DMAIC Case Study:
Intervention Rate Reduction in Industrial Moisture Analyzer Post-Sale Service

John Meng, Senior Consultant at Tactegra

March, 2017

Tactegra applied the DMAIC Process, a data-driven variation reduction process, for its client, HG, a leading industrial moisture analyzer manufacturing company. The purpose was to help this client reduce the frequency of field services needed during the warranty period after sale (post-sale intervention rate under warranty). Doing so would reduce customer process downtime, increase customer satisfaction, and reduce field service costs to improve the return on investment (ROI) for the business.

HG Business Background

HG sells industrial moisture analyzers in a variety of global markets including the cement industry, food industry, and raw material powder industry. Its products can be found in over 70 countries, operating through a network of subsidiary companies and distributors. Its global sales and service organization uses a globally structured supply chain and multiple logistics centers to serve its customers.

HG has regional field service centers in every continent, each servicing its regional customers by providing part replacement, on-site diagnostics and adjustment, and repair. A typical service center includes a help desk and a field service team. The service decision, although following a corporate procedure, is made at the local level by either the help desk or the field service engineers.

Understanding Intervention Rate

Any of the following occurrences is considered as one intervention in the field:

- The product is returned for exchange or repair
- Any part or component is replaced
- On-site diagnostics or adjustment

The intervention rate for a specific type of moisture analyzer in a specific time period is defined as:

Intervention Rate (IVR) =
(number of interventions during the time period concerned for moisture analyzers under warranty)/(total number of moisture analyzers under warranty during the time period concerned) x100

The intervention rate can be tallied daily, weekly, monthly, or yearly.

Company Concerns About the Intervention Rate

HG measures its Intervention Rate monthly and had concerns about a specific moisture analyzer with a 6.5% IVR versus the target IVR of 3%. The management plans to improve the IVR of this type of moisture analyzer to 3% or lower to significantly improve customer satisfaction, raise product competitiveness, and reduce service cost.

At the current IVR level, the company received negative customer feedback, had a disadvantage compared to its competitors with an estimated 4% IVR, and lost several million dollars in 2016 on this

moisture analyzer model alone. Since the industrial moisture analyzer marketplace is extremely competitive, it is critically important to minimize IVR. What is learned from this project can also be implemented with other product types, as well as new product designs and launch.

DMAIC Process Background Information

The DMAIC acronym stands for the five phases of the cyclical process: Define, Measure, Analyze, Improve, and Control. This structured problem-solving method builds from phase to phase with the goal of finding and implementing solutions to problems. The Define phase will help determine what to measure. The Measure phase will provide the information to analyze. The Analyze phase will determine what needs improving. The Improve phase identifies what needs to be controlled. DMAIC is the correct method for process improvement when the problem is complex or the risks are high.

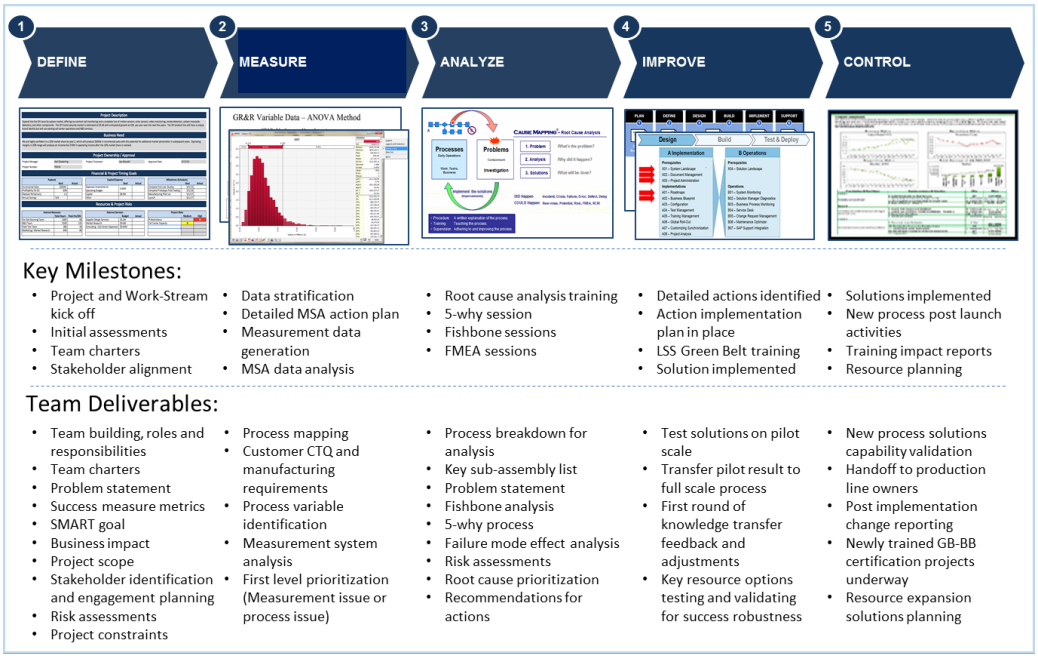

Figure 1. DMAIC process with milestones and deliverables.

- *Define*: Lays the foundation for the project by defining what the issue is and its business impact if the issue is not resolved. Boundaries for the project are determined, as is the process flow. Team members and resources for the project are identified. A communication plan with team members and stakeholders is established. Each of these components leads directly to a focused project problem statement and an agreed-upon project timeline.

- *Measure:* Determines how and what to measure to see current process performance and find the deficits of the process. Measurement relies on understanding the process steps, validating the measurement system, defining performance standards, determining the capability of the process, and identifying gaps between the process performance and performance standards.

- *Analyze:* Defines performance objectives. Determines when, where, and how the defects occur using such tools as Pareto charts, fishbone diagrams, histogram, SIPOC, and others.

- *Improve*: Identifies gaps between current performance and desired performance. Screens for potential causes of variation and discovers interrelationships between them using a tool such as the Design of Experiment (DOE) to set processes that interact to produce the desired result. Potential solutions are selected and prioritized. Solutions are trialed, often on a pilot scale, to test the hypothesis and optimize the process for maximum potential. Improvement conditions are transferred to the full-scale process for implementation and optimization to realize the targeted improvement result.

- *Control:* The process of validating the measurement system and evaluating capability is repeated to ensure that improvement continues and keeps the process from reverting back to old methods. Steps are then taken to control the improved processes, by establishing long-term measurement, monitoring, and reaction plans to transition process to owner. Tools used at this stage include statistical process control, mistake proofing, and internal quality audits.

HG IVR Define Phase

Objective: To clearly define the problem, build a cross-functional team, and mobilize resources to work towards the committed goal.

Project Problem Statement: The 2016 Monthly Intervention Rate (IVR) of the moisture analyzer globally is at 6.5% versus the business target of 3%. The business expectation is to improve the moisture analyzer IVR to 3% or lower to significantly improve customer satisfaction, raise the company product competitiveness, and reduce service cost. The impact of the improvement is in several million US dollars annually for this one moisture analyzer alone.

Goal: Reduce the Intervention Rate from 6.5% to 3% within the time period jointly agreed upon by Tactegra and the client.

Method: Tactegra chose to use the DMAIC methodology to achieve this goal in order to identify, document, and prioritize key root causes and provide potential solution recommendations for reducing the Intervention Rate to the 3% goal.

Resources: HG chose team members from their internal organization to work with Tactegra specialists to drive this project. The team is a cross-function team consisting of experts in the area of customer service (sales, help desk, supply chain, quality engineers, R&D, etc.) as well as key stakeholders such as supervisors, managers, and executives through the VP level.

HG IVR Measure Phase

Objective: To make sure that the process performance can be measured correctly and accurately, and these measurement systems can be used to identify the gap of the current performance and the performance target.

Main Metric: The intervention rate (IVR) for a specific type of moisture analyzer in a specific time period is defined as:

Intervention Rate (IVR) =
(number of interventions during the time period concerned for moisture analyzers under warranty)/(total number of moisture analyzers under warranty during the time period concerned) x100

Sub Metric: Daily Intervention Occurrences as measured by this description: Daily Intervention occurrences reported from the field globally.

Process Mapping: During this phase, Tactegra used process mapping to define and identify intervention process variables and importance. Team members also interviewed the help desks in each region to verify the process steps.

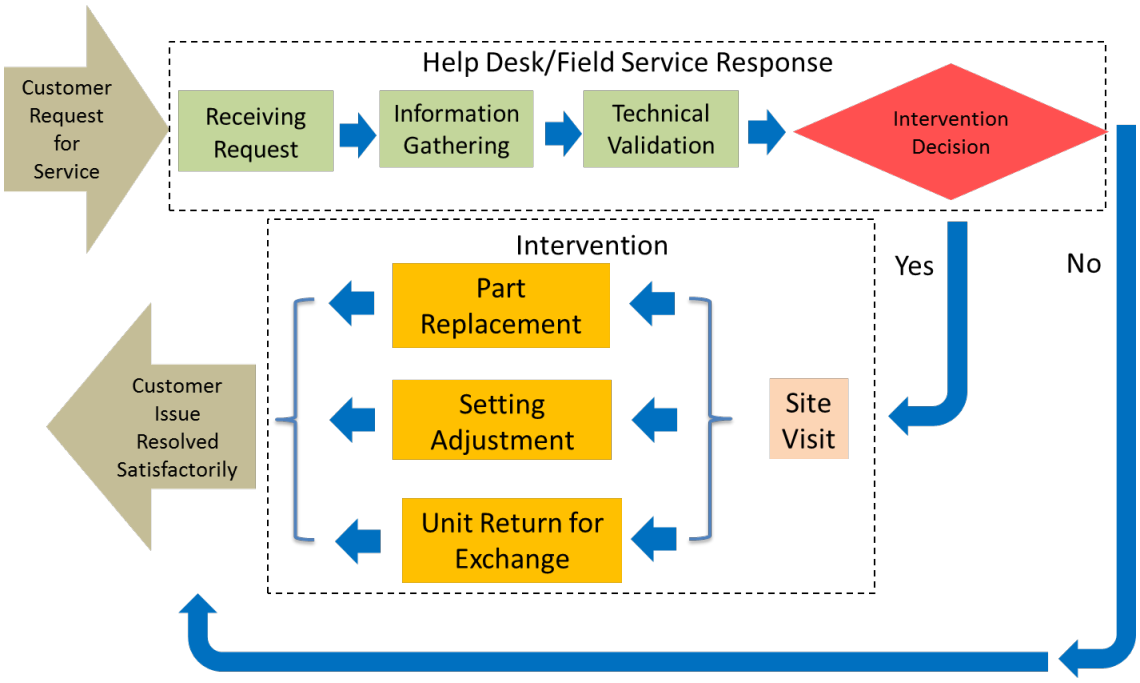

Figure 2. HG post-sale field service process flow

Intervention Rate Measurement Metrics: HG has established a set of metrics to report the field interventions. The metrics are listed in the table below:

Table 1: HG intervention measurement metrics.

Step	IVR Service	Testing Metrics
1	Part Replacement	Occurrences per number of moisture analyzers under warranty
2	Site Adjustment	Occurrences per number of moisture analyzers under warranty
3	Moisture analyzer Returned for Exchange	Occurrences per number of moisture analyzers under warranty

Current Intervention Performance: The daily intervention occurrences data, Figure 3, shows that the variation of the moisture analyzer defects is driven mainly by natural causes (within 3 Standard Deviations), an indication of a systematic process issue.

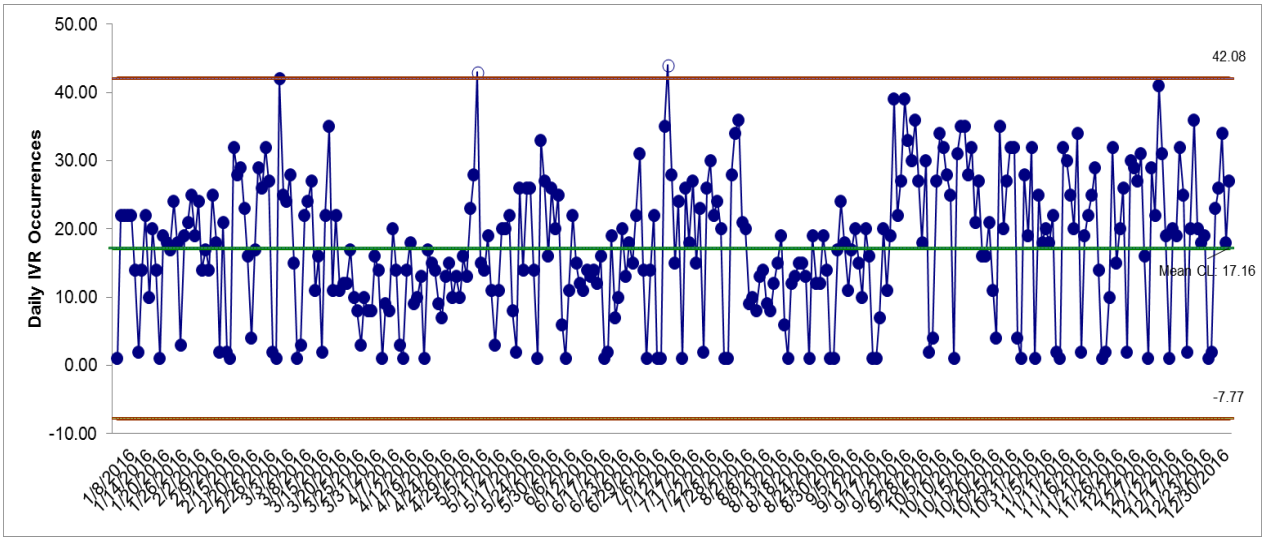

Figure 3. HG daily intervention occurrences in moisture analyzer post-sale service process

If the requirement is for the service team to reach 3% monthly intervention rate goal, it means the number of average daily intervention occurrences should be reduced from the current daily average occurrences of 17 to 8 or below. Using 8 occurrences as the upper limit with a target of 4 occurrences per day, the current process capability can be statistically assessed as shown in Figure 4. It is clearly seen that the current process has been performing poorly with 79% of the days (Actual % > USL = 78.8%) during the period studied with daily intervention occurrences higher than 8.

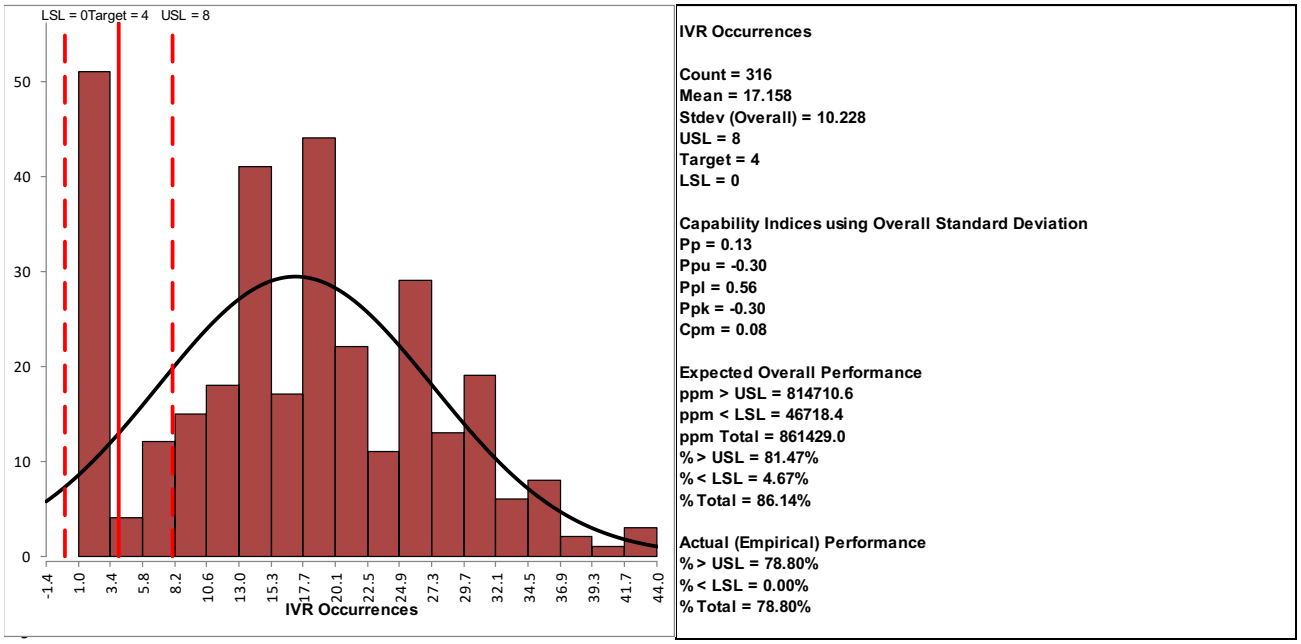

Figure 4. HG service intervention process capabilities

Measurement System Analysis (MSA): When evaluating the measurement system precision, two main characteristics include repeatability and reproducibility. Repeatability means that the measurement result is repeatable by the same operator on the same part with the same measurement method and equipment. Reproducibility means that the measurement can be taken by different operators each

getting similar results. If the variation from repeatability and repeatability is at the same level or higher than the actual process variation, the measurement system is deemed as incapable of measuring the Intervention Rate Variation.

Example Of MSA – Intervention Decision Process: One of the evaluations on the Intervention Rate measurement system is to understand how the decision is made at the regional help desk centers on whether or not to send field engineers to a customer site, which is an automatic intervention generation if it occurs. Three regional help desk centers were selected for this study. The results are listed in Table 2 through Table 4.

Table 2: HG help desk decision measurement system evaluation – within appraiser

Helpdesk Center	Appraiser	# Inspected	# Matched	Percent	95.0% LC (Score)	95.0% UC (Score)	Fleiss' Kappa	Fleiss' Kappa P-Value
Center 1	A	20	15	75.00	53.13	88.81	0.2832	0.1027
	B	20	17	85.00	63.96	94.76	0.6931	0.0010
	C	20	12	60.00	38.66	78.12	0.1209	0.2944
Center 2	A	20	12	60.00	38.66	78.12	0.1919	0.1954
	B	20	17	85.00	63.96	94.76	0.6992	0.0009
	C	20	10	50.00	29.93	70.07	0.0000	0.5000
Center 3	A	20	11	55.00	34.21	74.18	-0.2903	0.9029
	B	20	15	75.00	53.13	88.81	0.2832	0.1027
	C	20	18	90.00	69.90	97.21	0.7619	0.0003

Table 3: HG help desk decision measurement system evaluation – between appraisers

Between Appraiser Agreement	# Inspected	# Matched	Percent	95.0% LC (Score)	95.0% UC (Score)	Fleiss' Kappa	Fleiss' Kappa P-Value	Fleiss' Kappa 95.0% LC	Fleiss' Kappa 95.0% UC
	20	0	0.00	0.00	16.11	0.1606	0.0000	0.1251	0.1960

Table 4: HG help desk decision measurement system evaluation – vs. reference

All Appraisers vs. Standard Agreement	# Inspected	# Matched	Percent	95.0% LC (Score)	95.0% UC (Score)	Fleiss' Kappa	Fleiss' Kappa P-Value	Fleiss' Kappa 95.0% LC	Fleiss' Kappa 95.0% UC
	20	0	0.00	0.00	16.11	-0.2044	0.9999	-0.3077	-0.1011

As indicated in the results, the three help desk centers repeated poorly with only a few moderate agreements. Between the help desk staff members, the reproducibility of the response is poor. The agreement with the reference standard response was even poorer representing a negative value. This means that:

- The chance to reach the same decision by a different staff member for the same customer request is extremely low.
- There is an even lower chance for all the members to match the reference score as shown by the extremely poor accuracy.
- The decision on whether to have an on-site intervention or not is almost a random event, left mainly up to individual's discretion.

Findings:

- Variation of Intervention occurrences is driven mainly by natural causes, an indication of systematic process issue.
- Field service data shows there is a significant gap between the current performance and business target.
- HG has a customer service procedure on how to response to customer service request. However, there is not clear criteria for its use. This is reflected in the Measurement System Evaluation result.
- The current decision process on how to respond to customer requests does not follow a clear pattern from location to location or from person to person.
- Help desk resolution rates from three help desk centers are significantly different from location to location.
- A designed measurement system (reproducibility and repeatability) study on those three locations shows:

    - 67% of help desk personnel failed to repeat the result with the same customer request. Poor repeatability means that an operator will make different decision at any given time for the same customer request.
    - The probability to reproduce the same result between the operators is almost zero. Poor reproducibility means that a different person will make a completely different decision for the same customer request.
    - The chance to agree with the standard reference result is also zero. Poor standard reference agreement means that the decisions made by the operators have no accuracy. In other words, whether to have an on-site intervention or not is almost a random event based upon the individual's discretion.
    - Other factors, such as specific customer demand and customer importance to the business, will further complicate the decision process.

HG IVR Analyze Phase

Objective: To define performance objectives and identify sources of process variation.

Tools Used for Analysis: The team performed a 5 Whys analysis, SIPOC, Fishbone Analysis, and Risk Analysis to determine why the FPY problems existed and to find the most significant reasons or causes.

- *5 Whys Analysis*: Repeatedly (at least five times) ask the question "Why" to peel way the layers to get to the root cause of a problem and determine the relationship between different root causes. It is most useful when problems involve human interactions.
- *SIPOC*: The acronym SIPOC stands for suppliers, inputs, process, outputs, and customers which form the columns used to analyze a problem. This diagramming tool helps identify the relevant elements to improve a process.
- *Fishbone Analysis*: Diagram used to identify variations, with causes grouped into categories, such as people, methods, machines, materials, measurements, and environment.
- *Risk Analysis*: A step-by-step approach for identifying all possible risks of failure in a design, a manufacturing or assembly process, or a product or service.

Reasons for Interventions: Analysis of the 2016 field data shows that the interventions are generated due to four major categories: malfunctional parts, adjustment required for drifted moisture analyzer settings, diagnostics required for abnormal moisture analyzer behavior, and software upgrade. The percentage contribution of each category is illustrated in the pie chart below (Figure 5).

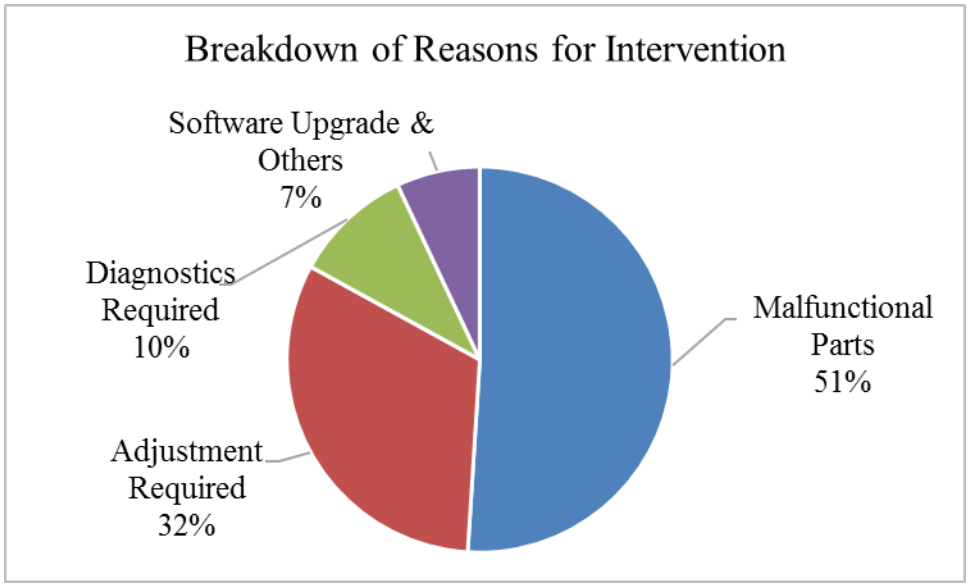

Figure 5. HG reasons for post-sale interventions

The following observations have been summarized from the analysis:

- IVR occurrences were mainly driven by natural variations. In other words, the current intervention rate is not driven by any assignable causes but by variation embedded in the system.
- Effect at Customers - 82% of the interventions in 2016 were due to moisture analyzer lockup, no reading, and poor measurement consistency reported by customers.
- Failure Mode - 91% of malfunctions of the moisture analyzers were due to transmitting antenna, receiving antenna, electronic board, and software failures. 88% of these failures were caused by defective parts and incapability of the automatic controls to restore the normal operation conditions.
- Among the replaced parts, 58% related to the transmitting antenna including transmitting sensor, transmitting antenna board, and deflector. 14% were related to receiving antenna parts. 11% were related to main electronic control board. 8% were related to a specific optional part.
- Among the on-site adjustments, 56% adjustments were related to transmitting antenna surrounding conditions such as cleaning, deflector adjustment, and reset. 18% were related to receiving antenna condition adjustments such as moisture sensor. 12% were related to programming adjustments.
- Due to such the high intervention occurrences in the short life cycle of this type of moisture analyzer, the assumption is that these failures might not be primarily caused by part natural failure, rather than by defective parts and other uncontrolled application variables

Risk Analysis: Risk analysis was conducted on the major components to assure that potential failure modes at customers and their associated causes were considered and addressed.

Transmitting antenna:

- Dust and contamination along the microwave penetration path are the high risk variables.
- Electronic board connection and its interaction with temperature are other high risks.
- None of these variables are controlled, and none of them have good detection.
- Current automatic cleaning may not be adequate to resolve some of the dust and contamination issues, which leads to frequent cleaning and sometimes unnecessary part replacement.
- More complicated sensing design and running higher speeds might compound these issues.

Transmitting Sensor:

- Dust, contamination, and ambient environment (temperature, vibration, humidity, etc.) around the sensor are the high-risk variables.
- Only 18% of variables are controlled, and none of these variables have good detection.
- Current automatic cleaning may not be adequate to resolve the dust and contamination issue, which sometimes leads to transmitting sensor replacement.
- The sensor natural life performance might also play a role.
- More complicated design and running higher speed might compound these issues.

Receiving Antenna:

- Field electrostatic level, sensor failure, dust, and contamination around sensing area are the high-risk variables affecting receiving antenna performance.
- Only a few variables are controlled, and none of them have good detection before failure.
- More complicated design and running higher speeds might compound these issues.

Electronic Control Board:

- Premature failure and bad connections are the highest risk for the control board.
- None of variables are controlled, and none of these variables have good detection.
- This might be a combination of design and quality issues.

Control Software:

- Program bugs and operator errors are the highest risk for software.
- 48% of the variables are controlled or monitored.
- Most of these variables have some level of detection.

HG IVR Improve and Control Phase with Recommendations

The main reasons identified from the Analyze phase for field intervention are malfunctional parts/components, adjustment, diagnostics, and help desk capability. The following are the recommendations to move to the Improve and Control Phase.

- Address Help Desk and Field Service intervention decision process issues:

- Define customer under-warranty request response standards
- Provide training to help desks and field service teams

- Complete Risk Analysis process on the high risk variables:

  - Generate a list of potential solutions to control high risk variables
  - Develop an Effort-and-Benefit Matrix to prioritize solutions for actions

- Implement solutions, examples include:

  - Develop a supply quality control plan, such as a SPC process for each of critical suppliers.
  - Modify the company service data collection system to link directly from failure to root cause when interventions occur.
  - Find effective solutions to eliminate dust and contamination from transmitting antenna and receiving antenna.
  - Adopt Quality Function Deployment and Risk Analysis for moisture analyzer design process.
  - Use Design of Experiment to optimize microwave intensity and moisture sensing system design.
  - Establish life cycle database for critical parts, sub-assemblies, and moisture analyzers.
  - Add one checkpoint in product design phase for manufacturability with customer approved consistency.
  - Use statistical data to consider multiple variables instead of using the single variable approach for problem solving.
  - Provide problem solving training to employees.

The Path Forward for HG

With root causes identified and solutions identified, the path forward for HG to achieve 3% Intervention Rate is to continue the DMAIC process by focusing on three distinct projects (Figure 6):

1. Part Replacement Reduction – focusing on part reliability reducing IVR by 1.6%.
2. On-site Adjustment Reduction - reducing IVR by 1.2%
3. Help Desk Capability Improvement - reducing IVR by 0.5%

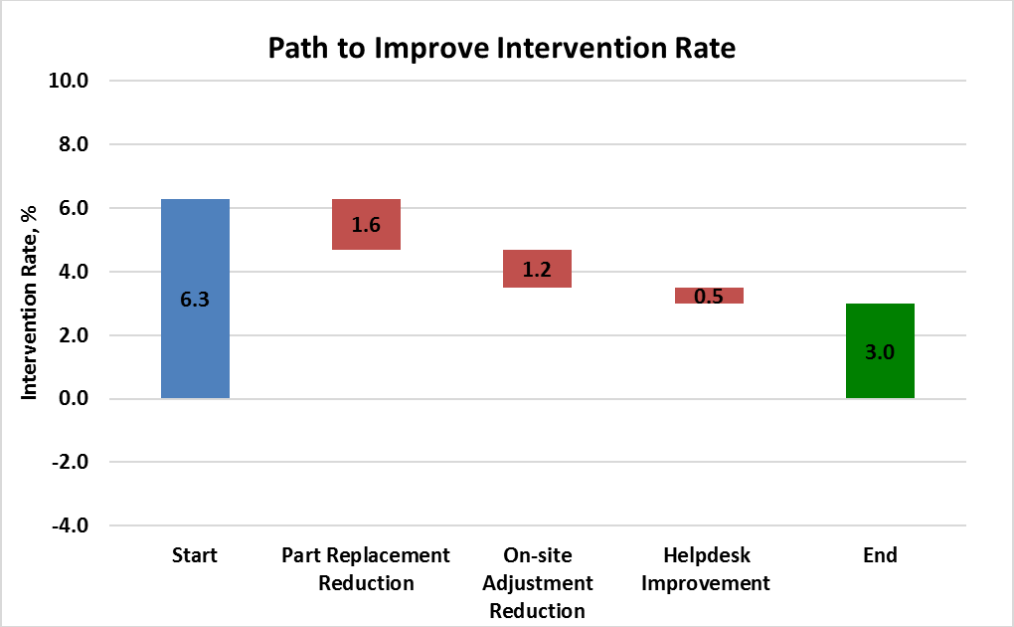

Figure 6. HG path to reduce intervention rate

As HG integrates solutions found during the DMAIC process, they will see Intervention Rate improvement.