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IMPROVING PRODUCT QUALITY AND PRODUCTION YIELD IN WOOD FLOORING MANUFACTURING USING BASIC QUALITY TOOLS

Abstract: *Since the last recession the hardwood flooring industry is currently enjoying strong growth. With this growth come new challenges for manufacturers of hardwood flooring. QEP Wood Flooring division, located in Johnson City, Tennessee, USA is a midsize flooring company which historically struggled with high customer claims. In 2016, QEP's Johnson City management team implemented an initiative to address the top three leading causes of defects and waste in their hardwood flooring panels. A systematic plan was devised and implemented by utilizing basic quality tools and methods such as Define, Measure, Analyze, Improve, Control (DMAIC), root cause analysis, 5-why, check sheet and deployment of effective employee awareness training. As a result, QEP Wood Flooring division reduced 81.56% in chip-out, increased 1.7% in production yield, saved over $90k annually in customer claims while improving the quality of their products and increasing customer satisfaction. This study contributes to the body of knowledge by providing an effective process and low-cost tools to improve the quality of wood flooring products elsewhere in the wood flooring industry.*

Keywords: *Hardwood flooring; Quality; Waste reduction; Production yield; Continuous improvement.*

1. Introduction

Since 2011 sales in the U.S. hardwood flooring markets have steadily increased after several years of decline due to economic conditions in the U.S. and the rest of the world. In recent years, a strong job growth and low mortgage rates have fueled the U.S housing market. As a result, demands are high and hardwood flooring companies are enjoying significant growth in sales according to the National Wood Flooring Association 2017 sponsored Catalina Report (Catalina Report, 2017). However, the report cautioned U.S. hardwood flooring manufacturers of new challenges. These challenges are from foreign competitors capitalizing on the upturn in hardwood flooring sales by importing products at costs lower than what U.S. manufacturers can offer. This represents a 34.9% domestic sales increase in dollars of foreign wood flooring product since 2014 (Garvey, Gayton, Tallman, & Young, 2019). Increase in demand has also driven up log cost, which is another major challenge that hardwood flooring manufacturers are facing. Foreign competition and rising log costs have decreased U.S. based hardwood floor manufacturers profit margins, forcing them to

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rethink their operations in terms of productivity (also known as yield) and product quality. These actions are a must in order for manufacturers to reduce costs, minimize waste and scrap, and improve quality as consumers trend away from wall-to-wall carpeting.

QEP's Wood Flooring manufacturing facility in Johnson City, Tennessee is a midsize hardwood flooring company, which has operated under many different owners and names (three of them being in the last eight years) since they opened their doors in 1898 (Harris Wood, 2019). Multiple changes in owners over the recent years have brought with it new visions and diverse flooring products for the flooring manufacture; however, their manufacturing processes remain virtually unchanged until recently. Decades old production processes have gradually lessened product quality and yield, and employees who perform these processes continue to carry out the same old daily routines without much consideration of their actions on production outputs.

Routine processes are inherent parts of most manufacturing; these processes require continued evaluation to ensure the greatest efficiency and product quality possible. Allowing quality issues to go unresolved can result in customer returns, waste, material rework, and loss of sales (Arthur, 2019; Chandra, Kapil, & Dinesh, 2017; Radej, Drnovšek, & Beges, 2017). However, the most important cost of poor quality for hardwood flooring manufacturers can be loss of reputation and customer satisfaction due to negative word-of-mouth publicity (Gunasekaran, Subramanian, & Ngai, 2019). Therefore, when defects or poor quality are present, a thorough investigation of the overall process is warranted to find and eliminate the root cause that contributes to product waste and defects.

In 2016, QEP's Johnson City management team implemented an initiative to address the top three leading causes of defects and waste in their hardwood flooring panels. The goals of these efforts were to drive down the product costs, increase yield and customer satisfaction. The three quality improvement projects selected for this effort were end chip-out, product off-color, and inconsistent grading. These three areas were selected because of their great potential to increase product quality and yield, while reducing manufacturing costs through waste reduction and minimizing customer claims. With current challenges surrounding the hardwood flooring industry, this initiative is important to QEP because it allows them to remain competitive in the wood flooring industry by providing their customers quality products at competitive prices. During these improvement processes, clear concise quality methods were established and documented, and are key elements in maintaining all improvements.

2. Literature Review

Hardwood flooring is one of the most timeless and preferred options for home buyers. Hardwood floors are durable, versatile and with proper care can last many years. It is considered earth friendly, renewable, and sustainable material. However, transforming a forest tree to beautiful hardwood floors involve many different processes and materials including energy usage and supply chain (Kung, 2013). An efficient manufacturing process not only lowers the raw materials needed to create them, but also require less energy, and smaller carbon footprint (Bowyer, 2009).

The history of wood used as flooring dates back to 1600s in Europe (Sidler, 2011). During the Colonial Era (1604 – 1780) abundance of wood made wood flooring popular in North America. There are more than 20 tree species that provide excellent wood for flooring. But common domestic hardwood species used for flooring in the U.S. are red oak, white oak, sugar maple, red maple, ash, birch, walnut, cherry, beech, hickory and pecan making up almost 70% of the hardwood market. Each wood provides distinctive appearance and color tone but possesses inherent defects which are removed during the manufacturing process to provide better strength and stiffness of the finished product.

Due to the scarcity of information on the hardwood flooring manufacturing process, it is assumed that hardwood flooring production practices are approximately similar among companies in the U.S. and around the world. Most wood flooring manufacturing is semi-automatic, which means it involves human and machine operated processes. Kiln dried (to specific moisture content) lumbers first milled in desirable width and thickness. In the next step graders detect any defects or structural faults in the planks to cut out. Planks are then planed and levelled on all four sides to smooth saw marks. Next a machine cuts the tongue and groove edges that make the panels fit together tightly. In the last step, planks are stained to desired color with several coats of protective finish or they are shipped unfinished to the marketplace (BuildDirect, 2019).

In 2019, the U.S. sales of wood flooring are estimated to be 1.5 billion square feet or $3.3 billion (Hirschhorn, 2019). With the volatility in residential sector and availability of alternatives, the U.S. wood flooring manufacturers around the country face a challenging and changing market environment. Most of these challenges stem from increased competition from luxury vinyl tile, increased lumber costs, and higher import costs. Higher import costs are due to the additional tariffs imposed on Chinese-made flooring. Since most of these factors are beyond their control, wood flooring manufacturers now mostly focus on internal systems such as wood quality and manufacturing process to reduce waste and increase yield.

During manufacturing of wood flooring, there are several areas where inconsistency in process can significantly compromise the quality of the finished product. One such area is grading, which typically is a manual process, can result in inconsistency among graders. This can generate over or under estimation of wood defects such as knots, wood tone variation, mineral streaks, etc. in the wood resulting waste and poor quality in end product. Inaccurate machining during tongue and groove may result in excessive chip-out which may reduce yield, product return and customer dissatisfaction. Color mismatch can be another source of product return. There are lack of studies focusing on hardwood flooring quality improvement processes. As such, this article focuses on key areas of hardwood flooring manufacturing and provides guidance on quality improvement of such processes.

3. Research Objective and Methodology

Customers of hardwood flooring value the natural texture of hardwood floors. They also value the durability and quality of hardwood floors that can last for many years. Hardwood has natural varied grain patterns, color variation, and character such as knots, pinholes and mineral (darker) streaks. Different wood species and the region of the country they are grown in create certain nuances in the resulting character of a board. This is part of what makes wood flooring so appealing to so many homeowners. However, working with a natural material like wood with many inherent properties is no easy task. Minor variation in manufacturing (such as staining) coupled with wood variation can produce noticeable flaws in finished products which often result in high customer claims.

Historically, customer claims for the QEP Johnson City flooring products were significantly high. Defects in wood panel, product color mismatch and inconsistent grading were identified as the major causes of most customer returns and yield loss. In order to regain trust and customer satisfaction, QEP devised and implemented a systematic process using basic quality tools. The objective of this study is to demonstrate how using basic quality tools and focusing on key areas of production, QEP improved product quality and customer satisfaction, while improving production yield.

In order to fulfill the research objective, a mixed method study was designed. Three key areas in production: machine set-up and milling, product coloring/staining, and grading were selected. It is hypothesized that production processes in these three areas result in greatest number of defective finished products resulting most customer returns and waste. Therefore, for QEP, production processes in these three areas provided the greatest opportunity to improve product quality and yield. Three min-projects, each focusing on one of the three areas, were investigated as follows:

1. Data collection: observing and documenting key processes in the production (qualitative) and identifying deficiencies in the process using basic quality tools and methods (quantitative).
2. Data analysis: summarizing quantitative and qualitative data to understand severity and sources of deficiencies in the processes.
3. Solution design and implementation: implementing recommended improvements and collecting data for validation of improvement.

Sufficient data are gathered both prior to and after each project in order to demonstrate the effectiveness of each project. In addition, the three projects selected set the foundation for future improvement projects, while using basic quality tools and methods.

4. Project Chip-Out

End chip-out occurs on the end corners of flooring after it is end-matched with a tongue & groove or click locking profile. Chipping out of the corners creates a void noticeable when installing flooring (Figure 1). This results in customer dissatisfaction and product returns which significantly affected QEP's profit margin and reputation. Engineered Department (EGD) operators who are responsible for setting up milling equipment, and maintaining proper product tolerances have no specific adjustment requirements to follow in order to eliminate chip-out whennoticed. When the operators were asked where they felt the end chips were coming from, most of the time the answers given were either the moisture content in the material was too low (dry), or it was just the nature of the particular wood species due to the fact that chip-out was more prevalent in some species than others.

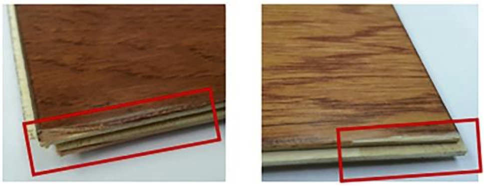


Figure 1. Chip-out on the Corners of Flooring

4.1. Quality Tool

Steps taken to resolve the EGD chip-out problem starts with using a structured data driven Six Sigma Methodology known as DMAIC. The acronym stands for Define, Measure, Analyze, Improve, and Control which is a data-driven, customer-focused, structured problem-solving framework (Berardinelli, 2012). It builds on learning from previous phases to arrive at permanent solutions for difficult problems. Several studies identified that DMAIC is appropriate improving current process when 1) problem is complex, 2) risks are high, 3) the goal is to reduce waste, 4) high customer dissatisfaction or 5) variation reduction (Uluskan, 2016; Mast & Lokkerbol, 2012; Shankar, 2009; Sokovic, Pavletic, & Kern Pipan, 2010). Based on complexity and characteristics of QEP's chip out issues, DMAIC deems most appropriate.

Define phase accurately and succinctly defines the problem with project measures. For this project, the quality issue was excessive chip out in QEP's flooring panel resulting customer dissatisfaction and returns.

The goal was to identify the root cause of the issue and improve the process with a target of 5% or less chip out in all panels.

The **Measure** phase is when the true process is identified and documented. This step involves data gathering; this is achieved by random sampling of EGD production runs throughout a two-week period. Four species of wood are included during the sampling process (hickory, red oak, walnut, and maple). At each random sampling interval, each end of 100 consecutive pieces of flooring was inspected for chip-out; the number of chips found during the sampling process was then documented and shown in Figure 2. As evident the average chip-out was 11.7% for the insert end and 11.6% for the non-insert end, both were significantly higher than the allowable range of 5%. Current QEP process generates high percent of chip out panels which are more prevalent in Hickory and Red Oak (14.28%) than Walnut and Maple (8.95%). This was consistent with each species given their structural fiber make-up.

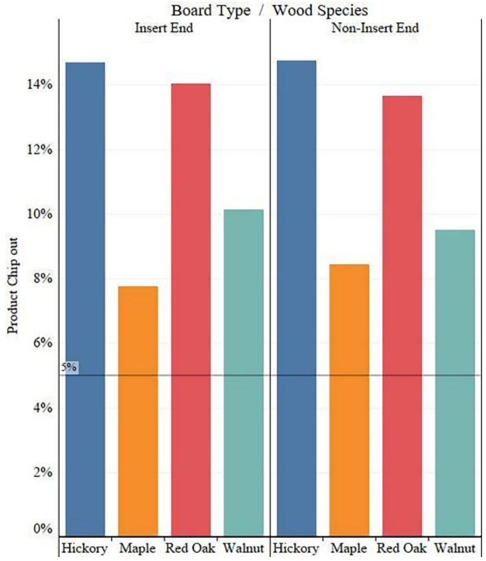


Figure 2. Chip-out rates based on wood species and panel types

The next step is **Analyze** to determine the root cause of what part of the milling process is causing the problem. This is accomplished using a cause-and-effect diagram, otherwise known as the Fishbone (Ishikawa) Diagram. The Fishbone is one of seven basic quality tools, and is used to list many possible causes or problems (Tague, 2005). The diagram in Figure 3 lists four categories that the most probable cause of chip-out will fall under: people,machine, material, and methods. Each main category was subdivided into sub categories in order to list more specific causes of chip-out under the four main causes. Results of the four possible contributing factors were evaluated and shown in Table 1.

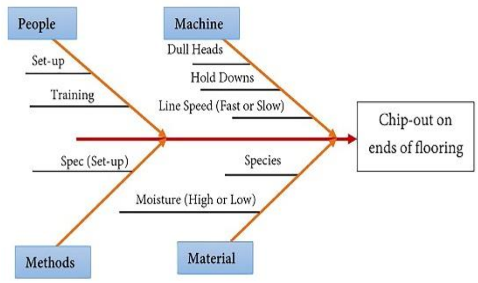


Figure 3. Cause-and-Effect diagram listing most probable causes of chip-out

Moisture content in wood species and manufacturers specifications for machine set-up were acceptable. As such, methods and materials were ruled out as the root cause of the chip-out. However, investigation into machine and people revealed that the main contributing factor for chip-out was operator set-up during placement of the three cutting heads which are used to mill different parts of the tongue and groove profile. It was determined by watching the set-up process that operators were using head #3 to cut a larger portion of the final profile than the head was designed to cut, which left less material for cutting head #2 to cut.

Table 1. Evaluation and root cause decision for flooring panel chip-out

Factors	Evaluation	Root Cause Decision
Methods	Manufacturers Specifications for machine set-up are acceptable	Ruled out
Material	Moisture Content: For moisture content samples from the test run were collected from four wood species. Test results showed moisture content of 6.5% to 8.5% among wood species which is within the acceptable range of 6% to 9% Wood Species: inherent wood properties beyond control	Ruled out
Machine	Line speeds were adjusted at different rates during a test run and determined to not be a contributing factor to chip-out. Hold downs that maintain constant positioning of the flooring as it goes through the milling process were properly adjusted	Dull machine head
People	When evaluating the operator set-up process, it was discovered that this process was not consistently followed; in addition, each operator's set-up was slightly different based on their experience level. Operator training is another factor to consider as no standard training processes are in place.	Variation in operator set-up and lack of operator set-up training

Figure 4 provides a simplified visual representation of how various parts of the tongue and groove profile are milled by each cutting head. Blue, red and green colors indicate specific areas of the tongue and groove profile that are cut by cutting heads 1-3. Notice the difference in the amount of material cutting heads #2 and #3 mill between diagram A and B. In diagram A, cutting head #3 is required to only mill the bevel part of the overall profile. In diagram B, it is noticeable that cutting head #3 is also cutting part of the tongue & groove profile in addition to the bevel resulting excessive chip-out. It was also observed that during the milling process when chip-out was present, changing cutter headsdid slightly decrease the number of chip-out occurrences. So, a dull cutting head could also be a root cause of chip-out.

The **improve** part of the DMAIC process uses data analyzed in the previous step to come up with viable long term tested solutions to improve the part of the process that is causing the issue or issues. The set-up process mentioned above was a common practice as it decreased the changeover time between products of different thicknesses. When each of the three cutting heads was properly set-up during a test run, chip-out immediately decreased. A written set-up process was incorporated in the operator's daily set-up tasks. At the beginning of each production run, each operator requires to sign-off on each set-up task. EGD Department supervisors and quality control auditors are responsible for ensuring operators properly set-up and sign-off on the set-up process prior to each run. A training plan was also included in the improvement part of the process to bring focus on the importance of proper machine set-up, as well as cleaning and sharpening schedule to ensure cutter heads are not in use for extended periods of time.

Figure 4. Schematic diagram of cutting heads 1-3 milling profile

The final step in the DMAIC process requires **controlling** of changes and improvements made to the process. This requires continuous monitoring newly implemented processes to ensure gains made are sustained over time. To sustain the improvements made in the EGD department, three follow-up actions are implemented:

1. Operator set-up check lists, and cutter head cleaning and sharpening scheduled check sheets.
2. Daily Supervisor checks – Supervisors are required to make frequent checks to ensure operators are performing proper set-up procedures.
3. Quality control auditors make frequent checks of the process to ensure proper set-up and documentation procedures are followed.

4.2. Results of chip-out improvement project

After implementing the improvements, a similar two-week test run was conducted to evaluate the effectiveness of the milling process and chip out issue. As shown in Table 2, at the beginning of the chip-out project, the average amount of chip-out during a given production run was 11.7% on the insert end of the line and 11.6% for the non-insert end. Results after the chip-out improvement project show the average amount of chip-out dropped to 2.4% on the insert end of the line and 1.9% on the non-insert end of the line. This is a 79.5% reduction in chip-out on the insert end and 83.62% reduction on the non-insert end and overall reduction of 81.56% in chip-out. This has saved QEP over $78,000 in return claims in 2018.

Table 2. Before and after data collected during chip-out project

Insert End					
	Hickory	Red Oak	Maple	Walnut	Average
Before	14.7%	14.1%	10.1%	7.8%	11.7%
After	2.4%	2.8%	2.1%	2.4%	2.4%
Overall Reduction in Chip-Out					**79.5%**
Non-Insert End					
	Hickory	Red Oak	Maple	Walnut	Average
Before	14.8%	13.7%	9.5%	8.4%	11.6%
After	1.3%	2.0%	1.8%	2.3%	1.9%
Overall Reduction in Chip-Out					**83.62.4%**

5. Project Product Off-Color

Depending on product color and extent to which color is mismatched, product off-color creates color differences between different lot numbers produced, and can result in noticeable color variations when installing flooring from multiple lot numbers as seen in Figure 5. Due to the difference in how line operators view color, off-color runs are the leading cause of product defects from the pre-finish department at QEP. If stain color during the production run does not match the color standard, then the finished productis considered defective; this contributes to waste of raw materials and lost production time, and if not caught before boxing, pay-out in the form of customer claims. Pre-finish department line operators use experience, and trial and error to match flooring stain colors to established color panel standards. Color panel standards are built once product development teams approve new stain colors for customer products. During the initial color set-up of a new product, detailed notes are kept as to what dyes are added to a base stain in order to achieve a specific color. Once a specific color is finalized, the detailed notes are stored in an electronic data base as the stain recipe for use in all future production runs for that particular product.

However, due to natural color variation in woods, it is standard practice to make small color adjustments to the original stain recipe using dyes and solvents. The color is then compared to color panel standards previously approved by the product manager specialist. These color adjustments are made using experience and trial and error.


A. Flooring panel does not meet color standard

B. Flooring panel color mismatch

Figure 5. Product off-color

5.1. Quality Tools

Maintaining a consistent color match between production runs (lot numbers) reduces customer claims by ensuring a consistent flowing color throughout different flooring lot numbers. For this project, in order to determine whether product off-color is a main quality concern a **pareto analysis** was conducted (ASQ, 2019; Sahay, 2017). A pareto analysis consists of listing causes of occurrences in order of frequency from most to least creating a pareto distribution, then plotting the results on a graph called a pareto diagram. Five primary pre-finish flooring defects – off-color, rough finish, adhesion, chatter, and gloss, were identified. Data gathered from three months of quality audits is used for pareto analysis and displayed in a pareto diagram. After plotting data, it is clearly evident that product off-color is a significant issue (Figure 6).

In order to identify the root cause of the off-color problem the "**5 why technique**", which is one of the seven basic quality tools, was used (Bialek, Moran, & Duffy, 2009). The 5-Why technique uses a series of five questions, each starting with "why", in reference to the current issue. This technique helps redefine the problem statement as a series of causes and effects, and helps identify the source of the problem. Four pre-finish line operators were interviewed with "5 why technique". Their responses are summarized in Table 3. The "5 why technique" reveals that operator opinions, coupled with pressure to get production lines running as fast as possible causes variation between operator color-sets.

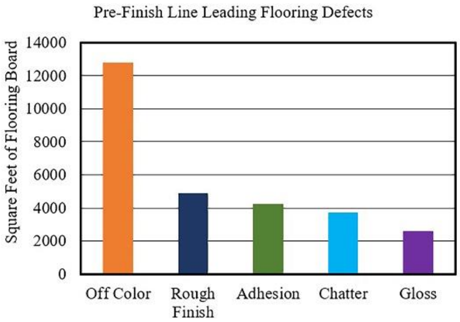


Figure 6. Pareto diagram; top five defects found during quality audits

5.2. Corrective actions for off color

It was decided that the best way to eliminate color variation among line operators was to take out the operators' guessing by using an electronic color spectrophotometer (Figure 7A) to read each stain color setup. A color spectrophotometer measures full color spectrum for a physical sample, but for our application a Hunter Color Scale (Figure 7B) is needed as these two items are used together to determine correctness of color match and needed color adjustments.

The Hunter L, a, b Color Scale is a diagram used in conjunction with the color spectrophotometer to assist operators in determining the correct direction to adjust stain color in order to match a given color standard. The three-color axes read by operator on the color spectrophotometer are L, a, and b, and these readings correspond to the three axes used on the Hunter Color Scale.On the Hunter Color Scale, "L" corresponds to the light-to-dark range; a "L" reading equal to 100 represents a perfect reflecting diffuser, and a "L" reading equal to

0 represents black. No numeric value range is assigned to “a” or “b”, however, positive “a” represents red, negative “a” represents green, and positive “b” represents yellow, negative “b” represents blue.

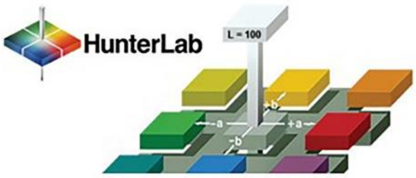
Table 3. The-5 why process used to determine root cause for product off-color

QEP **Pre-Finish Department** **5-Why Process to determine why production runs are started off-color**
• **Why** is the product defective? Because the stain color formulated by the line operators does not match the color standard • **Why** does the stain color not match the color standard? Line operators, in their opinion, feel the stain color matches the color standard. • **Why** do operators think the stain color matches the color standard? Line operators stand in different locations in the color room until the lighting is correct to make the color look correct. • **Why** do operators move to different locations in the color room until the color looks correct? Operators see color slightly different when standing in a single location vs. viewing color from multiple locations and angles. • **Why** do operators see color differently? This question could not be directly answered due to various opinions; however, some input from the operators were that height of the operator, reflection from the color room lights on the color standard, and personal opinion all contributed to various reasons why line operators feel the color match was correct to the color standard to where they are comfortable starting the production run.

Depending on the numeric values of L, a, and b from a sample color reading when compared to the numeric values of L, a, and b established on the color standard, the operator will know which color/s to add to the stain mixture to bring the current color reading from the test sample into acceptable range of the color panel standard.

In order to use the color spectrophotometer properly during production runs, base line readings for each color panel standard must be established. This data is then used to set an upper and lower control limit (color range) that color-sets must stay within in order for a production run to be considered serviceable.

A. Color Spectrophotometer



B. Hunter Color Scale.
Source: HunterLab (HunterLab, 2018)

Figure 7. Color Spectrophotometer and Hunter Color Scale

Sixty color readings were taken on each color panel standard in a left to right pattern starting in the upper left had corner of the color standard, and finishing with the last color reading being taken from the lower right-hand corner of the color standard.

The 60 readings were averaged, and the standard deviation of the 60 readings used to establish upper and lower control limits of positive and negative 1.5 and 3 standard deviations from the mean. Based on these results, L, a, b **control charts (**which is one of the seven basic quality tools**)** were developed for operators to plot each L, a, b color reading on both for production start-up and during production run color checks (Table 4). Three band (or range): Green, Yellow and Red are established for L, a, b. For operators to start a production run, the color readings from a spectrophotometer has to fall in green band, which is within 1.5 standard deviations above or below the mean. If the readings are in yellow band, which is between positive 1.5SD to 3SD and negative 1.5SD to 3SD of mean, operators can continue production runs, but must actively adjust color back into the green range. If a color reading is in the red band, i.e. above 3SD or below 3SD of the mean, the operator must stop the production run and re-establish stain color back into the green range.

Table 4. Color chart L,a,b data to create control charts

	L	a	b
+3SD	21.34	25.40	22.44
+1.5SD	19.20	23.94	20.20
X (Mean)	17.05	22.48	17.96
STDEV	1.43	0.97	1.49
-1.5SD	14.91	21.03	15.72
-3SD	12.76	19.57	13.48

5.3. Implementation of off-color process improvement

Prior to starting a production run, operators must follow the steps in Table 5 when setting color. These steps were developed to guide operators through a standardized systematic process that reduces guessing when setting color. Due to natural color variation and unique characteristics within and between variouswood species, deviations to thecolor-set steps are sometimes required. When it is necessary to deviate from these steps the Quality Manager, Line Supervisor, and Line Operator are all required to work together and agree upon the final color match, while using the Color Spectrophotometer to the greatest extent possible.

5.4. Off-color improvement project results

Prior to the off-color improvement project, it was common practice for pre-finish line operators to start production runs when color-sets were close to matching the color standards visually, based on the operators' opinion. After implementing the use of the Color Spectrophotometer and an established process check list, production runs cannot proceed until color set-ups fall within a given range on the color standard. These process changes reduced off-color customer claims by an average of 10% between the years 2016-2017 and 2017-2018, which can be seen in Figure 8. This decrease represents a cost savings of $13,928 annually.

Table 5. Operator color-set procedures

QEP

Pre-Finish Department

Line Operator Color-set Procedures

1. Mix initial stain color from color recipe established during product development.
2. Run five character neutral sample panels down the line for staining and check color with Color Spectrophotometer.
3. Compare sample color numeric values (L, a, b) to color standard L, a, b charts (Table 4).
4. If sample color numeric values fall within the green range of the color standard L, a, b charts, start production run. If not, proceed to step 6.
5. Make color adjustment to initial stain mix, in the direction of color needed based on sample color numeric values and Hunter Color Scale.
6. After color adjustment is made, run five more character neutral sample panels down the line.
7. Check color with Color Spectrophotometer and repeat above steps 4-7 until sample color falls within green range of color standard L, a, b charts.
8. Start Production run; check and document color readings (L, a, b) every 15 minutes. Adjust color as needed to stay within the green range.

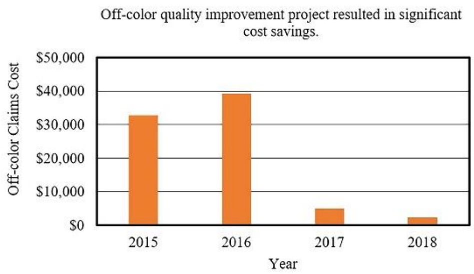


Figure 8. Annual savings of off-color claims

6. Project Inconsistent Product Grading

Inconsistent grading creates waste by removing natural character and minor defects allowed by local and industry product standards, while allowing true defects to remain in the product that should be removed. Figure 9 illustrates differences in the amount of natural color variation (character) between a select, and number 1 common grade of lumber (NWFA, 2015). At QEP inconsistent grading is a major source of waste resulting in reduced yield.

Figure 9: Grading variations in Red Oak flooring panels
Source: National Wood Floor Association (2015)

6.1. Quality Tools

Visual observation of the grading process was conducted for three hours each shift over a period of five days. A **check sheet** was used to collect information about defects and variation in grading. Considered as one of the seven basic quality tools, a check sheet is a structured instrument for collecting and analyzing data (Tague, 2005). Results of the observation revealed that splits, knot holes and raised grain in the face of the flooring are the three common defects in the wood (Figure 10). Interestingly all three types of defects are commonly overestimated by the graders.

Another observation was the position at which the graders marked defects to be cut out. Although the EGD department uses a standard set of grading rules for graders, data revealed a great deal of variation exists in what graders considered defects. This resulted in a great deal of variation in what defects were being marked as bad material and what defects were let go as good material. At grading stations one and two, graders opinions varied as to what defects of similar nature they would mark, and what defects they would let go. At grading station three, downstream from grading stations one and two, it was also observed that graders would let some defects, marked at grading station one and two, go by as good, and mark for defecting out some defects not previously marked at grading stations one and two. Such inconsistent grading contributed to increased waste and reduced yield.

In order to remedy the inconsistent grading practices, QEP created a structured training program for the graders. The grader training was conducted by meeting with the graders as a group, first on a weekly basis for 3 weeks, then bi-weekly for another 3 weeks, ending in an ongoing monthly meeting. Defect sample panels were also built and were used during the grader training sessions; the sample panels are now stored at the grading stations for use as a quick reference example. These efforts highlighted the fact that grading in EGD is an important job and if not performed properly can result in waste, low yield, and increased cost. During training meetings, graders offer input on various situations that others in the group learn from, thus bonding the graders in EGD as a cohesive team that now work together.

6.2. Inconsistent grading improvement project results

In the past, product grading or grader training was not viewed as much of important toward production yield. Therefore, historical data for QEP production yields are considered to be a good baseline for past grader performance. Therefore, historical data for QEP production yields are considered to be a good baseline for past grader performance. At the completion of the inconsistent grading project, data collected over a period of time showed an immediate improvement in QEP panel yield. Overall panel yield increased on average by 1.7% as shown in Figure 11. This increase in panel yield represents a $167,500 savings annually for QEP.

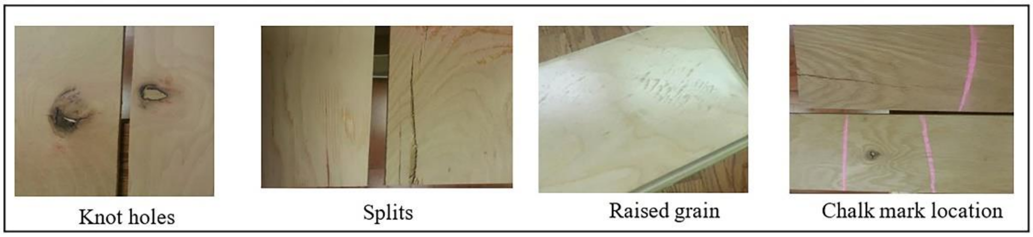


Figure 10. Common defects and graders' marking

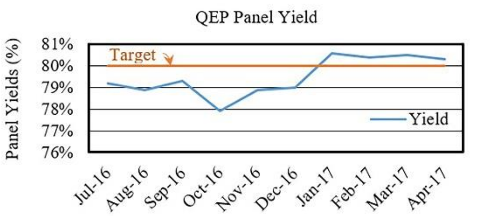


Figure 11. QEP panel yield increase of 1.7%

7. Conclusion

As U.S. and World hardwood flooring industry faces many challenges, U.S. based hardwood flooring companies are learning to operate more efficiently in order to stay competitive in the market place. QEP is one of those companies; through the use of simple but effective quality methods and tools, QEP developed a strategy to reduce waste, while improving yields and overall product quality. The three improvement projects (chip-out, off-color, and inconsistent grading) QEP initially focused on proved to be successful in reducing waste, while improving yields and product quality. In 2017 QEP exceeded its panel yield goal of 80%, which resulted in over $167,000 in savings. Chip-out in panels decreased 81.56% (over $78,000 savings) and off-color savings in product claims was over $13,000 annually. These projects demonstrate the power of the seven basic quality tools and can serve as a model for other hardwood flooring companies for their continuous improvement initiatives. These improvement projects also serve as stepping stones to future continuous improvement projects for QEP.

Although these projects resulted in great benefits to QEP, continuous monitoring of the manufacturing processes, in order to identify negative process shifts, are needed to prevent stagnation of quality and employee motivation. Setting monthly, bi-monthly and/or even quarterly manufacturing improvement goals, starting with easily achievable goals in order to show initial improvement, is a valuable tool in motivating employees to continuously strive for process improvement. Employees who perform daily manufacturing tasks are in the best position to make improvement suggestions. Offering rewards for improvement suggestions can have a positive impact on sustained continuous improvement and employee motivation within departments. Daily quality supervisor involvement can play a significant role in continuous improvement outcomes within departments and should be exploited to the fullest extent possible.

8. Recommendations

Wood flooring industry is competitive. Quality product and efficiency in manufacturing are the keys to survive in this industry. Empowering employees where every employee have a passion to imbue rather than simply follow instructions can create a culture of quality. In such environment total quality will sustain and thrive. Based on the success story of the QEP, this study proposes a framework for quality (Figure 12) and has following recommendations for wood flooring companies elsewhere:

1. [PLAN] customer centered quality
2. [DO] continuously identify and implement low cost quality methods in order to produce best quality product
3. [CHECK] understand what drives cost and how to control it
4. [ACT] invest in employee training and motivation

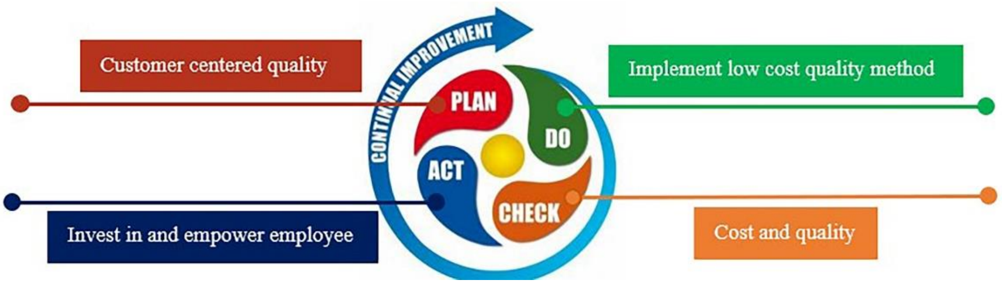


Figure 12. A Framework for continuous improvement of quality

9. Limitations

While working on the three improvement projects listed in this article, one factor that continually plays a role in limiting consistent project results is raw materials received for processing. As wood is a natural grown product, environmental factors such as geographical growing and harvest locations, weather, length of growing seasons, and so on all contribute in making the raw materials used in manufacturing hard wood flooring anything but consistent. Unlike man made materials, natural color variation, wood character, fiber structure, species etc. vary from truck load to truck load. This natural variation continually plays a role in how panels will be milled and how the materials natural color will affect stains and top coats when they are applied. As such, final results may vary due to variation in raw materials.

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