QUANTIFYING IMPACTS OF STEEL SUPPLIER QUALITY TO COMPARE SUPPLIERS' RATIONALIZED COSTS

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By
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CERTIFICATION OF APPROVAL

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DEDICATION

This project is first dedicated to my wife, Danielle. You continue to show me that choosing to spend the rest of my life with you was the greatest choice I have made in my life. I would not have been able to complete this project and program without the incredible amount of sacrifice and support you have given to me and to our family.

Secondly, I dedicate this project to my mother and father, who have also pushed me to grow and expand my horizons. I am eternally grateful for all the time and energy you spent with me to mold me into the person I am today. I love you both.

I also dedicate this project to my brother, Ryan, who challenged me to continue my education through his own successes. You are an inspiration and a great confidant.

Lastly, I dedicate this project to my wonderful children who sacrificed numerous Saturdays and nights to let me complete this project and program. You are the reason for all of this work and are well worth the effort.

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ABSTRACT

Tinplate used in the food can manufacturing industry is supplied by steel manufacturing firms across the world that have different capabilities and varying levels of quality. The goal of this paper was to identify the impact of steel defects on a can manufacturing company. The author studied the fundamental structure of a 3-piece can manufacturing process and used cost estimates to look at the contribution margin differences between the sale of prime quality cans and cans claimed for a steel defect. The information from the margin comparison was applied to the overall contribution margin as the percentage of defects increases over the total supply. The relationship between margin and changes in the claim rate was used to analyze 2 theoretical suppliers and identify the price implications if the customers have different levels of quality. The results show that defects always represent a loss due to the reduced contribution margin of replacement production and that as defect rates increase the contribution margin will decrease. These results support the conclusions of previous studies on the customer perception of quality and the correlations between quality and profitability. There are implications for suppliers that have differences in relative quality compared to competitors. Higher quality is important for maintaining and improving customer-supplier relationships.

CHAPTER I

INTRODUCTION TO THE STUDY

Background

In the United States, approximately 27 billion metal containers are manufactured annually for the purpose of storing and protecting food products (Can Manufacturers Institute, 2016). The food product classification for metal containers includes coffee, fruits, vegetables, soups, seafood, shellfish, pet foods, fruit/vegetables juices, infant formula, dairy products, and other miscellaneous food products. These containers are generically called food cans. The total annual number of cans is divided between two substrate classifications: aluminum and steel. For this project, the author focused solely on the portion of metal food cans that use steel for the body construction. The steel used in the fabrication of food cans is a low-carbon grade of steel that is designated specifically for tin mill products. Specific processes and raw materials are required to produce steel acceptable for tin mill products. A detailed explanation on the process of manufacturing steel for tin mill products is given in the Appendix. This type of steel is purchased from a variety of suppliers in countries located around the world.

Steel food cans are formed and assembled using high-speed manufacturing equipment to create cans of various sizes and shapes. There are three basic categories for the components that make up a complete steel food can: ends, two-piece cans, and three-piece cans. Ends are the closures for both two- and three-piece cans. They are fabricated out of two types of steel: either electrolytic tinplate (ETP) or chromium-coated, tin-free steel (TFS). The steel for end fabrication is coated with an enamel as a full steel coils or after it has been sheared into cut sheets. Examples of the types of ends are shown in Figure 1 below.

Figure 1. Examples of three different styles of ends. From left to right, the styles area sanitary end, a Stay-On-Tab (SOT) beverage end, and a Full-Panel, Pull-Open (FPPO) end.

Two-piece cans are formed from flat sheets into a seamless cylinder with one closed end. The cans are formed through drawing processes using presses and forming dies that create the bottom of the container and the side walls. These cans can be formed out of coated steel or raw tinplate coils that will receive an interior and exterior enamel coating after fabrication. Examples of different styles of two-piece cans are shown in Figure 2. After the can is filled with product, an end is applied to the open end of the container and mechanically attached to seal the container using a forming process called seaming. The closed container is made up of two components, or pieces, the can and the end.

Figure 2. Examples of two different two-piece can styles. The cans shown in the left and center images are straight-walled, draw-redraw cans. The can in the right image is a beaded, drawn and ironed can.

Three-piece cans are created from flat sheets. These flat sheets are formed into cylinders through a mechanical forming process. The edges of the sheet that run the length of the cylinder are welded together, creating an open-ended cylinder. The cylinder is put through a variety of forming processes depending on the dimensional and structural requirements of the finished container. The final forming process in three-piece can manufacturing is the application of an end to create a closed-bottom cylinder. The end is attached using a forming process called seaming to create a hermetic seal. After the can is filled with product, an end is applied to the open end of the container and mechanically attached to the open end of the can to seal in the product. A filled three-piece steel food can is made up of three components, or pieces, the can body and the two ends.

Statement of the Problem

Steel food cans are made in large quantities using different manufacturing methods. The steel used to manufacture these products can be purchased from a variety of suppliers domestically or internationally. Metal is ordered from suppliers with a defined set of specifications. These specifications include dimensional requirements, mechanical properties, chemical compositions, shape properties, tin coating properties, base steel cleanliness, and surface cleanliness. These requirements outline the criteria to identify incoming steel as prime or defective. Material that does not meet these requirements is the focus of this project. Defective materials reduce the efficiencies of the manufacturing processes. They create waste through production of cans that do not meet customer specifications, reduce production due to stoppages to identify the cause of the defect and create downtime to complete a corrective action. These wastes increase the costs of manufacturing and affect the operating expenses of both the steel supplier and the can manufacturer.

Purpose of the Study

The purpose of this study was to identify a framework to quantify the impact of noncompliant steel on can manufacturing. Each defect type can have a different effect on the manufacturing process and the finished product. The author outlines a specific defect and the impact of that defect for a specific phase of the manufacturing processes to identify the cost implications. This impact can be quantified using the associated material and manufacturing costs for each completed stage prior to the defect being identified. The result of the study outlines a method to calculate the costs of defects that can be applied to other types of defects and other can fabrication methods. Using this methodology, future research and calculations will be able to accurately identify the costs of steel defects for a specific manufacturing company. These identified costs can be used to accurately compare suppliers based on their steel price and take into account a supplier’s specific defect cost impacts based on its historical quality data.

CHAPTER II

REVIEW OF THE LITERATURE

Supplier Quality

The concept of supplier selection is a widely researched topic in business with analysis coming from different fields of study like strategy, marketing, and management. In the research phase, a common theme of supplier quality was found in a significant number of articles. An article by Weber, Current and Benton (1991) conducted a review of 74 articles to identify the criteria viewed as important for supplier selection. Based on the analysis of the articles, vendor quality was ranked as the number one criterion and given a rating of critical importance in supplier selection criteria. This conclusion was supported with a follow up study by Kar and Pani (2014) that showed product quality was viewed with a high relative importance across 12 industries and was individually rated with the highest importance from supply chain and procurement managers in the iron and steel industry. This research showed that supplier quality is viewed as an important criterion by supply chain management and procurement professionals. It is important that supply chain managers and procurement specialists regard quality to be important, but it must be determined whether product quality has an impact on business performance. Research by Phillips, Chang and Buzzell (1983), "provides strong evidence for the influence of product quality on business performance." Their analysis of different business types showed that higher product quality had an indirect positive effect on ROI through a variety of factors that lead to improved market share. The direct positive correlations with higher relative quality were found with higher prices and improved market position. Jacobson and Aaker (1987) considered the different business factors that can be influenced through quality and found there to be a significant positive correlation with profitability (ROI), price compared to competition, and market share. Based on their analysis, they attribute the increased profitability to customer value on quality as a means of product differentiation and a way to improve positioning as a premium product. Their theory also helps to explain the positive impact on price. The higher valued product will garner a higher price and lead to increased returns. Conclusions presented by Kroll, Wright and Heiens (1999) further support these results. Their work looked at the impact of quality on the competitive advantage of a firm. They found that product quality also had a positive relationship with returns and market share. The identification of these positive correlations shows quality is a valid factor to consider on the steel suppliers' impact on the food can manufacturing industry.

Definition of Material Requirements

The steel used in food can manufacturing is a specialized product that has been refined over many years for most manufacturers. There are specific requirements the steel must possess for material to meet the customer's specifications. The generally accepted industry standards for tin mill products are laid out in specifications maintained by the American Society for Testing and Materials. The standards establish industry ranges for properties, but allow that alternate agreements can be made between supplier and customer. The general requirements for tinplate are given in the ASTM standard A623-16 (ASTM, 2016). For the purposes of this project, the requirements for tin mill products are broken down into three categories: dimensional properties, mechanical properties, and physical properties.

The dimensional properties for tin mill products outline the requirements for tin mill products that are defined through ordering and that are simply measured by units of length. These properties include gauge, coil width, and shape. Gauge is a term for the thickness of the steel substrate. Gauge can be ordered by thickness, for example in inches, or by the unit of base weight. In the American can manufacturing industry, base weight is a unit of plate thickness based on the weight of a specific surface area of tinplate. The surface area of plate equals 31,360 in^2 and is referred to as a base box. For example, if one base box of tinplate weighs 100 pounds, the plate is referred to as 100-pound plate or has a base weight of 100. The thickness conversion from base weight to inches is given by the ratio of 0.00011 inches per pound of base weight. Using the same example, tinplate with a base weight of 100 pounds would be 0.011 inches thick. Coil width is defined as the width of the steel perpendicular to the length of the coil. This dimension is defined in the ordering process and can vary depending on the width capability of the different machinery involved in the shearing, punching, or drawing of the steel coils. The final dimensional property is shape. Shape is a term that encompasses the different deviations of coils from a perfectly flat plane. The ideal coil and cut sheet is perfectly flat. The different types of deviations are described in the following section.

The mechanical properties outline the strength, formability, and performance characteristics of the steel. These properties are measured through a series of tests to compare values of current production against a defined standard developed during the research and creation of a given product. The properties most critical for steel in food can manufacturing are yield strength, ultimate tensile strength, elongation, hardness, springback, and earing. From Turner (2013), these properties “must be understood and taken into account in the design of metal packaging.” Yield strength is a measure of the maximum force applied to a material before plastic deformation occurs. This point represents the transition point where the deformation of the material changes from reversible to permanent. The ultimate tensile strength is the maximum amount of force a material can withstand before breaking. This strength is always equal to or greater than the yield strength of a material. Elongation is the increase in length as a percentage of the original length of the test sample before failure. It is a measurement of ductility of a material and defines the amount of deformation a material can withstand before breaking. Hardness is a material’s resistance to plastic deformation. The hardness of a material is tested with an indenter set to a specific amount of force and with a specific indenting tip. There are many different scales of hardness for different metals. For tin mill products, all hardness measurements use the Rockwell C hardness scale. This test is a quick and simple test that can approximate yield strength. Tin mills often utilize this test for verifying properties between different operations. Springback is a measure of the material’s resistance to bending around a standardized mandrel and can be used to estimate yield strength. This test is a quick way to approximate yield strength, but is sensitive to differences in thickness of samples. The method and apparatus for testing springback is outlined in Morgan (1985). The last mechanical property is earing. Earing is the measure of planar anisotropy in the drawing of flat steel. This is the measure of disproportional drawing of metal across different planar directions of the starting flat sheet. The measurement is given as a unitless ratio and listed as delta-r (Δr). The ratio can be either positive or negative and the ideal value for drawing uniformity is zero. These tests make up the methods used to identify and compare mechanical properties of the steel purchased from tin mills.

The physical properties outline the chemical composition of the steel substrate, the composition of the surface coatings, and the surface conditions of the finished coils. The chemical composition of the steel is defined by the amount of different elements present within a given percentage. As laid out in ASTM standard A623-16 (2016), there are three main steel compositions in tin mill products. They are Type-D, Type-L, and Type-MR. Each has a different limit for specific residual elements to yield different mechanical properties and corrosion properties. The level of residual elements has a significant impact on the corrosion performance of the base steel as shown in Lueck (1974) and Kamm (1989). This project focused only on the Type-L specification, the most restrictive classification for residual elements. The tin coating weights are specified by pounds of tin per base box. The ordered tin weight differs from the actual weight of tin on the plate as explained in Robertson (2012). The ordered weight is twice the actual amount applied to a specific side. For example, tin plate with a coating specification of 0.50/0.20 pounds of tin per side will target a weight of 0.25 pounds on one side and 0.10 pounds on the opposite. This difference in ordered from delivered tin weights is from the original coating method of tin using liquid tin baths. With hot dipped tinplate, it was not possible to apply different coating thickness; tin weights were given as overall weights per base box. The chromium coating for tin-free steel products is measured in milligrams per square foot, or per square meter in metric. The last requirement of tin plate is the surface condition of the finished coil. As laid out in Turner (2013), the surface condition and the surface coatings play a significant role in the adhesion and performance of the protective and decorative coatings applied to food cans. The surface conditions of tinplate include surface roughness, the composition of the surface coatings, and mill oil application. The primary specification for surface condition is surface roughness. This is a property controlled in the mills rolling operations. The next requirement is mill oil. Mills apply food-grade oil to prevent oxidation and to improve feeding of coils through presses and through coil shearing lines. The overall surface condition requirements are that the coils are free of contaminates and surface defects.

Definition of Material Defects

Following the definitions of material requirements, material defects are broken down into the same three categories: dimensional properties, mechanical properties, and physical properties.

Dimensional defects include any defect that causes a coil to fall outside of the ordered dimensional specifications. This could include out of specification gauge, out of specification coil width or out of specification shape. There can be numerous causes for coil width to be delivered out of specification. Coils are trimmed to their ordered width at the mill and poor setup of the trimming knives can create coil width defects. One type of width defect from trimming is camber. Camber is the measure distance of the edge of a coil from a straight line. An example is shown below in Figure 3.

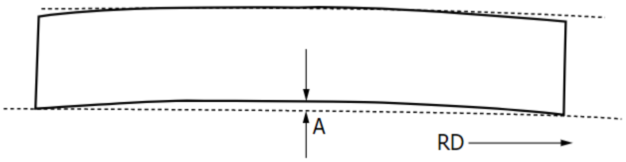

Figure 3. Illustration of camber in a long section of a coil. RD indicates the rolling direction of the coil (ASTM International, 2014).

Another defect associated with trimming is lateral weave. This defect is very similar to camber, but the deviation of the coil edge to a straight line oscillates back and forth across the reference line. An example is shown in Figure 4.

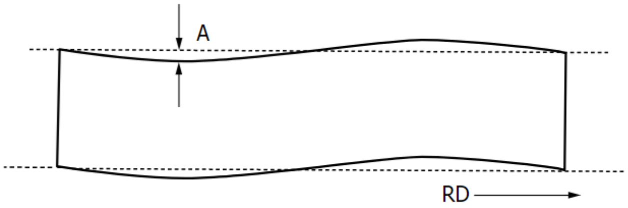

Figure 4. Illustration of lateral weave of the width of a section of a coil (ASTM International, 2014).

Coils can also have metallurgical defects at the edge of the coil that result in a large crack at the coil edge. Shape defects are classified by the type and location of deviation from a completely flat plane. The generally agreed-upon definitions and representations of the most common shape defects are listed in ASTM standard

A987/A987M-7 (2014). The most basic shape defect is coil set or reverse coil set. Coil set is an excessive bow of the coil toward the eye of the coil when it is rolled out. The bow is generally uniform across the width of the coil, as shown in Figure 5.

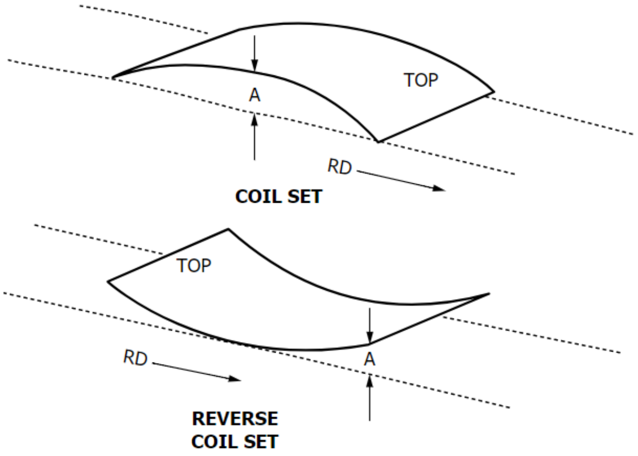

Figure 5. Illustration of the coil set and reverse coil set defects in a cut sheet (ASTM International, 2014).

Reverse coil set is the same as coil set, but indicates the opposite bow direction. Another defect that is uniform in distribution is crossbow. Crossbow is the lifting of the edges perpendicular to the rolling direction of a coil, as shown in Figure 6.

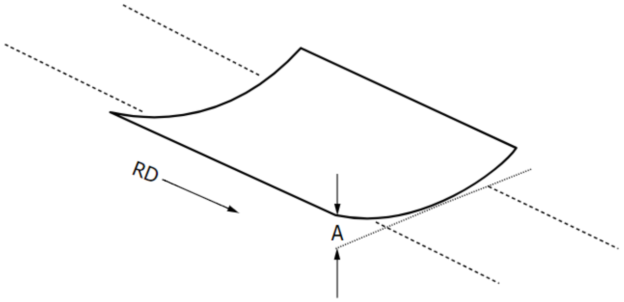

Figure 6. Illustration of the crossbow defect in a cut sheet (ASTM International, 2014).

There are defects that are not uniformly distributed across the width of a coil or the length of a cut sheet. The first type of defect is defined as wavy edge. Wavy edge is an overreduction of thickness at the edges of the coil resulting in a length difference between the edge of the coil and the center of the coil. The increased length at the edges causes the coil edge to oscillate from the reference plane as a way to accommodate the difference in length. In the example shown in Figure 7, the edges ripple while the center of the strip is flat to the reference plane.

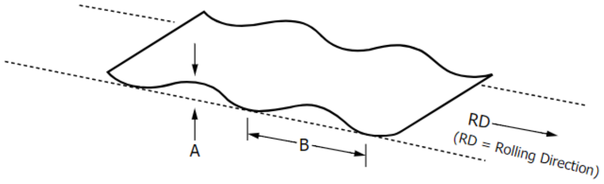

Figure 7. Illustration of the wavy edge defect in a section of coil. In the illustration, the center of the coil is flat in reference to the two-dimensional plane of the coil (ASTM International, 2014).

The next defect, full center, is a similar defect, but with a different localization. Full center is an overreduction of thickness located in the center of the coil that results in a difference in length between the center and the edges of a coil. The resulting difference in length causes the center of the coil to oscillate from the reference plane to accommodate the difference. In the example shown in Figure 8, the dotted lines represent a wave in the center of the strip while the edges remain flat.

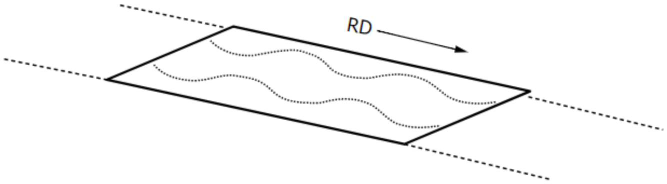

Figure 8. Illustration of the full center defect on a section of coil. In the illustration, the edges are flat in reference to the two-dimensional plane of the coil (ASTM International, 2014).

Another localized shape defect is edge lift. This defect is isolated to a single side of a coil and is generally uniform in amplitude. It does not oscillate as is the case with wavy edge. An example is given in Figure 9.

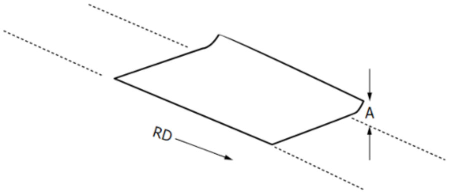

Figure 9. Illustration of the edge lift defect on a cut sheet (ASTM International, 2014).

The last defect, most commonly seen in the cut sheet form and is the result of a combination of shape defects creating the condition called twist. Twist defines a shape condition that causes the lift of one corner of a cut sheet and lift in the opposite direction of the opposite corner of the cut sheet. It is shown below in Figure 10.

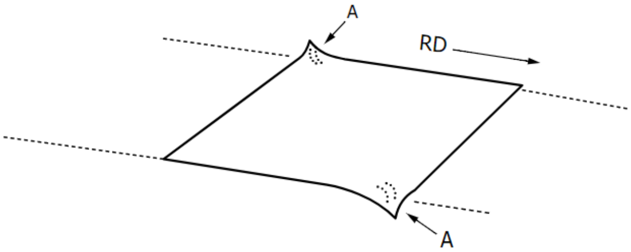

Figure 10. Illustration of the twist defect in a cut sheet (ASTM International, 2014).

Mechanical defects include any failure that causes a coil to fall outside of the ordered strength and formability specifications. This includes out of specification yield strength, tensile strength, elongation, and hardness. For the drawn products, an out of standard value of delta-r would also be considered a defect.

Physical defects include any out-of-specification condition that deals with the chemical composition, the metallic coatings, and the condition of the surface of the coil. An above-specification level of a residual element can have a large impact on the corrosion performance of a filled container and would be characterized as a major defect. The negative impacts of elevated levels of copper, silicon, and phosphorus have been identified in Davis and Wiese (1981) and Kamm (1989). A localized compositional defect is a nonmetallic inclusion. These defects are caused by the presence of an oxide, a silica, or a sulfide in the steel that is physically, not chemically, held within the steel substrate. Large inclusions can break out of the base steel during fabrication, causing holes or cracks to form in the can end or body. Inclusions reduce the fatigue strength of the steel and contribute to fatigue crack propagation as stated in Atkinson and Shi (2003). Inclusions also create problems in drawing operations due to the additional gauge reductions in the forming processes and the potential for cracks or fractures to initiate at the surface of inclusions. The level of tin applied to the surface of the steel is a critical requirement. A below-specification weight on tin or chromium coating over the steel substrate would be classified as a defect. Above-specification levels are not defects, but would result in an increased cost for the coil mill. Surface defects can be physical characteristics of the surface. These types include out-of-specification surface roughness, surface dents, scratches, or other surface imperfections. One of the main surface defects is classified as lamination. A lamination is classified by foreign material or a steel surface defect that is rolled in during the reduction stages, but does not reincorporate itself with the base steel. These defects can separate from the steel substrate during fabrication leaving a hole in the end or can body. The last type of surface defect includes surface contaminates. These could include mill oil, dirt, dust, debris, or rust. These types of defects represent a contamination risk and can create defects in subsequent coating processes.

CHAPTER III

DATA ANALYSIS

For this project, the author will present a theoretical company that purchases steel from different suppliers that have varying levels of quality. A theoretical framework will be created around this company for the purpose of identifying the cost impact of quality. Opportunity costs of a specific defect regarding production losses at a single point in the manufacturing process will also be considered. Based on this analysis, the methodology could be extended to catalog the costs of all other defects at the different phases of the manufacturing process and for the other technology segments for food can manufacturers.

The defect type on which the analysis focuses is a large inclusion. Inclusions occur in the initial stages of the steel manufacturing process and are problematic for food can manufacture as they can pass through successive stages of fabrication until the nonmetallic particle dislodges from the steel substrate. They are a risk for holes in ends and cans, which are a critical defect for food canning customers. This analysis will focus on the impact of inclusions on three-piece cans only. To identify the opportunity cost of these defects, the author will look at the lost profit and the costs incurred by the can manufacturer that are not recouped with the current mill defect claim procedure. Opportunity costs are defined as “the return one could earn on the next best alternative” (Higgins, 2016). The option of selling finished food cans at full price is the best alternative when compared to a mill claim and should serve as the benchmark for comparing the two processes.

At each stage of manufacture, value is added to the steel through processing, application of coatings, and invested labor. For a three-piece can, the metal flows through four processes to create a finished can. The manufacturing stages for can assembly are outlined below with the labor costs in Figure 11 and the direct material costs outlined in Figure 12.

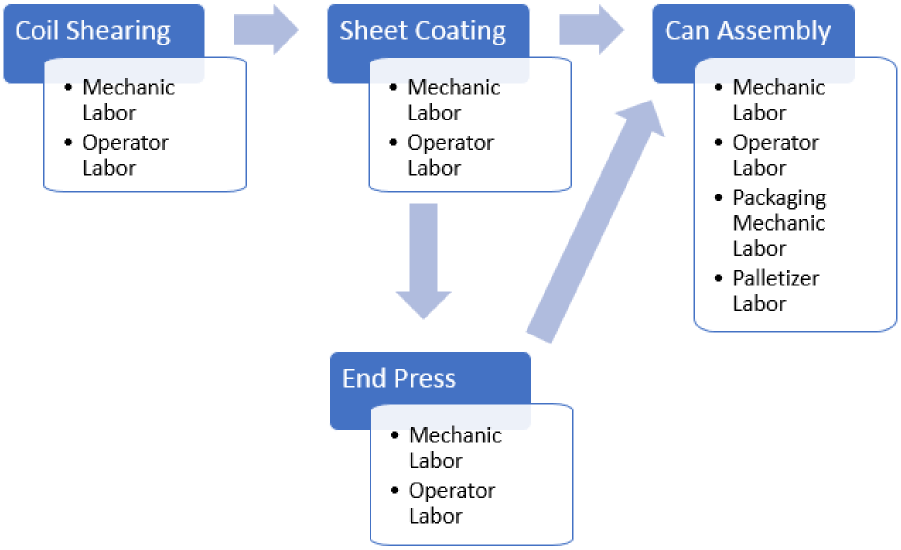

Figure 11. Stages of manufacture to create a three-piece can with labor and overhead for each stage. Cut sheets of steel are coated prior to use in the manufacture of ends or welded can bodies. Finished ends will be used to form the bottom of the welded can.

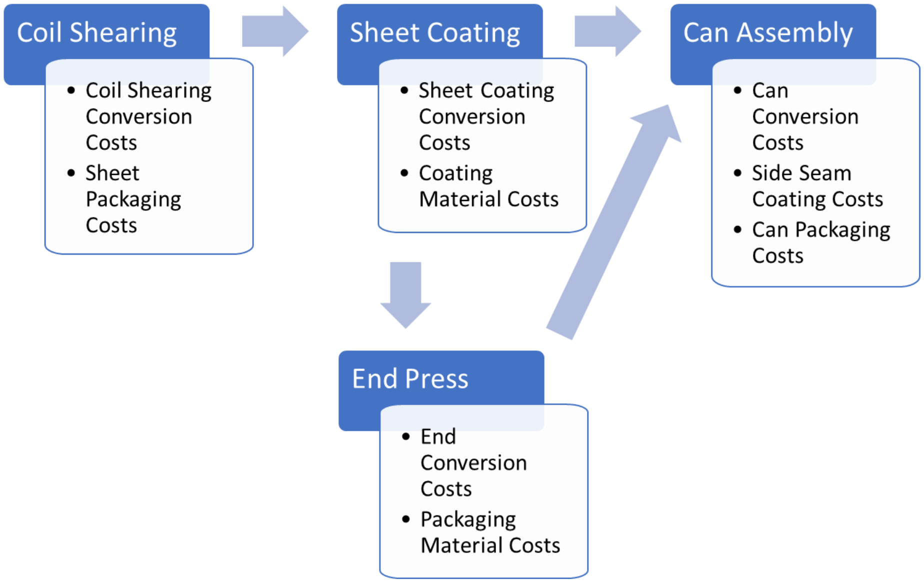

Figure 12. Stages of manufacture to create a three-piece can with material costs and conversion costs involved in each stage. Conversion costs represent assignable material scrap and other direct costs for each manufacturing process.

These costs are the direct costs for regular production prior to being transported to warehousing for storage. The current practice for dealing with defective steel is to claim back the value of the product to the responsible steel mill. An inclusion defect resulting in a mill claim would accumulate the total value of the direct material costs, the assigned direct labor, and conversion costs involving material scrap and other direct costs up to the stage where the defect is discovered. These costs are broken down by a per-unit ratio and multiplied by the total number of units to be claimed to create the value to charge back to the supplier. Following the approval of the claim, the defective product is removed from inventory and disposed of. At the point where the defect is found, the costs of manufacture for both prime and defective products are the same. After the defect is identified, the production line is stopped and the additional, unrecouped costs of the defects begin to accumulate. After the defect is identified, additional labor is added by manufacturing plant personnel working to identify the defect, to identify the root cause, and to isolate the affected production from prime inventory. The line will remain idle until workers identify the root cause of the defect, remove the defective production from the line, and restart the production process. This production time is lost and can result in additional production scheduling on an overtime basis. In this examination, we will assume the manufacturing line has excess capacity and will not attempt to factor in overtime costs. In addition to the added labor and production loss, the manufacturing company would also lose the potential profits on the cans that were claimed back to the mill. The production requirements to satisfy the customer's demand do not go away due to the claim, but would require additional production to meet the customer's needs. Figure 13 below diagrams the additional costs associated with the steel defect that are not recouped with the mill claim process.

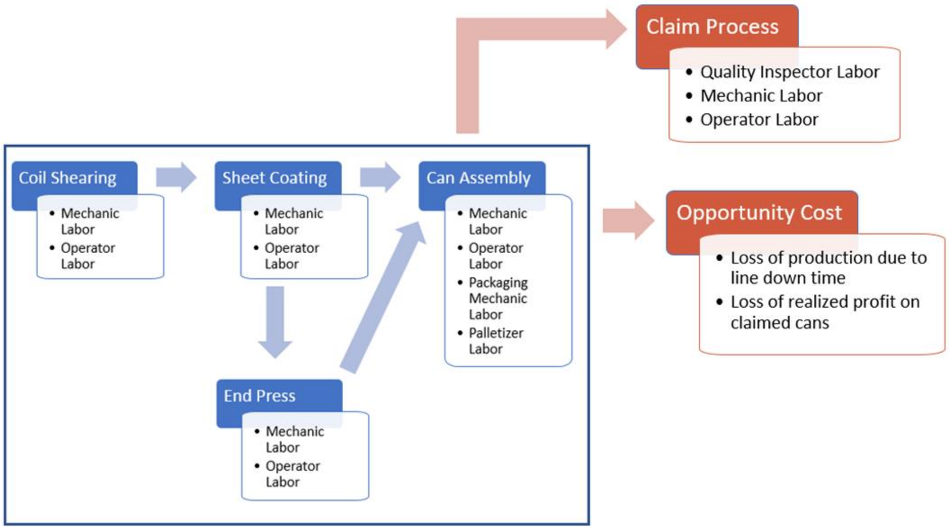

Figure 13. A diagram of the additional costs outside of the normal mill claim procedure. Costs inside the box are accounted for and recouped in defective production. Costs outside the box are not recouped in mill claims.

To compare opportunity costs for the prime product sale and the alternative of a mill claim, the following equations can be utilized to outline the cost breakdown and compare the two options. The scenario will compare the opportunities using an identical amount of product with the same variable costs.

$$Prime\ Product\ Value = \#\ of\ units\ \times \left(\frac{Price}{unit} - \frac{Variable\ Cost}{unit}\right) \tag{1}$$

Equation 1 shows the value breakdown for a conventional sale of acceptable quality food cans. The value is given as the sale price per unit less the amount of variable costs multiplied by the total amount of units. This value is generally referred to as a product's contribution margin.

$$Mill\ Claim\ Book\ Value = \#\ of\ units\ \times \left(\frac{Variable\ Cost}{unit}\right) \tag{2}$$

Equation 2 shows the value breakdown for a mill claim for a raw material defect. The equation shows that the value of the mill claim is equal only to the variable costs that have been added to the product.

$$Mill\ Claim\ Costs = \left[\#\ of\ units\ \times \left(\frac{Variable\ Cost}{unit}\right)\right] + \left(\sum Claim\ Labor\right) \tag{3}$$

Equation 3 illustrates the actual costs of a mill claim that take into account the additional labor spent on removing the defect from production and the administrative time spent processing the claim.

$$Variable\ Costs = \sum \frac{Direct\ Labor}{unit} + \sum \frac{Metal\ Costs}{unit} + \sum \frac{Other\ Mat'l\ Costs}{unit} + \sum \frac{Conversion\ Costs}{unit} \tag{4}$$

Equation 4 outlines the different costs that make up the overall variable costs for the cans in this mill claim example. The values and costs outlined in equations 1 through

4 can be used to compare the valuation of each opportunity. The opportunity cost of the prime production sale can be expressed as shown in equation 5 below.

$$Prime\ Product\ Value = \#\ of\ units\ \times contribution\ margin \tag{5}$$

To compare the two opportunities, we need to use the true value of the mill claim taking into consideration the costs of the additional labor spent on claims. The actual value of a mill claim is the difference between the costs of a mill claim and the book value of the claim that is credited by the supplier. The actual value of a mill claim is shown in equation 6.

$$\begin{gathered} Mill\ Claim\ Actual\ Value = Mill\ Claim\ Book\ Value - Mill\ Claim\ Costs \\ Value = \#\ of\ units\ \times \left(\frac{Variable\ Cost}{unit}\right) - \left\{\left[\#\ of\ units\ \times \left(\frac{Variable\ Cost}{unit}\right)\right] + \left(\sum Claim\ Labor\right)\right\} \\ Value = \#\ of\ units\ \times \left(\frac{Variable\ Cost}{unit}\right) - \#\ of\ units\ \times \left(\frac{Variable\ Cost}{unit}\right) - \sum Claim\ Labor \\ Mill\ Claim\ Actual\ Value = -\sum Claim\ Labor \end{gathered} \tag{6}$$

Comparing the valuations of the two opportunities reveals that the net value of a mill claim for finished cans is equal to the loss of all additional labor spent resolving the claim and the loss of operating margin for each unit claimed.

$$\begin{gathered} Opportunity\ Cost = Mill\ Claim\ Actual\ Value - Prime\ Product\ Value \\ Opportunity\ Cost = -\sum Claim\ Labor - \#\ of\ units\ \times contribution\ margin \end{gathered} \tag{7}$$

The opportunity cost shows that the mill claim is a far worse option if the opportunities are mutually exclusive.

With the assumption that there is excess capacity to produce cans, an example scenario can be proposed where a set of cans is claimed to a steel mill for an inclusion defect and the mill produces an additional number of cans to satisfy the original requirement. The following examples show the impact of the mill claim on contribution margin, using estimated costs and pricing for a set of 1,000 cans. Table 1 presents the case of a sale for 1,000 cans to a customer at a price of $500.

Table 1

Costs and Margin of a Can Sale

Units	Price	Metal Costs	Variable Costs	Claim Costs	Contribution Margin ($)
1,000	$500.00	$227.50	$122.50	$0.00	$150.00

The direct costs for the cans leave a contribution margin of 30%. The direct costs are broken down with 65% attributed to metal price and the remaining 35% making up the remaining variable costs. The corresponding option for a mill claim is shown in Table 2.

Table 2

Costs and Margin of a Mill Defect Claim

Units	Claim Value	Metal Costs	Variable Costs	Claim Costs	Contribution Margin ($)
1,000	$350.00	$227.50	$122.50	$24.00	($24.00)

This example outlines the costs and the net value of a mill claim for the same number of cans, but includes the additional costs of handling the mill claim and reflects the reduced claim value compared to the sale price of prime cans. The breakdown of the labor in the claim costs is shown in Table 3.

Table 3

Claim Cost Labor Breakdown

Job Classification	Labor Rate ($/hr)	Time Spent	Cost
Mechanic	$25.50	20 Minutes	$8.50
Operator	$15.00	20 Minutes	$5.00
Quality Inspector	$21.00	30 minutes	$10.50
		Total	$24.00

Combining the two opportunities identifies the adjusted contribution margin of the additional production due to the claim. The breakdown for this scenario is shown in Table 4.

Table 4

Costs and Margin of a Mill Claim and Replacement Can Sale with Loss of Claim Labor

Units	Price	Metal Costs	Variable Costs	Claim Costs	Contribution Margin ($)
1,000	$350.00	$227.50	$122.50	$24.00	($24.00)
1,000	$500.00	$227.50	$122.50	$0.00	$150.00
2,000	$850.00	$455.00	$245.00	$24.00	$126.00

The contribution margin for the mill claim and replacement production is 14.8%. Table 5 presents an alternate scenario where the additional labor costs for handling the claim are recouped.

Table 5

Costs and Margin of a Mill Claim and Replacement Can Sale with Recouped Claim Labor

Units	Price	Metal Costs	Variable Costs	Claim Costs	Contribution Margin ($)
1,000	$374.00	$227.50	$122.50	$24.00	$0.00
1,000	$500.00	$227.50	$122.50	$0	$150.00
2,000	$874.00	$455.00	$245.00	$24.00	$150.00

When the additional labor involved in processing the claim is accounted for in the claim, the resulting contribution margin is 17.2%. This is an improvement over the previous scenario, but still shows an overall decrease in the contribution margin from the ideal case. An additional view shows the impact on a theoretical product with a lower contribution margin. The ideal sale is given in Table 6 with identical costs and a reduced sale price.

Table 6

Costs and Margin of a Lower Price Can Sale

Units	Price	Metal Costs	Variable Costs	Claim Costs	Contribution Margin ($)
1,000	$475.00	$227.50	$122.50	$0.00	$125.00

With the reduction in price, the maximum contribution margin is 26.3%. This new contribution margin can be compared with replacement production following a mill claim. The example is given in Table 7.

Table 7

Costs and Margin of a Mill Claim and Replacement Can Sale at Reduced Sale Price

Units	Price	Metal Costs	Variable Costs	Claim Costs	Contribution Margin ($)
1,000	$350.00	$227.50	$122.50	$24.00	($24.00)
1,000	$475.00	$227.50	$122.50	$0.00	$125.00
2,000	$825.00	$455.00	$245.00	$24.00	$101.00

The contribution margin for the replacement production model at the reduced price falls to 12.2%.

Once the margin changes for individual transactions have been identified, the impact of an increasing defect rate as a portion of steel supply for our theoretical mill can be seen. Ratios can now be used to calculate these values and identify the change in contribution margin as the defect rate increases. The following equation can be used to determine the adjusted contribution margin (CM).

$$Adjusted\ CM\% = Prime\ \% \times CM\%_{Prime} + Defect\ \% \times CM\%_{Defect} \tag{8}$$

Equation 8 was used to calculate the adjusted contribution margin for an increase rate of mill claims as a portion of the total amount supplied. Table 8 shows the impact on contribution margin as the defect rate increases to 5%.

Table 8

Impact to Average Contribution Margin as Defect Rate Increases

Prime %	CM_{Prime}	Claim %	CM_{Defect}	AVG CM%
100%	30%	0%	14.8%	30.000%
99%	30%	1%	14.8%	29.848%
98%	30%	2%	14.8%	29.696%
97%	30%	3%	14.8%	29.545%
96%	30%	4%	14.8%	29.393%
95%	30%	5%	14.8%	29.241%

Using this data, a linear relationship can be identified for the change in contribution margin as the defect rate increases. This relationship can be used to compare an alternative mill supplier to the current supplier. For this example, Steel Mill A and Steel Mill B will be the two potential suppliers. Steel Mill A has a defect rate of 1% and Steel Mill B has a defect rate of 2%. Both steel mills have the same metal price of $227.50 per 1,000 cans and are both supplying metal with identical physical properties. The two steel mills will be compared under the assumption that they are competing over the same volume. Based on the data in Table 7, Steel Mill A will yield a contribution margin of 29.85% and Steel Mill B will yield 29.7%. The lower contribution margin for Steel Mill B will put it at a disadvantage in relation to its competition, Steel Mill A. To meet the contribution margin of the competitor, it would need to increase the relative contribution margin realized by its customer at the higher defect rate. Assuming the defect rate is fixed, the only item that Steel Mill B can change that will increase the contribution margin in this scenario is price.

If Mill B needs to match the contribution margin achieved with the higher quality steel from Mill A, Mill B must reduce its price enough for its contribution margin at 2% defects to equal the contribution margin for Mill A at 1% defects. Based on the relationship between defect rate and contribution margin percentage, the contribution margin at 2% defects for Mill B would be increased by 0.152%. With that data, a new metal price for Steel Mill B can be calculated using equations 9 and 10.

$$Contribution\ Margin\ (\$) = CM\% \times Sales \tag{9}$$

Since the relationship of contribution margin to defect rate is linear, we can add 0.152% to the contribution margin for Mill A at the 0% defect rate and use the simplified equation for contribution margin to identify the increased margin in dollars. Using the adjusted contribution margin of 30.152% for Mill B at a 0% defect rate, the increased contribution margin in dollars for Mill B is equal to $150.76. Using that adjusted contribution margin, the values from Table 1 can be used to identify the new metal cost.

$$\begin{gathered} Contribution\ Margin = \#\ of\ units\ \times \left(\frac{Price}{unit} - \frac{Metal\ Cost}{unit} - \frac{Variable\ Cost}{unit}\right) \\ Contribution\ Margin = Price - \ Metal\ Cost - Variable\ Cost \\ Metal\ Cost = \ Price - Variable\ Cost - Contribution\ Margin \end{gathered} \tag{10}$$

Using the same values for sale price, variable costs aside from metal and a zero-dollar claim cost, Table 9 below shows the adjusted metal price for Steel Mill B to match the contribution margin the customer realizes with Steel Mill A.

Table 9

Adjusted Metal Price for Steel Mill B

Units	Price	Contribution Margin ($)	Variable Costs	Claim Costs	Metal Costs
1,000	$500.00	$150.76	$122.50	$0.00	$226.74

CHAPTER IV

RESULTS

In the opportunity cost analysis for a single mill claim on a can assembly line, it was identified that claims represent a loss. Tables 3, 4 and 6 illustrated that claims with additional labor cost recouped, additional labor costs lost, and sales at different contribution margins all show reductions in contribution margin of replacement production. For alternate examples of different cans sizes and customers, the amount of reduction due to claims will vary because of differences in variable costs for different products and across different production facilities, but will always represent a loss compared to the alternative of selling prime finished production.

To identify the opportunity cost, the value of the mill claim needs to be compared to the value of the best alternative. Using the values stated in Table 1, Table 2 and equation 7, the differences between those two options can be identified. Based on equation 7, the opportunity cost becomes the loss of the added labor associated with the defect that is not recovered in the mill claim combined with the lost contribution margin. The opportunity cost for the mill claim in this example is a loss of $174.00 per 1,000 cans.

The impacts of the claim on the contribution margin if the two options are not independent was also identified. For each mill claim, an equal number of cans must be reproduced to make up for the deficiency in the customer’s order. For the 1,000 cans claimed, the can manufacturer will need to produce an additional 1,000 cans to fulfill the complete order. Table 4 presented a cost breakdown of the first production run that resulted in the claim and a second production run that yields a product the customer will buy.

The contribution margin for the production outlined in Table 1 was identified at 30%. The contribution margin for production that resulted in a claim and a second production run is reduced to a contribution margin of 14.82%. The change in contribution margin as claim percentage increases is shown in the following Figure. Based on the data created using equation 8 and displayed in Table 8, the contribution margin is reduced by 0.1518% per 1% increase in mill defects.

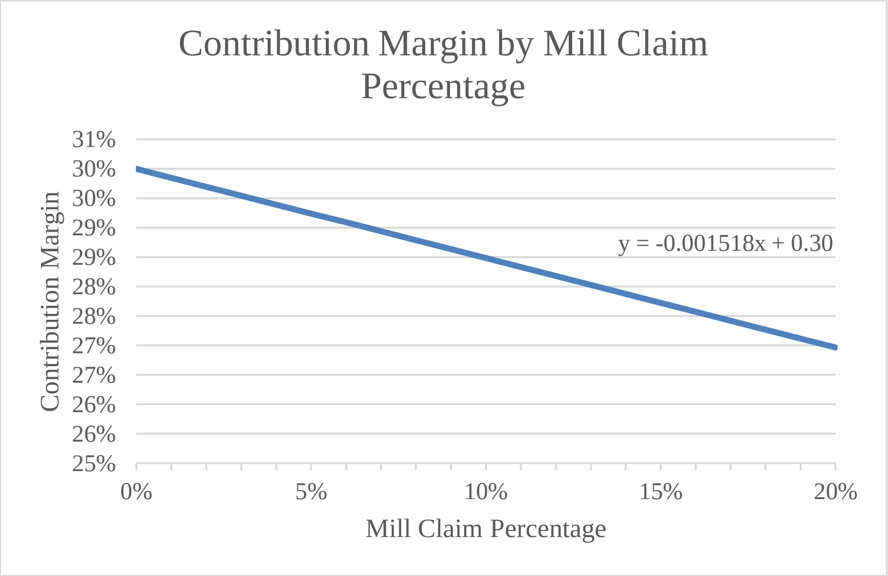

Figure 14. Graph of the change in contribution margin as claim percentage increases for the test scenario. The margin is reduced by 0.1518% per percent increase in claim percentage.

Using the theoretical food can manufacturing company, this information was applied to two steel suppliers to compare the cost of defects for each of their steel suppliers. If two suppliers produce the same amount of steel for a can manufacturer for the same finished product with same variable costs, they can be compared against each other. If Steel Mill A supplies steel that contains defects in 1% of their production and Steel Mill B supplies steel that contains defects in 2% of their production, the cost difference between the two suppliers is 0.1518% of the contribution margin. The manufacturing company needs to identify the opportunity with the lowest cost to realize the maximum benefit. For Steel Mill B to be competitive, it would need to offset the costs of the increased defect rate either by improving quality to match its competitor at the same price or by offering better terms to its customer. The reduction needed can be identified by using the linear relationship shown between the contribution margin and defect rate presented in Figure 14. For Steel Mill B to equal the costs of Steel Mill A, it must reduce its price to match the contribution margin achieved with Steel Mill A. Figure 15 shows a graphical representation of the adjusted contribution margin for Steel Mill B in relation to Steel Mill A.

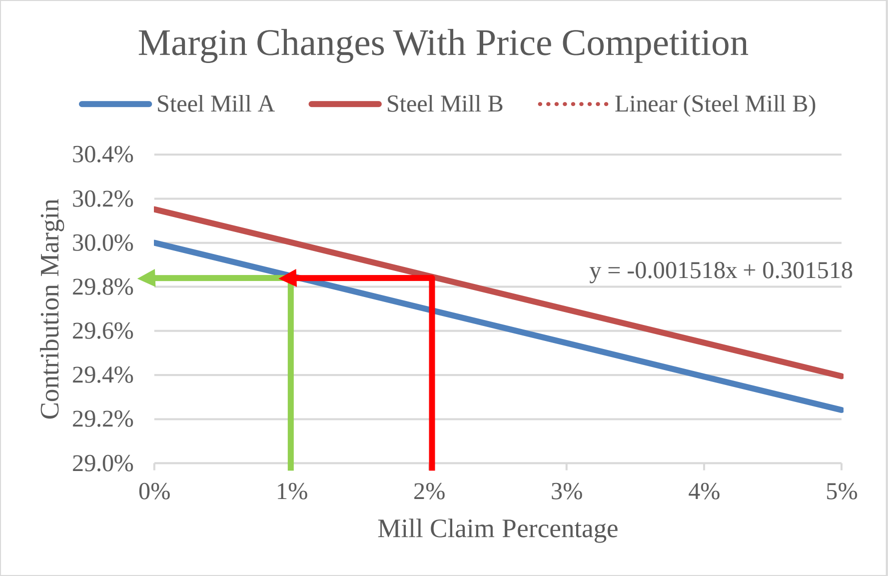

Figure 15. Steel Mill B can reduce their price to match the customer contribution margin achieved with Steel Mill A. The new contribution for Steel Mill B at 0% claims would be 30.1518%.

Steel Mill B's new price can be calculated by using the contribution margin at the 0% defect rate and increasing it by the supplier difference of 0.1518%. The ideal case of 0% defects in Table 1 identified the cost of the steel to be $227.50 per 1,000 cans for a 30% contribution margin. For Steel Mill B to give its customer an identical contribution margin at the higher claim percentage, it would need to offer its steel at a price of $226.74 per 1,000 cans, as shown in Table 9.

The amount of contribution margin lost with an increase in mill claim percentage is important due to the scale of can manufacturing operations. Depending on the size of the customer, small reductions in margin can have significant impacts on profits. To identify the impacts of customer scale, the author looked at different supply volumes. The can manufacturing industry is based on high speed manufacturing to produce large volumes of food cans to supply the food canning industry. The percentage change on the contribution margin is small, but has an increasing effect as the production volume increases. Figure 16 shows the differences in contribution margins in dollars for different production volumes as claim percentages increase.

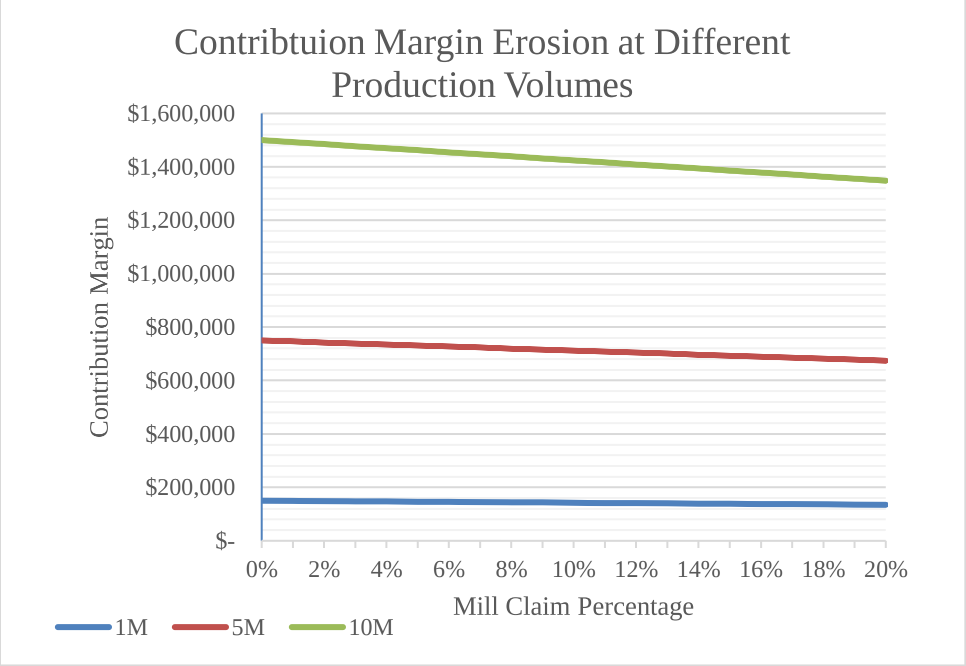

Figure 16. As production volume increases, the reduction in contribution margin due to increased mill claims increases the loss in dollars.

At a production level of 1,000,000 cans for the theoretical company, a 1% increase in claim rate represents a reduction in contribution margin of $75,882. If the production volume is increased to 10,000,000 cans, that reduction also increases by a factor of 10 to $758,820.

CHAPTER V

DISCUSSION AND IMPLICATIONS

Discussion

The stated goal of this project was to identify a method for calculating the impact of steel defects on can manufacturing companies to assist in accurately comparing suppliers with varied levels of quality. A review of literature on the impact of quality found that there is a positive correlation with a firm's quality and its profitability. In the author's example, it was shown that there is a negative margin for individual mill defects when additional claim labor is not recouped and that the margin of the replacement cans produced to satisfy the customer requirements will be reduced due to the net loss on the claimed production. As the supplier's percentage of claims increases, the contribution margin for the customer decreases. This result mirrors the conclusions of Phillips et al. (1983), Jacobson and Aaker (1987) and Kroll et al. (1999). Their conclusions show that relative quality shows a positive correlation with profitability and returns for producers. For the steel customer, the quality of its supplier has a direct impact on product quality. When steel suppliers reduce defect rate and improve quality, the can manufacturing firm will see a relative increase in contribution margin due to the reduction in claims. The same relationship will exist for the contribution margin of the steel mill as well. As the defect rate falls for the steel mill, its contribution margin should grow due to reductions in claim payouts and reductions in replacement production to fulfill claimed metal volumes. The similarities in the effect of product quality between supplier and customer are repeated throughout the supply chain and produce a symbiotic relationship due to the mutually beneficial effects of supplier on customer. The mutualistic relationship between supplier and customer can exist in a few different ways. The positive correlation of relative quality and market share was shown in Jacobson and Aaker (1987). As the relative quality of the can manufacturing firm increases due to the increased quality of the steel supplier, the can manufacturer would see a positive impact on market share. With the increased market share of the steel customer, the steel mill should see a corresponding increase in volume. The mutualistic relationship between steel supplier and steel customer is further strengthened with improvements in quality. As discussed in Kroll et al. (1999), increased quality follows “the premise that customers are drawn to quality outputs and they form loyalties to the providers of those outputs.” As the relative quality of the steel supplier increases, the steel customer relies more on the supplier to continue supplying a high-quality product due to the improved margins seen with a high-quality producer.

Food can manufacturing companies should use this concept to look at other can manufacturing methods to identify the cost impacts for each supplier. As demonstrated through the example of a theoretical manufacturing company, this would be an important step in identifying the relative quality of each steel supplier and the detailed cost impact of its defects. For a can manufacturing company to calculate the cost impact for an individual supplier, it would need to look at many different variables to create a detailed analysis. Variables that must be considered include the variable costs for each can specification including metal costs, coating costs, and other manufacturing materials, the manufacturing overhead for each individual manufacturing facility, the type of defect, the cost to isolate defective product and complete the claim, the opportunity cost at each manufacturing phase, the number and type of defects for each supplier, and the total volume of steel purchased from the supplier. These variables are specific to an individual company and manufacturing site cost structure and pricing agreements between steel supplier, manufacturing company, and food can customer. By identifying accurate cost implications for each supplier's defects, the can manufacturing company will have data to support discourse with their suppliers on defect reduction efforts or price implications for increased claims. Supplier and customer relationships are crucial for the success of both firms. These relationships require dialogue and supporting data to make decisions that will yield positive results for both parties.

Theoretical Implications

The results of this study further support the conclusion that relative quality has a positive correlation on profitability of a producer. This correlation can be seen with the can manufacturing company in this author's example and can be extended down the supply chain to the steel supplier. As the can manufacturing company loses margin through replacement production, so does the steel mill through its own replacement production. Suppliers have a definite impact on the operations of their customers and a vested interest in their customers' success. The results show that perceptions of early studies and literature were accurate in their belief that quality is an important criteria in supplier selection. An increased defect rate has a measurable impact on customer profitability and would impede firms in realizing their full margin potential.

Relative quality for steel suppliers can be used to improve market share and positioning. The discussion on quality and customer loyalty in Kroll et al. (1999) touched on an interesting point regarding quality and the supplier-customer relationship. The premise is that customers are attracted to quality and form attachments to those suppliers. The premise should also follow that lower quality suppliers would have trouble forming long-term relationships. Strained or poor supplier relationships pose a serious threat in the current global steel market. The increases in steel production capacities for emerging markets like Russia, Brazil, and Ukraine after a period of rapid growth and the steep decrease in demand for steel in China have left the industry with overcapacity and excess inventory (ArcelorMittal, 2017). With an overall decrease in tinplate demand worldwide and excess production capacity in some of the world’s largest markets, steel suppliers will exploit any advantage to maintain or increase the market share to improve their utilization. This leaves steel producers with lower relative quality at a disadvantage to competitors. Lower quality mills will feel increased market pressure from the oversupply and possibly lose market share to new market entrants or current competitors with higher quality. These steel mills must endeavor to improve their quality to match the market quality expectations. This change will improve their image with supply chain and procurement managers, help improve their market share, improve their customer relationships, and improve the profitability of their customers.

Managerial Implications

As stated earlier, supplier and customer relationships are crucial for the success of both firms. The literature and project results show that quality has an impact on the profitability of can manufacturing companies and it is important to pursue a detailed analysis on a larger scale to better define the full impact on contribution margin. The main reason for further work on this topic is to generate data to have improved dialogue with suppliers and their impact on the customers in can manufacturing. This cost analysis on defects will give supporting data to supply chain managers on the implications of varying levels of supplier quality. This data will help guide supply chain managers to make better decisions regarding the differences in quality of alternative suppliers. By better understanding the impact of quality on profitability, the steel supplier and can manufacturer can assess claim levels and the impacts to both businesses. This information could be used in a few different ways to affect change in a can manufacturer's supply relationships.

The first method would be an open dialog to review the supplier's relative quality and its impact on the customer's business. An analysis of defect types and defect volume can be completed to create business cases for potential improvements to reduce the amount of defects. The goal of these business cases would be to improve the profitability of both companies. This level of dialog and collaboration is a good example of a mutualistic relationship between supplier and customer. As a supplier improves quality, the relationship with the customer strengthens and both companies would improve profitability together.

The supporting data on the impact of defects can be used to effect change in suppliers that are unwilling to improve their level of quality. These changes can be tied to costs like the scenario presented in Figure 16. With supporting data, those costs can be used to negotiate price reductions for lower quality suppliers. The impact of a supplier’s quality would also be used to identify future supply levels for different mills based on their ability to meet higher quality requirements for critical customers of the can manufacturers. Through analysis of the cost structure, contribution margins, and the quality impact, a supplier could be removed from consideration for certain supply requirements. These implications can also be used to urge suppliers to improve their quality for fear of losing volume or being replaced by a competitor with a higher level of quality.

A third option for using the impact of quality to effect change in steel supplier relationships is during initial supply agreement negotiations. When can manufacturing firms are approached by or seek out new suppliers, they can use this information to assist in crafting supply agreements that account for the value of quality. Initial agreements could be made with either historical quality data provided by the supplier or set at negotiated levels that correspond with penalties or incentives if the supplier’s quality was to decline or improve. These types of negotiations would convey the importance of quality to potential suppliers and protect the manufacturing company from future changes in a supplier’s quality negatively affecting the can manufacturer’s profitability.

The data outlining the cost impact of quality can become an important asset for comparing steel suppliers and for improving the throughput and operating margin for any can manufacturing company.

CHAPTER VI

CONCLUSIONS

This study looked at the impact of quality of tinplate steel suppliers on their food can manufacturing customers. The results showed that mill claims lower the contribution margin of the cans produced as a replacement for the claimed production in the welded can technology segment. This result was confirmed in scenarios where additional labor used to process the mill claim was recouped or not and at different starting contribution margins. As the relative number of claims increases for a supplier, the customer's contribution margin decreases in a linear relationship for this example. Using this relationship, it was shown that a steel supplier with a 1% difference in defect rate compared to an alternate supplier would need to adjust their steel price by $0.76 per 1,000 cans to yield the same customer contribution margin as their competitor.

These results confirm the conclusions reached in the literature review that showed a positive correlation between relative quality and profitability. The results relate to implications made by Kroll et al. (1999) that customers are attracted to quality and form loyalties to high quality suppliers. These implications are supported by the results of this study. If higher relative quality increases profitability, customers would be reluctant to give more business to a lower quality supplier. The implications of these result show the importance of supplier-customer relationships and the impact a supplier can have on a customer. These results can be used in collaborative efforts to improve supplier quality, prod unwilling suppliers to improve their quality, or negotiate new supply agreements. The results are limited since they are from a single manufacturing technology. The results for the specific scenario show a need for further analysis to verify the results with the other technology segments to identify the impact of quality for all of the remaining segments.

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APPENDIX

APPENDIX

STEEL MANUFACTURING PROCESS

These grades of steel are created through an extensive process using a set of furnaces, a casting operation, a series of reduction mills and heat treatment operations that conclude with an application of a protective coating as the last step before delivery to the customer. The starting ingredients for steel are taconite, a low-grade iron ore, coal, and limestone. Taconite rock is processed through grinding and magnetic separation of the ferromagnetic material present in the rock. This material is then rolled with a binder material, like clay, and fired to create taconite pellets. These pellets are higher in iron ore content that the original rock and are transported from the mining location to steel processors. Coal must be refined into a product called "coke" prior to being used in manufacturing steel. Coal is converted into coke through carbonization in an oxygen-starved environment. Coke is high in carbon content, low in impurities and provides high thermal energy when added to the blast furnace. The taconite pellets, coke and limestone are added to a blast furnace. The blast furnace is used to convert the iron ore into liquid iron, remove impurities from the iron and to add carbon to the liquid iron. The materials are heated using hot air to provide energy for the chemical processes necessary to reduce the oxygen content of iron ore. The coke, limestone, and oxygen in the furnace work to remove oxygen from the iron ore and remove impurities, like Silica, Alumina, Magnesia, and Calcia, from the hot metal, which is removed from the furnace as liquid slag. The molten iron is removed from the bottom of the blast furnace through tap holes. This molten iron is poured into specially designed rail cars that transport the metal to the next process.

The next process is called the basic oxygen furnace. This furnace is where the liquid iron and solid scrap steel are converted into refined liquid steel. In the basic oxygen furnace, solid scrap steel is added to the furnace and liquid iron is added on top of the scrap. High purity oxygen is injected into the furnace at high speeds, which removes some carbon and impurities from the metal. The removal of these elements creates a layer of slag that rises to the top of the liquid. The time of the oxygen addition and the chemical composition of the scrap steel is tightly managed to control the finished chemistry of the liquid steel. Molten steel is then poured into a ladle, a large container lined with refractory brick, which will transport the steel to the casting operation. The ladle is emptied into the continuous caster through a reservoir called a tundish. The tundish maintains a continuous flow of liquid steel into the caster during ladle changes and aids separation of oxide inclusions prior to casting. As the liquid steel flows into the caster, it is cooled by a mold that defines the shape of the steel and forms a shell for transporting the continuous strand to additional cooling zones in the casting process. After the mold, the strand is cooled using rollers and cooling sprays to further solidify the steel. As the continuous strand of steel from the caster grows in length, the strand will be cut into pieces, or slabs, which are removed to allow for them to completely cool to ambient temperature. Following the cooling process, the slabs are transported to a furnace that will completely heat the slabs to approximately 2100°F. After completing the reheat process, the slabs are transported to the hot strip mill.

The hot strip mill is comprised of a series of rolling operations that are designed to reduce the thickness of the slab from the original thickness of eight to nine inches down to 0.07 to 0.10 inches. There are two phases of reductions at the hot strip mill. The first phase occurs at the roughing stands. Each roughing stand is made up of a single set of rolls arranged in a vertical stack that apply force to the slab to reduce its thickness. Each stack is made up of work rolls that make contact with the steel and a set of backup rolls that apply force to the work rolls. These stands reduce the thickness of the slab from the original thickness down to approximately one inch as the slab passes through each stand. After the slab exits the last roughing stand, it is transported on rollers to the finishing stands. Before the slab is fed into the first finishing stand, the leading edge is sheared to give the end a rectangular cross section. As the slab is fed into the first finishing stand, each successive stand must be running at a higher speed that the previous stand to account for the growth in length of the slab. Depending of the final requirements of the finished coil, the slab is reduced to between 0.070 and 0.10 inches. The coil is coiled through the finishing stands and has cooling spray applied to it prior to the strip being coiled and allowed to cool to room temperature. The strips are coiled at closely monitored temperatures to achieve desired metal properties for cooled coil. This coil is commonly referred to as a “hot band”. The hot bands are too thick and sort for use as tin mill products. They must go through further processing before they have the desired properties.

After the hot bands cool, they must be cleaned of any oxides that have formed on the exterior of the strip. This process in steelmaking is called pickling. Pickling uses inorganic acids to strip oxides from the surface of the strip leaving a clean surface which is ready for further thickness reduction at the cold mill. Depending on the capabilities and setup for each mill, hot-rolled, pickled coils can be oiled and recoiled to be transported to a separate cold mill or can be fed directly into a cold mill that is built in tandem with a pickling line.

The cold mill has a series of reduction stand like in the hot strip mill. Each stand is made up of a set of vertically stacked rolls made up of work rolls and backup rolls. The amount of reduction taken at the cold mill and in each stand are calculated and carefully controlled. The amount of reduction taken in the cold mill is calculated to correspond with the cold reductions that will take place at later operations and to achieve the desired final thickness. After reducing the thickness of the strip in the cold mill, the steel is too hard and does not possess the desired mechanical properties for tin mill products. The coil must be softened through a heating process called annealing.

Annealing is the process of heating steel to allow the metal to become softer and more formable. Annealing can be accomplished in two ways: in batches or continuously. The batch annealing process heats cold-rolled coils as a set in an oxygen-starved environment. This prevent the coils from forming oxides on the surface of the coil. The coils are heated uniformly so that each part of the coil is maintained at a set temperature. The coils are held at a constant temperature for a set amount of time and are slowly cooled to prevent the mechanical properties from varying throughout the thickness of the coil. The batch annealing process can take between ten and thirty hours to complete, depending on the desired properties of the heat-treated coil. The continuous annealing process feeds the coil through a series of furnace towers that heat the coil in an oxygen-starved environment at a controlled speed and temperature. The coil is cooled following the heat-treating process and is recoiled. The continuous annealing process takes minutes to complete and depends on the distance traveled and the speeds that the coil travels through the line. Continuously annealed products generally have more uniform properties and is the desired process for most tin mill products. Following the either annealing process, the coils will go through a final thickness reduction process at the temper mill.

The temper mill is the final thickness reduction of the coil and will impart the final mechanical properties to the steel. The temper mill is broken down into two different grades of finished product: single-reduced or double-reduced. The single-reduced grade has a small amount of cold reduction taken by a single stand or a set of stands. This reduction creates uniform mechanical properties for the coil following the annealing process. The double-reduced grade has a larger amount of cold reduction taken by a set of two or three stands. The greater amount of reduction yields a stronger steel than produced in the single-reduced grade. The formability of the double-reduced steel is lower than single-reduced, but is adequate for most forming operations. Both reduction processes impart the desired surface finish to the steel coil. The surface roughness can range from very smooth to very rough. The surface texture of the steel is determined by the forming operations that will be used in the can making process. After the final mechanical properties are set in the temper mill, the coils are sent to a coating line.

Tempered coils that will be used for tin mill products need a protective coating. They are coated with two different metallic exterior coatings. The two coatings are tin and chromium. The two coatings are electrolytically applied as a finish to prevent corrosion of the base steel. The tin coating is applied to protect the base steel and acts as a sacrificial anode in the corrosion process. The tin corrodes before the steel, protecting the structural portion of the container and extending the life of the product and can. Steel with a tin coating is commonly called tin plate. When the tin is applied using plating tanks, the product is called electrolytic tin plate, or ETP. The chromium coating protects the steel from oxidation during storage and transport, but does not offer any protection from the food contents when the container is filled. Chromium-coated steel for food cans was developed after tin-coated steel and is often called tin-free steel, or TFS. To extend the life of TFS components, food-grade packaging coatings are used on the interior and exterior of the item.