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A BLENDED APPROACH OF LEAN SIX SIGMA AND TRIZ TO DISCOVER AN OPTIMAL LEVEL FOR EMPLOYEE EMPOWERMENT IN PURCHASING INDUSTRIAL MATERIALS

Abstract: *A This paper focuses on using Lean Six Sigma principles incorporated with TRIZ to develop a strategic approach to establish the level of empowerment. Leadership decisions can either overly empower individuals beyond acceptable levels or under empower them and do not provide any benefits. The latest trend within all organizations is to invert the organizational triangle. All organizational leadership seeks to leverage the workforce to make decisions and prevent bureaucracy by empowering individuals closest to the process. One area that gets a lot of focus and attention is the Inventory Management department, where goods are purchased for the services. Researching historical spending via the Six Sigma DMAIC program structure and fundamentals of the TRIZ principles were exploited to develop the optimal value ensuring there is significant satisfaction of the customer.*

Keywords: *Six Sigma; Lean Manufacturing; Employee Empowerment; Procurement; Inventory Management.*

1. Introduction

This publication presents a blended strategy utilizing Theoria Resheneyva Isobretatelskehuh Zadach (TRIZ) and Six Sigma Define, Measure, Analyze, Improve, and Control (DMAIC) process to seek an optimal level of employee empowerment based on statistical analysis. Every organizational leadership seeks to leverage the workforce to make decisions and prevent bureaucracy by empowering individuals closest to the process. The level of empowerment and decision making is generally made based on some perceived structured delegations of authority. Without a strategic approach, these actions do not achieve objectives supported by the empowerment action. Decisions either overly empower individuals beyond acceptable levels or under empower them and do not provide any benefits. This research concentrates on the Materials Management (MM) within a manufacturing facility. The MM department in a production facility's main task is determining manufacturing requirements for producing goods. Wild (1995) segments MM responsibilities into scheduling of manufacturing processes and material handling. Material handling is further expanded to obtaining, storing, and distributing goods.

Organizations struggle with the level of workforce empowerment. Typical management actions are made based on the assumption that employees use power recklessly, resulting in losses to operations. Fernandez and Moldogaziev (2013) discuss

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the significant improvements empowered employees contribute to an organization. Their research discovered empowerment generates job satisfaction, organizational commitment, and innovation in addition to performance improvement. These empowerment traits on employee behaviors and work ethic result in a significant impact on the operation's performance. Leadership profoundly understands the impact of empowerment and continuously seeks to find an optimal solution to the level of employee empowerment. This paper explores a manufacturing sector's concern around the empowerment of plant-level employees to manage operational needs. The focus is centered on durable goods required to support equipment and functional needs. The bureaucracy around waiting on approval is a significant and consistent complaint of the plant floor workers about the plant leadership team. The question "Why do I have to wait for name to approve? Do they not trust me to make the correct decision?"

A manufacturing facility contains a dedicated location where durable goods to support production equipment needs and functional department requirements such as mops, gloves, etc. are stored. Plossl (1990) shows beside improvements in product quality and automation, component expenditures are another significant opportunity for cost improvement in manufacturing. MM is a business activity that operates just like a store. Items are either hand-selected or order via a computerized method for purchase. Monthly purchases are reviewed and filed within the finance department of the organization. Yearly audits for cost summary of all purchases are reviewed and used to develop cost projections to use for budgetary input for the following year. Due to having a direct financial impact, leadership is resistant to release control and empower lower-level employees to make financial decisions to run their operations. This mindset is a result of mistrust or historical interaction that resulted in unnecessary spending.

Empowerment levels within MM occur in a cyclical pattern without any analysis of departmental requirements or historical spending. The level of empowerment for spending occurs based on a safe cost determined by the department leads. The value is chosen based on the assumption of needed daily spending allowance. Implementation of a restrictive cost allowance for material purchases results in operational inefficiencies. This generates a complete reversal of restrictions, and management laxes spending limitations. Lifting restrictions drive employees to start purchasing more than needed gradually. Single item purchases migrate to bulk buys resulting in increased monthly expenditures. During financial reviews, management discovers increase purchasing cost and mandates restriction on purchasing allocation for employees and adds layered approval of purchases. This cyclic change in the policy demotivates the workforce and influences the distrust of management.

Development of an allocation amount that satisfies both workforce and management, a methodology needs to support both requirements. Bowen and Lawyer (1995) investigation focus was limited to expenditure at the extreme levels. They compared no spending and unlimited spending allowances within the service industry. Research confirms out of control conditions with unlimited purchasing policy and inefficient operational results with no spending allowance. The workforce desires empowerment to purchase essential inventory items with minimal supervision. Management wants an amount that limits and controls the spending of non-essential items. A solution that fully achieves both requirements is needed to provide a comprehensive answer.

2. Literature Search

A comprehensive review of publications discovered insights in the application of processes and tools. Literature search focuses

on classification of key areas MM, Six Sigma, TRIZ and employee empowerment. MM is the process investigated in a manufacturing facility not meeting plant floor customer expectations. DMAIC and TRIZ are methodologies used to understand concerns and develop solutions.

MM is an area with extensive publications. Authors reveal significant opportunities within manufacturing. Ondiek and Odera (2012) discover having a clear understanding of the production requirements provides significant material cost reduction of the product being manufactured. MM performance can be measured based on how effective the processes are executed (Sjøbakk et al., 2015). MM system impacts cost just as much as the production output (Ulrich & Pearson, 1993). Improvements in the utilization and distribution process directly impacts financials for organizations.

Zhao and Zhao (2013) investigate the incorporation of TRIZ and DMAIC to increase customer satisfaction. They focused on the innovativeness properties in TRIZ to develop new ideas and the DMAIC process to improve product quality. Wang (et al., 2016) uncovered product development as an ideal case for the application of TRIZ and Six Sigma. A recent case study presented from the Dow Chemical Company shows the combined effect of TRIZ with Design for Six Sigma (DFSS) most dramatically (Barry et al., 2010).

Six Sigma is a disciplined process improvement methodology. Although Six Sigma only emerged as a unique discipline rather recently, the tools and approaches it uses were created over the long history of quality management, which itself has drawn on other disciplines such as industrial engineering, statistics, human resources management, and organization theory (Evans & Lindsay, 2014). Six Sigma methodology can be applied to various concerns outside the quality space. Some recent publications leverage application within supply chain logistics, health care, and mining industry (Jayaram, 2016; Liberatore, 2013; Kesek et al., 2019). Usage can be applied to any process or service that does not meet the customer expectations.

Employee empowerment is a highly researched topic within the management profession. Several studies have confirmed "Employee Empowerment" as a critical business success element (Jarrar and Zairi, 2002). Actual definition ranges based on the authors' viewpoint (Honold, 1997). Empowerment requires a total alignment between people, tasks, technology, information flow, rewards and organizational hierarchy (Sahoo and Das, 2011). Decision-making is divided into three types strategic, tactical and operations according to pyramidal classification (Pardo de Val and Lloyd, 2003). Empowerment can be highly structured or flexible (Brymer, 1991). Regulation of employee empowerment is complex because empowerment is a perception (Greasley et al., 2005).

3. Methodology

3.1 Theory of Inventive Problem Solving

TRIZ is a Russian acronym Theoria Resheneyva Isobretatelskehuh Zadach "Тхеориа Решенеыва Исобретателскехух Задач" meaning Theory of Inventive Problem Solving. This methodology supports lateral thinking problem-solving strategies. Lateral thinking focuses on using a creative mindset in resolving issues instead of a rational approach (Al'tshuller, 1999). Both the creative and rational problem-solving techniques entail good and adverse techniques for resolving simple and complex concerns.

TRIZ strategy exploits two concepts contradiction and innovation (Savransky, 2000). The development of an innovative solution eliminates or minimizes the contradictions. The innovation solution birthplace is within historical submitted patents. Various patents have eventually

resolved either current problems or problems with similar concerns. Innovation starts at reviewing contractions and searching inventive principles for a solution(s) that support similar conditions. Understanding these two principles leads to a solution proposal.

Table 1 displays TRIZ thirty-nine engineering parameters supporting a solution for any concern. Concerns are categorized as one of these contradictions (Kang, 2004). Once a contradiction that supports the problem statement is discovered next step is finding a solution.

Table 1. Thirty-Nine Conflicting Matrix (Ekmekci & Koksal, 2015)

1	Weight of moving object	21	Power
2	Weight of stationary object	22	Loss of Energy
3	Length of moving object	23	Loss of Substance
4	Length of stationary object	24	Loss of Information
5	Area of moving object:	25	Loss of Time
6	Area of stationary object	26	Quantity of substance/the matter
7	Volume of moving object	27	Reliability
8	Volume of stationary object	28	Measurement accuracy
9	Speed	29	Manufacturing precision
10	Force	30	External harm affects the object
11	Stress/Pressure	31	Object-generated harmful factors
12	Shape.	32	Ease of manufacture
13	Stability of the object's composition	33	Ease of operation
14	Strength	34	Ease of repair
15	Duration of action by a moving object	35	Adaptability/Versatility
16	Duration of action by a stationary object	36	Device complexity
17	Temperature	37	Difficulty of detecting and measuring
18	Illumination intensity	38	Extent of automation
19	Use of energy by moving object	39	Productivity
20	Use of energy by stationary object		

Table 2. Inventive Principles (Ekmekci & Koksal, 2015)

1	Segmentation	21	Skipping
2	Taking Out	22	Blessing in Disguise
3	Local Quality	23	Feedback
4	Asymmetry	24	Intermediary
5	Merging	25	Self-service
6	Universality	26	Coping
7	Nested Doll	27	Cheap Short-Living Object
8	Anti-Weight	28	Mechanics Substitution
9	Preliminary Anti-Action	29	Pneumatics and Hydraulics
10	Preliminary Action	30	Flexible Shells and Thin Films
11	Beforehand Cushioning	31	Porous Materials
12	Equipotentiality	32	Color Changes
13	The Other Way Round	33	Homogeneity
14	Spheroidality-Curvature	34	Discarding and Recovering
15	Dynamics	35	Parameter Changes
16	Partial/Excessive Actions	36	Phase Transitions
17	Another Dimension	37	Thermal Expansion
18	Mechanical Vibration	38	Strong Oxidants
19	Periodic Action	39	Inert Atmosphere
20	Continuity of Useful Action	40	Composite Structures

Solution implementation requires a review of several different innovative patent solutions. TRIZ has a standard of 40 innovative solutions display in Table 2. Analysis of one or more of these solutions provides potential innovative resolution to the concern.

3.2 Six Sigma DMAIC

Six Sigma DMAIC is a structured problem-solving methodology. Each letter in DMAIC represents a phase within the problem-solving cycle, Define, Measure, Analyze, Improve and Control. Following the DMAIC structure ensures exploration of all avenues for concerns with the discovery of Key Process Input Variables (KPIV), a function of Key Process Output Variable (KPOV). The accomplishment of each phase is performed serially. Figure 1 illustrates DMAIC's ideal structure flow.

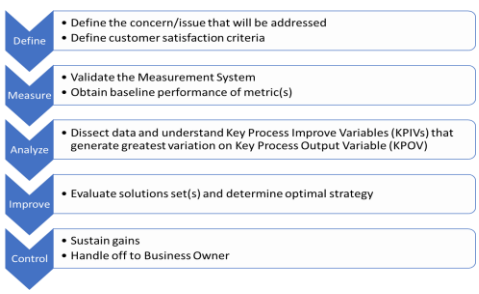

Figure 1. DMAIC Process Flow

3.3 Define

The first step within the DMAIC Six Sigma structure is Define. This step is crucial to the success of the project. The Define phase dissects the Voice of the Customer (VOC) and translates into a measurable parameter. VOC expresses a subjective statement for the failure to achieve satisfaction. Investigation of the subjective statement drives conversion to a product or service measurement with direct influence. Significant time and resources are required to understand VOC and determine a measure that indicates success or failure of meeting the customer expectation.

The project scope definition is another outcome during the Define phase. Scoping helps drive the alignment of the team members and what will be analyzed and what will not. Teams need to balance what is impacted by the project and not limit to a small of an area but also try not to resolve all concerns. If the scope is too broad, teams get distracted with too many items, and the project will either take too long to finish or possibly never succeed. A narrow scope misses KPIVs that have a significant effect on KPOV.

A project charter is initiated in the Define phase. This provides an agreement between the Six Sigma professional(s) and the process owner. It clearly states the project objectives and defines what the success of the project looks like. The Six Sigma project requires resources and cross-functional engagement for success. The project charter requires sign-off by stakeholder on the project team. The act of signing provides ownership of the project by all parties.

3.4 Measure

The measure is the second phase of the DMAIC process. The Measure phase outcome is the baseline performance of the process. The assessment of current performance levels is calculated to support the impact of the project. Measure drives two critical objectives of the project, validation of measurement system and the baseline performance. Before starting an analysis of any data, the measurement system requires sanitization for accuracy. All concerns and discrepancies require resolution before any further progression in the project can be done. If a measurement system does not exist, a pseudo measurement system collection plan is developed. Having any compromise within data measurement will either extend the time to correct concern(s) or the problem-solver will never achieve success.

3.5 Analyze

The analysis phase concentrates on reviewing all the variation of the inputs in the process and discovering the key ones to evaluate. Every process is composed of variation that drives undesired outputs. This variation is the result of KPIVs. The analyze phase undercovers a couple of KPIVs that influences the most significant impact on output. These KPIVs are further researched in the Improve phase.

3.6 Improve

Improve phase accepts KPIVs from the Analyze phase and discovers which ones can be controlled at certain levels to ensure customer satisfaction. Not all KPIVs are considered for project improvement. Factors like cost and level of difficulty to control are used in the assessment study to sort out KPIVs to less than two factors. Six Sigma profession applies a strategic cost-benefit analysis matrix to understand all KPIVs status in the project improvement output clearly. A careful exploration into KPIVs leads to the maximization of performance levels to gratify customers.

3.7 Control

The control phase centers on the institutionalization of solutions developed to ensure the sustainment of success. This phase typically struggles in Six Sigma projects for completion. Teams celebrate success in the Improve phase and dissipate quickly after improvement. Members start working on other opportunities within the organization and neglect sustainment insurance. The control phase emphasizes key checkpoints within the process to ensure project alignment to the desired state. Any abnormal behaviors are quickly isolated, and containment actions are incorporated to realign.

3.8 Structured Approach

The above outlines highlight requirements for each of the DMAIC phases of the Six Sigma program. This structured approach generates an outcome from each phase that feeds the next phase in the process. Taking the problem statement and converting to a statistical value and utilizing data to uncover a solution is a very efficient problem-solving methodology. Problem-solving with Data Analytics (DA) removes any bias and emotionalism from the decision-making matrix.

4. Case Study

4.1 Define Customer Concern

Using the DMAIC Process, the problem statement defined by the workforce (customer) is "Management Does Not Trust Us To Purchase Materials To Drive Business." This mindset significantly impacts employee engagement and drives a separation between workers and management. This is a common scenario in organizations between the workforce and management. Workers view management as authoritative figures that want to control all aspects of the operation. Management considers the workforce without any control actions cost would go out of control. In times of hast, management takes a particular ballpark figure and empowers the workforce to purchase without approval. This policy change gradually starts to increase normally expected expenditures and eventually drifts out of control, driving expenses to become significant. Once cost significances reach a particular point, management reacts and regresses to old methods of additional approval chains. These actions become cyclical every couple of years.

The TRIZ contradiction matrix (9: Speed and 24: Lost of information) eludes to find a balance between providing an adequate level of empowering but not overly excessive (Mann, 2001). To undercover the appropriate purchase level, each item's current inventory

and cost need to be characterized. Figure 2 displays the pseudo price of all items housed in the stock. The figure indicates similar expenditure amounts between items and the total cost. The histogram clearly shows a significant long right screwed distribution with the majority concentrated within the 0 to X1 range for cost. The range of expenditures shows eight times from the low clustered spending. Warehouse inventory contains many low-cost items and spare of significantly higher cost. Characterization of data indicates a similar threshold for most of the expenditure for both items and total cost.

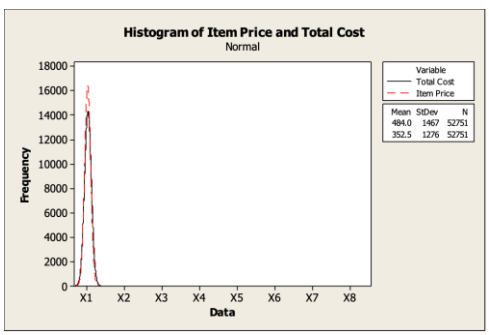

Figure 2. Total Cost of Items in Inventory

4.2 Measurement of Concern

A Measurement System Analysis (MSA) is a requirement before launching any investigation. Transactional projects are limited in MSA due to the nature of discrete data points in the calculation. A consistent failure of transactional-type projects is the assumption that MSA is ok since data validation was conducted during the initial program implementation. As the system evolves to support additional business needs, changes and modifications can adversely impact the accuracy of the data. A simple and effective method to analyze data measurements produced in report-type systems is the Youden plot. A Youden plot is a scattered plot of paired measurements (Shirono et al., 2013). Random report data is compared based on a known standard. Manual investigation of collected information is deemed as standard to validate against automated report data. Figure 3 displays a Youden plot constructed for a range of purchased items versus investigated cost. A perfect match of the manual calculated cost compared to the reported cost confirms MSA is ok. This supports the data obtained from the reporting system is accurate and sufficient for problem-solving.

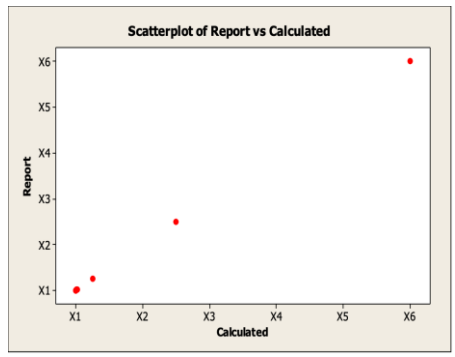

Figure 3. Youden Plot Report Data Cost vs Manual Calculauted Cost

Historical procurement analysis is required to determine the baseline impact of purchases. The categorization of spending data in figure 4 shows monthly expenditure data from three different yearly periods.

The figure shows a somewhat consistent spending month to month. No significant changes among the months between the three years. Minimal differences allow the future analysis of monthly expenditures to research the level of empowerment of the workforce.

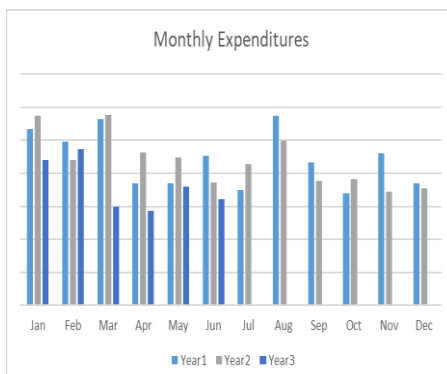

Figure 4. Pseudo Monthly Purchase Data

To support statistical data analysis of yearly expenditures, variance among the years must be non-significant. Figure 5 shows the Test for Equal Variance of monthly spending for three different years. A P-value greater than .05 validates no statistical difference in variance. This result allows further analysis for monthly cost comparison for statistical analysis. ANOVA test figure 6 on monthly cost expenditure for different years shows a high P-value indicating no statistical difference between monthly cost at a significant level of 95%. ANOVA does show a higher deviation for Year3 due to a smaller sample size and difference in manufacturing operating patterns.

The statistical analysis indicates expenditures between years are not statistically different. View of monthly data by year shows consistent monthly expense among the different years. This statistical validation justifies further analysis using one-year data to understand the impact of the problem across all yearly ranges.

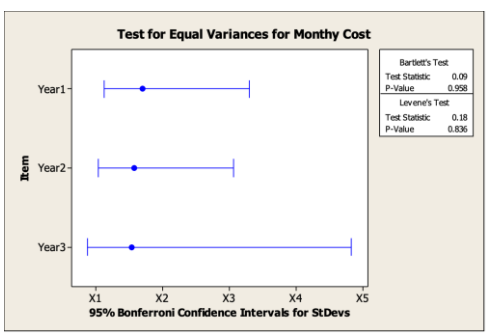

Figure 5. Test Equal Variance of Yearly Expenditures

4.3 Analysis of Concern

ANOVA table in figure 6 indicates Year1 as least deviation supporting best choice for deeper analysis. Characterization of spending habits includes item purchases and lot purchases. Item purchases are single-item costs. Lot purchase is the total transaction cost which can include multiple items. Figure 7 displays the percentage of purchases for item and lot breakpoints for an entire year. Approximately 80% of all item purchases fall within this range at breakpoint 6.

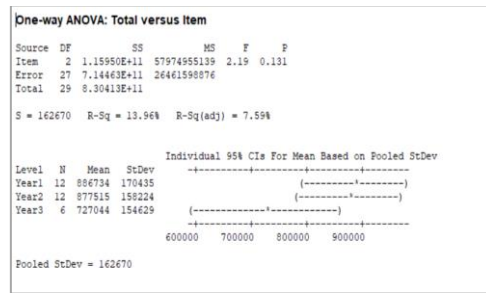

Figure 6. ANOVA Analysis of Yearly Purchases

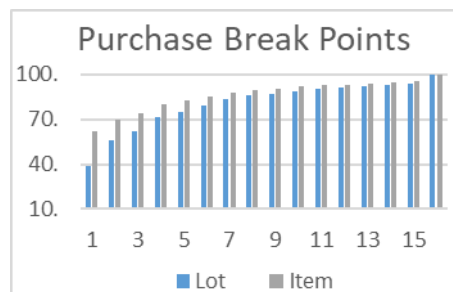

Figure 7. Purchase Percent for Item and Lot

A more in-depth investigation into price point #6, figure 8 shows consistent purchase spending percentage for several years. Individual item spending is consistently over 80% and lot spending over 75% for purchases. At a minimum, two-thirds of all purchases made will be supported by price point #6. The high percentage for item and lot supports breakpoint #6 as a potential optimal threshold for employee empowerment.

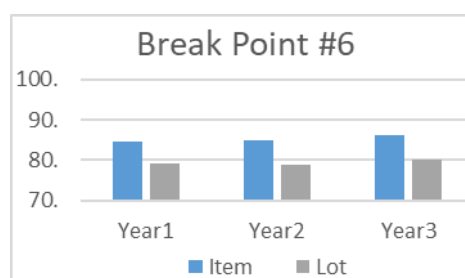

Figure 8. Breakpoint #6 Yearly Analysis

4.4 Improvement of Concern

Statistical analysis for several years is required to confirm the impact of breakpoint #6. The data was investigated monthly for each year to determine if the characterization of data changes significantly. The analysis supports similar expenditures for item and lot purchases by year and monthly.

For simplification of MM, the further analysis focuses on breakpoint #6 for lot purchases. Innovative principles from Table 2 item 25 indicates a solution self-service solution methodology. Self-service is the goal for employee empowerment. Lot purchase allocation amount allows more straightforward management and control of spending allocation. Figure 9 shows monthly data for lot purchases of items within breakpoint #6. The characterization of monthly data at breakpoint #6 incorporates a balanced solution satisfying workers and management. This breakpoint encompasses over 80% of lot purchases for several years.

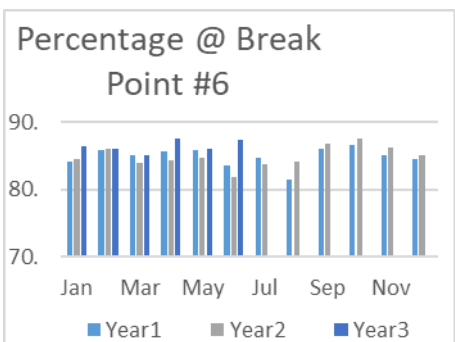

Figure 9. Monthly Data for Lot Purchases @ Breakpoint 6

Figure 10 shows a probability plot of monthly percentages of purchases within breakpoint #6. Data indicates a normal distribution for each sub-group (year). Normality is a requirement in statistical analysis for greater confidence in testing.

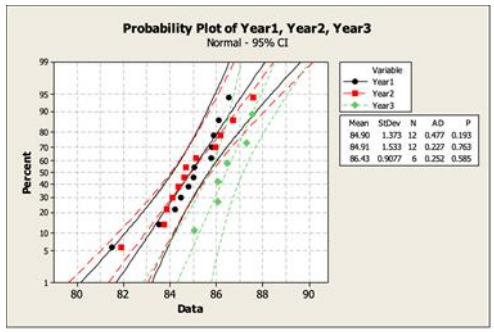

Figure 10. Probability Plot @ Breakpoint 6

Figure 11 displays the Test for Equal Variance of monthly expenditures for breakpoint #6 confirms NO statistical difference between years. The plot shows nearly a similar variation between years, significantly better than the previous analysis for all breakpoint spending per year. Bartlett's P-value of 0.467 also validates NO statistical difference in variance between years for breakpoint #6.

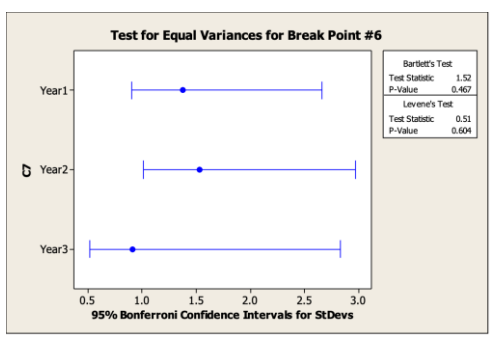

Figure 11. Test for Equal Variance for Breakpoint 6

Figure 12 shows the power and sample size test to determine the difference that is capable of being detected based on current conditions. Inputs from historical data show minimum samples of 6 per year, power of .90, and a standard deviation of 1.53. This power sample parameter set can detect a difference of 3.4% capability at 95% confidence. This is a sufficient difference to conclude between different samples.

Power and Sample Size

One-way ANOVA

Alpha = 0.05 Assumed standard deviation = 1.53 Number of Levels = 3

Sample Size	Power	SS Means	Maximum Difference
6	0.9	6.08539	3.48866

The sample size is for each level.

Figure 12. Power and Sample Size Analysis

Statistical analysis for monthly lot purchases at breakpoint #6 for several years in figure 13 shows no statistical difference. Year3 does indicate a higher deviation from Year1 and Year2 due to the smaller sample size. This result confirms breakpoint #6 is similar across multiple years and supports a level of employee allocation for 75% of all submitted purchase requests.

One-way ANOVA: Break Point versus Year

Source	DF	SS	MS	F	P
Year	2	11.12	5.56	2.96	0.069
Error	27	50.70	1.88		
Total	29	61.82			

S = 1.370 R-Sq = 17.99% R-Sq(adj) = 11.92%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	---------+---------+---------+---------+
Year1	12	84.898	1.373	(-------*-------)
Year2	12	84.914	1.533	(-------*-------)
Year3	6	86.429	0.908	(-----------*-----------)
				---------+---------+---------+---------+
				85.0 86.0 87.0 88.0

Pooled StDev = 1.370

Figure 13. ANOVA for Monthly Expenditures Per Year

4.5 Sustainment of Concern

A method of control is a requirement to ensure the sustainment of implementation. Characterization of data from the last several months of total purchases and frequency of purchases shows consistent spending. Incorporating this data into a control chart (figure 14) provides control points to monitor purchases. Any monthly purchasing exceeds X4 indicates an out-of-control condition. Also, monthly purchases frequency exceeding X5 indicates an out-of-control situation. These inflection points require monthly monitoring and reaction strategies if exceeded.

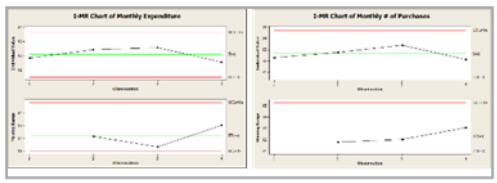

Figure 14. Control Charts Monthly Expenditure

The majority of process changes fail and revert to old ways due to out-of-control situations. Reaction plans must contain immediate actions to be incorporated and prevent disastrous consequences. Out-of-control expenditures drive knee-jerk reactions reverting to traditional methods of restriction.

5. Discussion

Literature review investigates employee empowerment as a broad topic. Assessments involve a survey of employees. The survey compiles how much freedom allocation is in the decision-making process. This research approaches empowerment from a specific decision category. The smaller boundary for assessment allows the researcher a concentrated assessment.

Viewing empowerment as a customer requirement allows the use of the problem-solving methodology. Transformation of empowerment level to a measurable allocation value was possibly by leveraging DMAIC and TRIZ methodology. Using a measurement value allows research to assess historical spending and develop insight into an optimal spending amount to provide a balanced solution for the workforce and management.

6. Conclusion

Utilizing a strategic approach to understand the problem statement from VOC provides a benefit to both parties (customer and producer) involved in the decision. Combining the TRIZ methodology with Six Sigma DMAIC enhances the solution strategy. The case study translated the

subjective statement "Management Does Not Trust Us" into a quantifiable value. Analysis of data showed different levels of inflections characterized by procurement amounts and frequencies. Comparing and assessing the different price points revealed a balanced value that provides adequate empowering and level of restrictions to support an ideal state. The release of control drives abnormal purchasing decisions. The establishment of limits based on historical spending ensures sustainment.

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