ANALYZING PRODUCT OVERFILL

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Abstract

A Midwest food producer's production processes were investigated to identify sources of product overfill, quantify the cost, and make suggestions for reducing the level of overfill. Product overfill occurs when a manufacturer packages more product than is statistically prudent in order to meet regulatory compliance. Overfill produces product giveaway which, at a large manufacturer, can cost millions of dollars in waste each year. Controlled, overfill can provide an adequate amount of protection from regulatory fines. However, when uncontrolled, the cost of overfill can greatly exceed the cost of noncompliance. Therefore, measuring and controlling overfill can be a significant source of cost savings. The factors investigated in this study were: day of the week of production (Sunday through Saturday), manufacturing line used, and the shift during which the product was produced. Significant differences were noted between shifts and between line numbers, though no difference between days of production was observed.

Introduction

A Midwest producer of boxed pasta products was the focal point of this study. The subject organizations, plant manager identified three project objectives. These objectives were: 1) identify significant sources/causes of product overfill; 2) quantify the financial impact of the overfill; and, 3) recommend solutions for reducing the level of product overfill.

The pasta packages, as with most food packaging in the United States, are subject to strict regulations governing the accuracy of their labels. With few exceptions, food packages sold in the United States must conform to a Maximum Allowable Variation (MAV). This value is the smallest acceptable product weight that can be sold to the general public while at the same time being the maximum weight that the actual product package weight is allowed to vary below the labeled weight [1], [2]. Failure to meet or exceed these minimum packaging requirements can result in substantial fines and penalties. The challenge for organizations is to balance the cost of overfill and the cost of compliance. The subject organization adopted a strategy known as overfilling which, while providing protection from regulatory fines, can result in expensive product giveaway. Overfill occurs when more product is placed in a package than is printed on the label. This practice ensures that a package will always exceed that product's MAV, thus protecting the company from regulatory infractions. The positive difference between the actual product and labeled amount is known as "giveaway" [3] and excessive giveaway poses financial risk to organizations.

In packing applications where a product is being filled into individual packages that have a nominal labeled weight, there are three risks that organizations face: 1) Under-filled packages could place an entire production run lot on hold and result in substantial rework; under-fill discovered at the retail level could result in a product recall, significant losses in sales revenue, additional re-work expenses, and damaged customer loyalty and organizational image. 2) Disproportionate and/or uncontrolled fill variation necessitates added labor in an attempt to better monitor and control packaging equipment to minimize negative impact. 3) Over-filled packages result in product "giveaway", which is lost revenue to the organization. Consider a product with a 1lb nominal labeled weight per package, which holds product worth $1.00 per pound, processed at the rate of 1,000,000 packages per week, 50 weeks per year. The savings generated by a 1% reduction in overfill could save 500,000 lbs per year or $500,000 per year.

Background

All food packaging processes contain natural variation. The magnitude of variation changes depending on the quality and age of equipment used as well as the tolerance levels for the specific process. However, even in the most tightly controlled environments, no two packages or products will consistently weigh exactly the same over time [4]. For the subject organization in this study, the natural process variation could cause less pasta to be packaged than is labeled. Thus, overfill was used to compensate for the variation intrinsic to the system.

For consumer protection, there are federal requirements regarding packaging and labeling practices to ensure that the package label is a true reflection of the amount of product contained. The federal government began regulating package labels after the 1958 amendment to the Federal Food, Drug, and Cosmetic Act (FD&C Act). Differences between labeled and packaged weight fell under the purview of a "misbranding" clause in the act [3]. Later, in 1967, the Fair Packaging and Labeling Act (FPLA) was passed adding additional labeling requirements for all consumer commodities [5].

Title 21 Section 343 of the FD&C Act states that any package bearing a label must contain “an accurate statement of the quantity of contents in terms of weight, measure, or numerical count...” [5]. Reasonable variations are permitted and are known as the MAV. These requirements necessitated fair disclosure of net contents, identity of commodity, and the name and place of a product’s manufacturer. The Food and Drug Administration (FDA) administers the FPLA as it pertains to food products [6]. Beginning in 1979 with the endorsement of the National Conference on Weights and Measures (NCWM), the National Institute for Standards and Technology (NIST) begin compiling the latest Uniform Laws and Regulations as they relate to the measurement and labeling of consumer quantities. This publication is NIST Handbook #130 and is the standard for uniform weights and measures laws and regulations in the United States [7]. If a company is found to have violated a labeling regulation, for instance by over-representing the contents of a package, that company will face stiff penalties including fines and other punitive measures as outlined in NIST Handbook #130 [8].

However, while creating the aforementioned legislation, regulators were aware of natural process variation in manufacturing [4] and took the principle of variation into account when establishing the packaging and labeling requirements [3]. The acceptable amount of variation for a particular product, i.e., the greatest amount that the actual measure of contents is allowed to vary from the labeled quality, is called the Maximum Allowable Variance (MAV) [1]. The MAV is determined on a per-product basis and is dependent on the type of product being packaged (labeled by weight, by volume, by count, etc.) and in what quantity. The values for product MAVs are determined by The National Conference on Weights and Measures and are published regularly in NIST Handbook #133 [1].

In addition to specifying MAV values, Handbook #133 also outlines test procedures for measuring and testing products for compliance. Specific product MAV values can be found in the Appendix of NIST #133. Natural process variation is intrinsic to the regulations; therefore, manufacturing processes are afforded a limited amount of regulatory protection while still maintaining the integrity of package labels. Since process variation is already part of the MAV value, penalties for noncompliance can be very strict. Penalties can include fines and even criminal damages awarded, depending on the frequency of infractions and whether or not they were intentional [8].

Furthermore, customer satisfaction and brand reputation may be negatively affected if a company is caught underfilling its products [9]. In 2000, a lawsuit involving a California man and under-filled Heinz ketchup bottles was settled. Heinz insisted that the ketchup bottles were not intentionally under-filled but damages were expected to total approximately $830,000 which included civil penalties and the estimated cost of the year-long practice overfill required of Heinz as part of the settlement [10]. Product overfill is often a deliberate strategy used by manufacturers to further guard themselves against regulatory fines and other legal actions and often a calculation is made that establishes the cost of overfill to be less than the cost of the penalties and fines associated with packaging infractions [11]. Therefore, while the cost of giveaway may be significant, overfill is often seen as the necessary cost of compliance.

Cost of Overfill

While product overfilling may be prudent and the cost per package may be minor, when the individual amounts of overfill are measured, summed, and annualized, the cost can become quite large. The degree to which overfill can damage a company’s bottom line increases with the scale of production.

Overfill and product giveaways are problems that have been examined and addressed at other manufacturing firms, often very successfully. Past successes from the literature were analyzed in order to provide guidance for implementing effective strategies. Swankie Food Products, a fish product manufacturer from the UK, successfully used statistical process control (SPC) tools such as control charts to gain insight into the nature of their manufacturing processes [11]. Control charts are graphs that are used to study how a process changes over time. These charts contain historical (and sometimes real-time) performance data along with lower and upper process control limits. The lower and upper control limits assist in determining if the process variations are under control [12].

As noted earlier NIST #133 standards do not stipulate limits for overfilling, only that fill weights are required to be above the MAV weight but as close as possible to the label declaration. The approach to meeting this regulation is to shift the curve up, so that the average is at or above the label weight, and the lower tail is just above the MAV weight. SPC tools allow organizations to tighten the curve, thus eliminating MAVs and producing less overfill.

These charts were used by Swankie Foods Products to determine if their production processes were out of control and thus a risk to the manufacturer. The Flavor Division and

McCormick, which manufactures sauces, dressings, and condiments, experienced overfill challenges that were addressed using the same GainSeeker SPC software that was implemented at the subject organization of this study. McCormick was able to reduce overfill material costs by up to 30% and realized three times their desired reduction using control charts from GainSeeker to understand their process variations [13].

Another food manufacturer (whose name was left unspecified for proprietary reasons) that also made use of similar SPC strategies (and also used the GainSeeker suite) was able to reduce their product overfill, eventually producing an overall savings of $3.4 million over six months [14]. Following an internal study, Heinz implemented an SPC initiative at a recently acquired small company (Heinz Single Service). This company produced a high volume of products, shipping 900 million units on 13 different filling lines. Heinz chose to use a product from MVI Technologies to handle the real-time data monitoring and was able to bring their levels of overfill completely under control in three months [15]. While the literature confirmed that standard SPC tools such as control charts, Pareto charts, and capability charts represent appropriate and effective approaches to controlling overfill, they provide no indications as to potential sources of overfill within a process as such information is often guarded and proprietary. The use of real-time data, as opposed to time-delayed data, to study a process was also repeatedly cited as advantageous when addressing product overfill.

The annual cost of overfill for the subject organization was reported by the plant manager to be just over $4,000,000. The pasta business unit with seven production lines was responsible for $1,250,000 of the overfill problem. The two production lines investigated in this study were responsible for $878,000 of product overfill for the preceding 12 months. [16].

Methodology

At the start of this project, the authors led a brainstorming session with management, line supervisors and operators, and maintenance and quality personnel. An affinity analysis was used to organize the participant's ideas as to the causes of product overfill. As such, each participant was asked to record each idea on a separate sticky note. While participants were writing their ideas, the authors randomly spread the sticky notes on a whiteboard so that all sticky notes were visible to everyone. The brainstorming exercise contributed 127 potential causes of product overfill. These 127 ideas were reduced to 57 unique ideas by eliminating redundancies and formalizing standard definitions.

Upon completion of the brainstorming activity, participants were asked to review the ideas and then look for ideas that seemed to be related in some way by placing like ideas in columns and repeating the process until all notes were grouped or assigned to a column. Upon completion of the grouping exercise, participants were then asked to determine a column heading for each group of related ideas. The column heading needed to be representative of all the individual sticky notes in the column. Column headings included equipment, operators/personnel, raw materials, the environment, operating procedures, and maintenance.

Once column headings were determined, each sticky note representing a column heading was pulled aside and all column headings placed in a circle. For each column heading the participants were asked, "Does this heading cause or influence any other idea?" Arrows were drawn from each idea to the ones it caused or influenced. This question was repeated for every column heading. The next step was to analyze the diagram and its relationships.

Upon completion, the researchers counted the arrows in and out for each column heading. The column headings with the most out arrows influenced the most other column headings. These are the basic "causes". The column headings with primarily incoming (to) arrows were the final "effects" that also may be necessary to address. The number of arrows is only an indicator, not an absolute rule. The results are shown in Table 1.

Table 1. Interrelationship Diagraph Ranking of Column Headings

Column Heading	*Out Arrows*	*In Arrows*	*Rank*
Equipment	1	2	4
Operators/Personnel	2	3	2
Raw Materials	0	2	6
Environment	1	2	4
Operating Procedures	4	1	1
Maintenance	2	1	3

The highest priority column headings were operating procedures, operators/personnel, and maintenance. At this point, the business unit manager reviewed the findings and selected three sticky notes from the operating procedures column heading to be the focus of investigation. These variables were: 1) day of the week, 2) line number, and 3) production shift number. The business unit manager cited shift operating differences as a potential cause of excessive product overfill. Operating differences included the number of people working per shift, clean-up or sanitization expectations per shift, and lack of training for third shift operators. Additionally, the three variables selected were deemed to be variations which were under the direct control of the business unit manager.

Automated Data Collection

The subject organization's attempts to quantify and control product overfill relied on automated data collection software from the GainSeeker software suite from Hertzler Systems, an industry leader in SPC applications. Data were extracted daily from the GainSeeker software for five months (January 4, 2011, through May 31, 2011). Both production lines were limited to one product mix for the duration of the study. Weight sets (five consecutive packages) had to be taken at least every 30 minutes with a recommended target of every 20 minutes. Weight control deviations were issued if there were more than 30 minutes between sample sets. When a weight deviation was issued, every package between the last acceptable weight check and the last package produced had to be individually weighed. Each production line produces between 230 and 280 packages per minute. Thus, there could be as many as 8400 packages that need to be individually weighed. This process must be repeated if any weight set of five packages fails to meet required weights.

The GainSeeker suite calculates a value called the Hertzler Target and uses historical data to account for process variation and minimizes overfill. If properly computed, the Hertzler Target is the amount of product to package so that the MAV weight will never be exceeded for a particular process. When using the Hertzler Target, overfill is defined as the amount of product that exceeds the target.

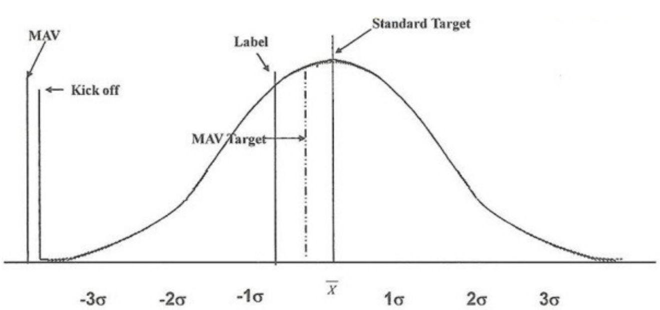

Figure 1. MAV and Target Relationships [9]

Figure 1 illustrates the relationship between the MAV, the labeled value, and the Hertzler Target. In this figure, the lines labeled "MAV Target" and "Standard Target" are both the Hertzler Target. If the production line uses a checkweigher (a highly precise machine to automatically check the weight of packaged materials), the MAV Target value is used. If a production line doesn't have a checkweigher, the Standard Target value is used to provide additional security [7]. The GainSeeker software supports SPC calculations and analysis. The researchers imported the data from GainSeeker into Minitab to conduct the analysis reported from this study.

Data collected from the GainSeeker software included: line number—one or two, product codes—only one product was run during the data collection period, Average of Hertzler (MAV) Target in grams, Average of Actual in grams, overfill in grams—the difference between the Average of Actual and Average of Hertzler Target, and Opportunity in dollars. Both production lines used checkweighers to monitor product weights.

Control chart data from GainSeeker revealed product overfill to be out of control. Prior to this study, management had not addressed assignable or common-cause data. Corrections to possible assignable causes were not documented or tracked. As directed by management, the researchers did nothing to correct the out-of-control nature of the process prior to analyzing the data. Management's first priority was to determine if there was a difference in overfill levels among the three variables cited previously.

Hypothesis

Three factors (each with multiple levels) were examined to determine their impact on product fill. These factors were: day of the week of packaging (Sunday through Saturday), shift number (1-3), and line number (1 or 2). The percent overfill (the actual of amount of product compared to the target value) was the dependent variable. To analyze which days, shifts, or line numbers produced the greatest amount of overfill, an ANOVA was used to analyze the level of each independent variable. This resulted in three hypotheses:

For days of the week (Sunday - Saturday):

$$H_0: \mu_{1d} = \mu_{2d} = \ldots = \mu_{7d} \qquad (1)$$

where μ_{nd} is the mean on day n (Sunday through Saturday).

For shift number (1, 2, or 3):

$$H_0: \mu_{1s} = \mu_{2s} = \mu_{3s} \qquad (2)$$

For line number (1 or 2):

$$H_0: \mu_{1l} = \mu_{2l} \qquad (3)$$

Data Analysis

Three factors were analyzed for their contributions to total product overfill. For simplicity, an analysis of variance (ANOVA) was used to check for differences in the amount of overfill present within each factor. For example, an ANOVA performed on the Day of Week factor would compare the variation of product that was produced on Sunday, Monday, Tuesday, etc. and determine if one of those days produced a significantly different amount of overfill. Interaction effects were not considered. All analyses were done using Minitab. As a standard, a 95% confidence level was selected for all analyses.

Day of the Week

The day of the week that the product was packaged was thought to be a potentially significant source of overfill. The day of the week itself was not thought to be a direct contributor, though data contained within the day was thought to be potentially significant (personnel configurations, proximity to the weekend, variations due to maintenance cycles, etc.). The ANOVA table for days of the week determined that this factor was not a significant source of overfill (see Figure 2). The p value exceeded the alpha value of 0.05 required to establish significance. It was therefore concluded that there was not a significant difference in the amount of overfill produced on the different days of the week.

Figure 2. Overfill versus Day of Week

One-way ANOVA: Diff versus Day of Week

```
Source        DF       SS    MS     F      P
Day of Week    6     2.82  0.47  0.06  0.999
Error        475  3470.23  7.31
Total        481  3473.05

S = 2.703   R-Sq = 0.08%   R-Sq(adj) = 0.00%

                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level       N   Mean  StDev  --+---------+---------+---------+-------
Friday     82  3.792  2.484    (--------------*-------------)
Monday     59  3.839  2.541   (----------------*----------------)
Saturday   59  3.967  2.803      (----------------*----------------)
Sunday     53  3.905  2.570   (------------------*-----------------)
Thursday   79  3.719  2.632  (--------------*--------------)
Tuesday    71  3.898  2.912      (--------------*---------------)
Wednesday  79  3.814  2.915    (--------------*--------------)
                             --+---------+---------+---------+-------
                             3.20      3.60      4.00      4.40

Pooled StDev = 2.703
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Line Number

Due to subtly different equipment and maintenance track-records on the two production lines, the specific production line that a product was packaged on was suspected as a significant source of overfill. As with days of the week, the two production lines were analyzed using an ANOVA. A significant difference between the production lines was discovered (see Figure 3). The p value was below the 0.05 threshold required for significance. It was therefore concluded that there was a significant difference in the amount of overfill produced between the two production lines.

Figure 3. Overfill versus Line Number

One-way ANOVA: Diff versus LN_Coded2

```
Source      DF       SS      MS      F      P
LN_Coded2    1   460.13  460.13  73.31  0.000
Error      480  3012.92    6.28
Total      481  3473.05

S = 2.505   R-Sq = 13.25%   R-Sq(adj) = 13.07%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N   Mean  StDev   --------+---------+---------+---------+-
1      149  5.300  2.695                                (-----*----)
2      333  3.185  2.416   (---*--)
                           --------+---------+---------+---------+-
                                3.50      4.20      4.90      5.60

Pooled StDev = 2.505
```

Shift Number

Shift number was suspected as a potential source of overfill due to different personnel configurations between shifts as well as disparate levels of training. After completing the analysis, it was concluded that there were significant differences in the cost of overfill between the three different shifts. Specifically, shift 3 produced significantly less overfill than shifts 1 & 2 (see Figure 4). The p value was under the 0.05 threshold for significance. It was therefore concluded that there were significant differences in the amounts of overfill produced among the three shifts.

Figure 4. Overfill versus Shift Number

One-way ANOVA: Diff versus Shift

```
Source   DF       SS      MS      F      P
Shift     2   211.73  105.86  15.55  0.000
Error   479  3261.32    6.81
Total   481  3473.05

S = 2.609   R-Sq = 6.10%   R-Sq(adj) = 5.70%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N   Mean  StDev   ----+---------+---------+---------+-----
1      161  3.987  2.577               (-----*-----)
2      165  4.545  2.706                       (-----*-----)
3      156  2.940  2.538   (-----*-----)
                           ----+---------+---------+---------+-----
                             2.80      3.50      4.20      4.90

Pooled StDev = 2.609
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Conclusions

Two conclusions were drawn from this study: 1) the line number the product was run on contributed significantly to product overfill—specifically line #2 produced the least amount of overfill ($p = 0.000$); and, 2) there was a significant difference in product overfill levels between production shifts—specifically the third shift produced the least amount of overfill ($p = 0.000$).

When examining the two production lines in more detail, the following characteristics were noted. Production lines 1 and 2 were both installed in 1969. The two production lines were located adjacent to each other. Production lines 1 and 2 produced the same products since installation. Minimal preventive maintenance had been performed. Both production lines were run until there was a mechanical failure that forced production to stop. At that time, repairs were made. Uptime or run-time percentages were greater than 95% for both production lines.

The analyses showed a difference in product overfill between the two production lines. However, the variables examined in this study were not directly attributable to these differences. The researchers recommended further analysis to determine the root cause of this difference. When examining employee work schedules and shift differences, the following characteristics were noted. Third shift was comprised of mostly new hires. Employees moved from third, to second, to first shift based strictly on seniority. There were fewer employees allocated to each production line on third shift. Third shift had the least amount of direct management supervision. Uptime or run time percentages were greater than 95% for all three shifts.

Managerial Implications

This study was the first in a series of ongoing studies to address product overfill. Thus, there are limitations in terms of managerial implications. The plant manager and business unit manager asked the authors to target "low hanging fruit" or opportunities directly under managerial or supervisory control to decrease product overfill without spending significant dollars to upgrade equipment and infrastructure. Furthermore, the researchers were asked to identify and raise additional questions for other improvement teams to address. Management wanted a fresh set of eyes and outside input into additional improvement ideas. Therefore, many of the managerial implications focus on identifying additional studies, data collection or experiments to be carried out in the future.

General Trends in the Food Processing Industry

The production facility in this study faced the same general trends found across the food processing industry. These trends include:

- Organization-wide Strategic Cost Reduction Goals

One question that needs to be addressed through further investigation is why the third shift—with the fewest employees on each production line—produced the least amount of product overfill. One assumption from the researchers was that the employees on the third shift did not have time to sit and watch the computer monitor as it tracks the real-time values for product overfill. Human nature tends to encourage operators to add their personal touch or setup expertise in an attempt to add value to their jobs. This may be one case where overall production would be better if the operators were more hands-off. Operators were observed making minor adjustments to product mixes, line speeds, fill pressures, etc., as soon as the monitors started to trend toward the MAV target. These changes may have been unneeded and just reflective of natural process variation. The researchers felt that the operators were over adjusting based on too little data and not utilizing the full potential of the GainSeeker software to see real production trends. One suggestion from the researchers to management was increased training, application, and interpretation of run and control charts. Specifically, operators need to know and understand the rules for run charts and proper use of such information for process improvement.

An additional recommendation regarding the differences in shifts was for management to facilitate an effort to minimize or simplify the steps and complexity of their standard operating procedures (SOPs). It was recommended that the SOPs include best-practice reviews and/or procedural checklists.

- Cleaning and Sanitization

It was noted by the researchers that first- and second-shift employees resisted performing regular cleaning and sanitization. The culture within the organization was such that employees on the first shift felt that they had earned a reprieve from cleaning and sanitization responsibilities. As such, even though the production line uptime percentages were almost identical, it was evident that the third shift was more conscientious and adept at performing mandated cleaning and sanitization duties. One question not addressed by this study was: "is there a relationship between the level of performance of cleaning and sanitization and product overfill?" This question needs to be addressed. And, if the findings support a relationship, management will need to undertake efforts to better communicate the importance of cleaning and sanitization to first- and second-shift employees.

- Utilization

One of the subject organization's strategic goals was to reduce operating expenses by 10% per year. Management must achieve these goals or face not being promoted or possibly even fired. Prior-year initiatives focused on production utilization.

The subject organization utilized Overall Equipment Effectiveness (OEE) to determine individual production line and overall plant production utilization. OEE takes into account all three OEE factors and is calculated as: OEE = Availability x Performance x Quality. Although the two production line OEEs were greater than 95%, management always tried to squeeze out that extra percent or two. This may have negatively impacted overfill for the first and second shifts. Since there was minimal managerial presence during the third shift, the pressure to increase line speeds and production rates was much less evident. Over the five-month period of this study the researchers often observed management and production line supervisors trying to increase the production line speed. It was the researcher's belief that there may be a point of diminishing returns. Although there was no empirical evidence to support this, it appeared that increasing production line speeds may have contributed to other mechanical, production, and operator problems. Therefore, the researchers recommended another study to determine the optimum production line operating speed. Such a study would need to examine both optimum production line operating speed and its relationship to uptime, as well as optimum production line operating speed and its relationship to product overfill.

Summary

The subject organization is in the initial stages of implementing a company-wide quality-improvement program. To date, the focus has been on reducing internal wastes (LEAN) and implementing six sigma projects to address process variations. This study was one of the initial six sigma projects. As with any organization, both lean and six sigma projects can have tremendous impacts on an financial performance. The product overfill problem discussed in this paper is a multi-million-dollar-per-year problem for this organization. What the subject organization found was that ongoing improvement initiatives require a culture change at all levels of the organization. Without the culture change they will never be able to achieve the full financial benefits of their lean and six sigma initiatives. People's daily routines must change. Managers and employees must now focus on new duties and responsibilities. The new emphasis is on data collection and problem solving. Managers, who in the past have relied on fire-fighting, are being replaced with people who can find data-driven solutions to problems. Organizations such as the subject organization in this study need managers and employees who can carry out experiments, analyze data, and solve problems. But, more importantly, they need to examine their organizational culture and values. After all, people are the key to the successful implementation of organizational change.

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