 40 shows pictures of a few posters made. This gave the 5th grade class an opportunity to express what food saving and sharing meant to them. After making posters, we, along with the 5th grade class decorated the walls of the cafeteria with the posters, as a means of spreading awareness, and educating the entire school on the importance of saving and sharing food.

Figure 40: Posters made by St. Patrick’s 5th grade class

5.4.3 Fifth Graders as Mentors

The end goal of this project was to hand over the food sharing and saving initiative to St. Patrick’s 5th grade class. In this way, we wanted to educate and inspire the students to take up leadership roles to drive this initiative and motivate students belonging to other grades. As part of this improvement phase, students from the Six Sigma in Practice class helped the 5th graders present a
food waste presentation in the form of a play to the younger grades. The theme of the play was to show how food can be used to help other in the community, especially the poor, and hungry.

We also set up a Food Savers club, led by the 5th graders, and had students from all grades to join the club by signing a ‘green’ contract by signing the poster shown in Figure 41. This approach was to create a sense of belonging, and unity amongst the students, to make them feel like they were all working towards a greater goal of fighting food waste. This idea was sparked by a similar anti-bullying sign that adorned the cafeteria walls. The motivation behind handing over mentorship responsibilities to the 5th grade students was to ensure that the project was left in the hands of St. Patrick’s students for future sustenance; the idea being that the younger students will listen to the older students, while creating a sense of pride amongst the students sparked by improvements in the process.

Figure 41: St. Patrick’s Food Savers Club poster
5.4.4 Spreading Awareness through Media

This Six Sigma project received a significant amount of media attention which further helped spread awareness on the need to curd food waste in schools, as well as on how Six Sigma is a useful tool that has widespread applications in initiatives that call for process improvements. Jane Santucci, an environmental freelance writer wrote an article drawing on the main essence of this project for the Tribune Star, dated November 26, 2017. During the Improvement phase at St. Patrick’s, a local news channel “WTHI” stopped by the school and did a news segment on what we were trying to accomplish at St. Patrick’s with respect to food sharing and saving. In this way, media helped as a channel for spreading awareness in Terre Haute, on the concepts of food sharing and saving, and played an important role in the improvement phase of this project. In addition to this, the website GoLeanSixSigma.com did a Just In Time Café podcast episode that spoke about this project and how Six Sigma’s DMAIC approach was implemented to carry out a social project with the goal of reducing food waste generated in K-8 schools. The Just In Time Café podcast is well known in the Lean and Six Sigma community as a good source of discussion on various Six Sigma projects being implemented across the country.

5.4.5 Purdue Extension

Purdue Extension is made up of a network of educators, specialists and volunteers that provides educational programs to meet the needs of the communities it serves. It should be noted, that upon completion of our project at St. Patrick’s, we wanted to provide the VCSC our data that showed the amounts of food wasted at a school cafeteria and how much food, that would have otherwise been discarded, could be redistributed to those children who needed food. We hoped that the data would encourage the VCSC to implement a food rescue program in its public schools, whose
students had a much greater need for food rescue than St. Patrick’s. In this regard, Allison Finzel of Vigo County Purdue Extension was a supporter of this project, and what we were trying to achieve, from the very beginning. She has been working on promoting food sharing initiatives across Vigo County schools. As part of the Improvement phase, Allison screened an inspirational short film for the students of St. Patrick’s that showed how a young middle school girl was taking inspiring strides to reduce the amount of food waste generated by her household.
5.5 Post Improvement Analysis

During the Improvement phase, we brainstormed ways to improve the existing process at St. Patrick’s that would result in a reduction in the amount of food waste generated, and an increase in the number of food items shared. As explained in the previous section, a majority of the improvement phase involved organizing activities that would educate the students and make them more aware of the importance of this food rescue initiative.

For example, we spent time making students aware that if they did not feel like drinking milk or eating certain pre-packaged food, the food share table was a good place to share their food instead of throwing them in the trash cans. We also designed informative posters and hung them across the cafeteria walls to remind students of what food items were a mandatory part of their lunch meals and what were not. This was especially important since most students would choose all of the available food items because they were under the assumption that they were all mandatory.

Once we implemented improvement activities at St. Patrick’s, we went back to St. Patrick’s and carried out another four days of data collection from May 9, 2017 to May 12, 2017. The main goal of carrying out this round of data collection was to analyze the data collected and see if there were any significant improvements to the amount of food waste generated and the amount of food items shared. Table 7 summarizes the data collected post-improvement.
### Table 7. Data collected post-improvement at St. Patrick’s cafeteria

<table>
<thead>
<tr>
<th>DATE</th>
<th>AMOUNT OF VANILLA MILK WASTED (lbs)</th>
<th>AMOUNT OF CHOCOLATE MILK WASTED (lbs)</th>
<th>AMOUNT OF STRAWBERRY MILK WASTED (lbs)</th>
<th>AMOUNT OF VEGETABLES WASTED (lbs)</th>
<th>AMOUNT OF FRUITS WASTED (lbs)</th>
<th>NUMBER OF MILK CARTONS SHARED</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/9/17</td>
<td>5.25</td>
<td>13.54</td>
<td>6.21</td>
<td>17.6</td>
<td>11.4</td>
<td>16</td>
</tr>
<tr>
<td>5/10/17</td>
<td>4.88</td>
<td>12.12</td>
<td>5.28</td>
<td>11.83</td>
<td>15.53</td>
<td>8</td>
</tr>
<tr>
<td>5/11/17</td>
<td>7.8</td>
<td>17.13</td>
<td>0</td>
<td>11.73</td>
<td>15.2</td>
<td>2</td>
</tr>
<tr>
<td>5/12/17</td>
<td>4.13</td>
<td>5.71</td>
<td>3.84</td>
<td>9.05</td>
<td>14.08</td>
<td>4</td>
</tr>
</tbody>
</table>

It is important to note that during this week of data collection there were a few special causes to our data. On May 9, 2017 the 8th graders went on a field trip and so did not consume any food and contribute to the data collected on that day. On May 11, 2017 the cafeteria did not have strawberry milk as a flavor option which explains why no strawberry milk was wasted on that day. Similarly, on May 12, 2017 kindergarten students, along with the 3rd, 6th, and 7th graders were not present for lunch in the cafeteria as they were either out on field trips or for sports competitions.

From the summary of total amount of food wasted, in spite of the special causes, it can be seen that the amount of food waste generated did not significantly improve even after the improvement phase. Table 8 shows the data collected pre-improvement phase. A comparison of the two tables shows us that the amount of food waste generated did not significantly change after implementing the improvement processes at St. Patrick’s. There are multiple possible reasons there was no
improvement in the food waste generated, these reasons are laid out as part of the ‘Challenges’ section later in the paper.

Table 8. Data collected pre-improvement at St. Patrick’s cafeteria

<table>
<thead>
<tr>
<th>DATE</th>
<th>AMOUNT OF VANILLA MILK WASTED (lbs)</th>
<th>AMOUNT OF CHOCOLATE MILK WASTED (lbs)</th>
<th>AMOUNT OF STRAWBERRY MILK WASTED (lbs)</th>
<th>AMOUNT OF VEGETABLES WASTED (lbs)</th>
<th>AMOUNT OF FRUITS WASTED (lbs)</th>
<th>NUMBER OF MILK CARTONS SHARED</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/4/17</td>
<td>6</td>
<td>7.43</td>
<td>5.6</td>
<td>15.53</td>
<td>17.1</td>
<td>9</td>
</tr>
<tr>
<td>4/5/17</td>
<td>7.93</td>
<td>11.53</td>
<td>5.31</td>
<td>14.04</td>
<td>8.4</td>
<td>13</td>
</tr>
<tr>
<td>4/6/17</td>
<td>6.24</td>
<td>11.1</td>
<td>7.48</td>
<td>16.35</td>
<td>12.38</td>
<td>13</td>
</tr>
<tr>
<td>4/7/17</td>
<td>5.01</td>
<td>9.48</td>
<td>6.61</td>
<td>11.24</td>
<td>18.53</td>
<td>10</td>
</tr>
</tbody>
</table>

From Table 7, except for data collected on May 10, 2017, and May 11, 2017 the remaining days all show special cause variations due to field trips scheduled for different grades. So, in order to compare the data collected before and after the improvement phase, only baseline data from May 10, 2017 and May 11, 2017 can be used in this comparison. By comparing the amount of food waste generated on May 10, 2017 and May 11, 2017 with all the four days in April, pre-improvement, it can be seen that the amounts of waste generated based on food items, be it, milk, fruits or vegetables have not changed significantly. This is an indication that despite the many measures taken by us to spread awareness and motivate the students of St. Patrick’s to reduce the amount of food wasted by them, there hasn’t been any significant improvement. This lack of
significant reduction in the amount of food waste generated can be explained through the many challenges, and obstacles faced during the improvement phase, and the project on the whole. This is explained in the next section under the project’s conclusion. However, a noteworthy point to keep in mind is that while the amount of food waste generated seems to have remained the same, St. Patrick’s is now contributing more and more food items to the food share table, which never occurred before without the implementation of the share table concept. In this sense, it can be said that there requires a lot more time and effort to be put in to significantly bring down the school’s amount of waste generated. The implementation of the food share table has helped in stimulating the school to actively contribute to the food rescue program by sharing unopened pre-packaged food items to those who need them that would otherwise go straight into the trash. In this way, St. Patrick’s school, today, is one step closer in their fight against food waste.
5.6 Control

The goal of this phase is to control the process to sustain the gains for the long term; and to
determine the next steps for ongoing improvement. From the start of the project, the end goal was
to hand over this initiative to the students of St. Patrick’s, with the 5th graders leading in the front.
Once this was achieved, the next goal was to implement the concept of the food share table across
other schools in Vigo County, Indiana. The output of this phase is to generate control plans,
completed documentation of results and recommendations for future projects.

5.6.1 Gage R&R with the Fifth Graders

Set Up of Study

The metric of interest for this Gage R&R was the weight of milk in its carton. We set out to
determine if future 5th grade classes could continue to sustain this process of reducing food waste
once we leave. The main take-away from the study was to determine how much of our process
variation was due to the measurement systems in use.

Upon setup, there were nine teams of 5th grade students consisting of two to three students per
team. One or two students from the Six Sigma in Practice class were then in charge of recording
measurements for each team. Fourteen full milk cartons were obtained from the cafeteria and then
emptied to varying levels. The cartons were split into two groups of seven and both sets of cartons
were individually marked with numbers one through seven, as shown in Figure 42. Their weights
were then measured using digital scales, by the 5th grade students. The digital scale used to weigh
the milk cartons is shown in Figure 43. Half of the teams used one set of the cartons and the others
using the second set. The sets were on tables sitting on opposite sides of the classroom. The Gage
R&R was with n = 2 replications, o = 2 or 3 operators, and p = 7 parts.
Figure 42: Fourteen milk cartons with varying weights, split into two equal groups for the 5th graders to weigh

Figure 43: Digital weighing scales used to measure varying weights of milk cartons

Data Collection

As defined in the Gage R&R process, the Six Sigma in Practice students were recorders and the 5th grade students were the operators, or appraisers. The recorder’s job in the Gage R&R is two-fold; randomize the milk cartons given to the appraisers and to not let other appraisers know the results of a previous group. These two parts are essential to determine whether there is variance
between operators or if there is variance within one operator (due to the measurement systems). The appraisers were also required to make “blind” measurements, meaning they couldn’t know which carton was being measured, what the previous measurement was, and what other appraisers’ measurements were. Additionally, the appraisers could not consult with other groups or know the results of the recorded data until the end of the study. This is to prevent any sort of bias or false reporting for the information conveyed to the recorders.

**Results Summary**

We did this study to determine if there was variation in our measurement system, which was using a digital scale to measure milk weights. If there was variation in our measurement system, we would need to improve it before we use that tool to take measurements, similar to the Gage R&R study carried out that resulted in us switching from the school’s old scale to these new digital scales.
Figure 44: Gage R&R report with run chart data
After conducting tests in Minitab, the following results were obtained: The Number of Distinct Categories was 297 indicating that our measuring tool - the digital scale - was capable of distinguishing the data from itself, discerning one part from another - therefore denoting it as an acceptable measurement system. The Components of Variation chart indicates that 100% of variation was due to part-to-part. This indicates that there were no repeatability issues, which means that there were no variations in the measurements taken of the same carton, by the same operator. The Measurement by Milk Carton chart indicates that there were no reproducibility issues, which means that there was no variation in the measurements taken of the same carton, by different operators. The Xbar Chart by Operator indicates that the overall mean of all measurements was 5.14 ounces. The R Chart by Operators indicates that the mean of the operators’ ranges was 0.01619 ounces. The blips on the R Chart by Operators were due to the digital scale itself, sometimes reading 0.04 in one direction or the other. Overall, the data concludes that the 5th graders are in fact able to determine the weights of the milk cartons.

In this manner, as part of handing over control of the project to the current 5th graders of St. Patrick’s, we taught them how to measure weights of milk cartons using digital scales by carrying out a Gage R&R study.

5.6.2 Control Post Project Completion

Since the long term goal of this project was to hand over the process to the students of St. Patrick’s, we handed over the project completely to St. Patrick’s during the Control phase, with the hope that its staff and students would carry on the effort to save and share food. Since the end of the project to now, a year has passed, and there has been no further involvement of the Six Sigma students at
St. Patrick’s. For starters, the Six Sigma class is scheduled only for the spring quarter of every year. The project culminated at the end of the spring quarter of 2017, after which both St. Patrick’s and Rose-Hulman Institute of Technology began their summer break. St. Patrick’s has carried on the effort since then, however, the school does not actively carry out any form of record keeping of the amount of food waste being generated. This sort of data recording requires a significant amount of time and effort by the students and staff of St. Patrick’s which may not be feasible with the school’s current schedule. While the St. Patrick’s staff confirmed with us that the food share table is still a concept that is being actively implemented at St. Patrick’s, the staff and students at St. Patrick’s don’t have any quantitative data that they can provide for us to carry out a comparative analysis on the amount of food waste generated in the past year. Without this data, there is no way of us know if there has been any long term reduction in the amount of food wasted. However, the fact that the share table is being used today, one year later, is a good indication of how the share table process of rescuing and saving unopened prepackaged food has been sustained by the students and staff of St. Patrick’s.

Since it is not feasible for the staff and students of Rose-Hulman Institute of Technology to constantly keep track of the food sharing activities at St. Patrick’s, nor is it feasible for the staff and students of St. Patrick’s to provide us with a constant feed of data tracking the amount of food waste generated, this leads us to a standstill where we have no visibility on the progress of project ever since it was handed over to the students of St. Patrick’s. This is a common issue that most Six Sigma projects run into when a transfer of responsibility of the process is involved.
5.6.3 Expanding the Project’s Reach

A long-term goal of this project was to implement a similar food rescue initiative to promote food sharing in other schools in Vigo County. During the summer of 2017, Dr. Diane Evans, the instructor of the Six Sigma class and Alison Finzel of Purdue Extension presented the project findings of St. Patrick’s to the Vigo County School Administrators (VCSA) to show them the potential behind implementing a similar food rescue campaign across all Vigo County schools. Overall, the VCSA were receptive, and willing to listen to what Dr. Evans and Allison had to present, however, they were still cautious about the idea of implementing a food rescue program across all schools in Vigo County. They were still worried about the possibility of shared food items affecting students’ health. Allison Finzel then requested permission to implement a trial pilot food rescue program at Farrington Grove Elementary School to which the VCSA agreed.

After the end of the project at St. Patrick’s, Allison Finzel of Purdue Extension, inspired by the growing number of food items shared through St. Patrick’s existing share table started a pilot food rescue program at Farrington Grove Elementary School in Terre Haute, Indiana. A share table was set up at Farrington Grove to promote food sharing so that so that instead of the food being wasted, it can be given to those who need it. Since the start of the academic year of 2017-2018 until March of 2018, Farrington Grove, thanks to the dedication of its students were able to rescue 15,145 food items, and 3,029 meals as shown in Figure 47. From the conversion shown in the poster below, 3029 rescued meals amount to 2424 lbs. of food rescued. This data was provided to us by Allison Fenzel of Purdue Extension. As of April 13, 2018 18,396 food items were rescued at Farrington Grove. These growing numbers provide us with the confidence to say that the share table concept is being sustained even after the completion of our Six Sigma project at St. Patrick’s.
Bolstered by the success of the pilot program at Farrington Grove, we were able to show the school corporation that food rescue is an easy way to get food to those that need it which would otherwise have been thrown away. Following this, the Vigo County School Corporation provided the green light to launch similar food rescue programs by implementing food share tables in all Vigo County schools. In this manner, the main motivation behind carrying out this project at St. Patrick’s has been sustained, and the scope of the project is now expanded to all schools in Vigo County, Indiana.
6. CHALLENGES

A look at the data depicted in Tables 9 and 10 of the Post-Improvement Analysis section of this project shows that there was no significant improvement in the amount of waste generated of food that was not prepackaged, and thus could not be saved. Although the food share table concept gained momentum as the project progressed, this lack of significant reduction in the amount of food waste generated was mainly due to certain factors that were beyond our control. This posed challenges to making changes to the food service process that we would have ideally liked to have seen put in place.

For example, legal laws about portion size restricted us from implementing a serving process that reduced their sizes. Also, some food could not be rescued, such as fruit served from a large open container instead of a single-serving closed cup. Most of St. Patrick’s cafeteria’s fruit and vegetable items were packaged in their lunchroom and could not be shared.

During the improvement phase, we realized that majority of the students were not aware of their food options; most believed they had to choose both a fruit and a vegetable as part of their meal. While we would have liked to have stood in the lunch line with the students to educate them of what food items were mandatory, the school’s regulations did not allow us to directly discourage students from taking too much food.

Another challenge was that the lunch periods at St. Patrick’s were directly followed by recess for every grade. Students were so eager to get to recess that they would barely eat their food, resulting in large amounts of food waste. An effective solution to this problem was for the school to schedule lunch periods after recess instead; this way students would come in with larger appetites, and this
would result in lesser food wasted. This was not a practical solution because of the school’s rigid daily routine, another factor that we had no control over.

The biggest challenge during this project, however, had to do with the difficulties in the logistics of doing an off-campus project in which the students from the Six Sigma class had to make multiple trips to St. Patrick’s school. St. Patrick’s was only a 10-minute drive from Rose-Hulman’s campus, however, the class’s meeting time was only 50 minutes. This made it difficult for us to spend significant amounts of time at St. Patrick’s, especially during the Improvement phase. The success of this project is directly proportional to the amount of time put into educating the students and getting them onboard the mission, and time was always something we were short of.

Finally, the customers of this project, that is, the students of St. Patrick’s belonged to a very young age group. Dealing with students from PreK-8 grade required us to spend a lot more time than we had the bandwidth for, and this is where the 10-week span of the project limited the extent of impact we created at St. Patrick’s school. Had this project been implemented in a high school or a university, students would have been far more receptive in their adoption of such a food rescue initiative.
7. CONCLUSION

This project’s goal was to apply Six Sigma methodology to a PreK-8 school cafeteria in order to measure the daily levels of food waste and convert it into meaningful data to be used to promote food rescue and reuse at the school, as well as other schools in Vigo County, Indiana. The project applied Six Sigma’s DMAIC (Define, Measure, Analyze, Improve, and Control) methodology which involved a series of phases, each with a unique, set goal. The first phase involved defining the process and the key stakeholders involved. The next phase involved measuring the existing amounts of food waste generated by the school’s cafeteria, before the start of activities used to promote food rescue and reuse. Following this, the data collected and the existing cafeteria process flow were analyzed to understand the KPIVs that were impacting the end result. Then, the Six Sigma class of Rose-Hulman Institute of Technology defined various approaches to improve the existing process. The final phase resulted in a complete hand over of the project to the 5th-grade students of the school to sustain the food rescue initiative in the future.

The goal of this project was to shed light on the practices of food rescuing and sharing, and to implement these processes at St. Patrick’s Elementary school by educating the students with the goal of having them lead the food rescue initiative in the long term. During the entire project, our completion was to the overall process as opposed to the results. We saw many gaps in awareness amongst the students that contributed to the food waste factor, and we tried to close these gaps by spreading awareness and educating the students about saving and sharing food. Our biggest achievement from carrying out this 10-week project at St. Patrick’s school was the adoption of the food share table concept by all students and staff. Until then, students were not inclined towards sharing their food as an alternative to discarding untouched, unopened, pre-packaged food. The
adoption of the food share table by the students led to the school saving many food items that could then be shared with people in need.

Although the food share table concept was gaining momentum, data collected from the post-improvement phase shows no significant improvement in the amount of waste generated of food that was not pre-packaged and so could not be saved. This lack of significant reduction in the amount of food waste generated was mainly due to certain factors that were beyond our control. This caused many challenges (which are laid out in the previous section) to making changes to the food service process that we’d like to have seen put in place.

Despite the many challenges faced during the project, overall, we were able to fit an entire Six Sigma Black Belt project within an academic quarter. What makes this project an interesting one is that it applies Six Sigma methodologies to drive social impact. Since implementing the share table concept at St. Patrick’s, this concept has been implemented in Farrington Grove Elementary School where over 8,000 food items were saved during an entire academic year. The potential behind implementing such a food rescue initiative has been realized through these projects at St. Patrick’s, and Farrington Grove, and the food sharing initiative is now scheduled for implementation across all schools in Vigo County, Indiana. The scope of our Six Sigma project has expanded tremendously and is proof that every school in the United States has the potential to implement similar food rescue initiatives while teaching students everywhere how to be socially inclined from an early age. Overall, this project shows the potential of using Six Sigma, a statistics-based methodology to bring about social change on a wide scale.
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