The Optimization of General Motors' Warranty System by Reducing Mean Time to Discover Failure

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Submitted to the Systems Design & Management Program
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ABSTRACT

Warranty is an important part of many organizations. Warranty costs take money directly away from corporations' bottom line. General Motors Corporations warranty liability costs its shareholders upwards of billion dollars annually. General Motors currently uses RedX, a systematic design of experiments methodology, to try to reduce warranty costs. Although this approach has reduced warranty costs, it has not done so neither fast nor sufficiently as high costs remains.

The General Motors' warranty system was mapped and diagnosed. Interviews were conducted with all involved parties with the warranty system. Competitors warranty systems were compared and contrast to General Motors' warranty system. Other factors considered were new quality methods.

The major factors limiting General Motors goals to reducing warranty are time to discover the failure and the time the fix the failure once it is discovered. Another factor is the culture and the lack of team environment within the warranty organization.

General Motors should use telematics, onboard diagnostics, signature analysis, and a systemic approach which involves integrating the design and warranty organizations to predict and quickly eliminate defects from its manufacturing facilities. This approach will either eliminate failures quickly or prevent them from even becoming failures in the first place.

Thesis Advisor:
Professor Dan Whitney, Engineering Systems Division
Center for Technology, Policy, & Industrial Development

ACKNOWLEDGMENTS

I would like to thank MIT for giving me the chance to finish this MS degree. MIT is unique and has been quite an experience. As the saying goes, "To stay at MIT is to change MIT. To change MIT is to change the world." I have had a lot of change and growth at MIT and I do plan to change the world. MIT has a reputation for the finest professors and students in the world. MIT also has a reputation for being the fountain of knowledge. As far as I'm concerned, these statements are extremely understated.

I would like to thank Daniel Whitney for giving his direction for this thesis. I thank my parents for instilling the desire for knowledge in at an early age and I would also like to thank my family for their support during this process.

The more discipline I have, the more freedom I have.

Website

http://www.jelani.net

Short Biography

Jelani Ellington began his career at Ford Motor Company in the Ford College Graduate management track group. His positions at Ford Motor Company included Body & Chassis Engineer, Corporate Liaison, Quality and Reliability, and Vehicle Operations. Following his time with Ford Motor Company, Ellington transitioned to the General Motors Corporation where he began as a Product Development Performance Integration Team Leader in charge of Sealing, Wind Noise, and Aerodynamics. Ellington also held positions in Quality, Corrosion and as a Warranty Reduction Leader. Ellington also worked with OnStar Corporation as a Business Planning lead.

A native of Baltimore, Maryland, Ellington received a Bachelor of Science degree in mechanical engineering from North Carolina A&T State University. As a GM Fellow, Ellington received a MBA from Indiana University's Kelley School of Business.

Ellington, who is an avid reader, holds a black belt in Kuk Sool Won and enjoys most water sports, especially SCUBA diving. Ellington also speaks English, Spanish, and some Mandarin Chinese

The author also wishes to note that the content of this thesis was edited for proprietary information before releasing it for final publication.

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1.0 Introduction

1.1 Background

In recent years, the global market place has become increasingly competitive. Automotive companies, which historically have had thin profit margins, are looking for ways to reduce costs to remain competitive and maximize shareholder value.

To date, there has been a lot of work and research done concerning the reduction of product development cycles and the decrease of available hardware properties to lower cost. However, not much research has been done on warranty systems. Warranty is yet another way to lower organizational costs.

Warranty is an important part of many organizations. Warranty costs take money directly away from corporations' bottom line. General Motors Corporations warranty liability costs its shareholders upwards of billion dollars annually. Why are its warranty costs so high? If the corporation had an effective warranty system in place would the information from the field be accessible to the designers who create the defective products? Would the warranty issues lessen or disappear all together? What needs to be done to fix or update products? Manufacturers can not have their vehicles updated online like Microsoft, and other software companies, do with their software. Each update or fix requires a large outflow of capital and lowers the perceived quality in the eyes of the consumer.

1.2 Organization

General Motors Corporation, the world's largest vehicle manufacturer, employs about 325,000 people globally. Founded in 1908, GM has been the global automotive sales leader since 1931. GM today has manufacturing operations in 32 countries and its vehicles are sold in 192 countries. In 2003, GM sold nearly 8.6 million cars and trucks, which represents about 15 percent of the global vehicle market. GM's global headquarters are located at the GM Renaissance Center in Detroit.

The GM Group of global partners includes Fiat Auto SpA of Italy, Fuji Heavy Industries Ltd., Isuzu Motors Ltd. and Suzuki Motor Corp. of Japan, which are involved in various product, powertrain, and purchasing collaborations. In addition, GM is the largest shareholder in GM Daewoo Auto & Technology Co. of South Korea. GM also has technology collaborations with BMW AG of Germany and Toyota Motor Corp. of Japan, and vehicle manufacturing ventures with several automakers around the world, including Toyota, Suzuki, Shanghai Automotive Industry Corp. of China, AVTOVAZ of Russia and Renault SA of France.

GM's automotive brands are Buick, Cadillac, Chevrolet, GMC, Holden, HUMMER, Oldsmobile, Opel, Pontiac, Saab, Saturn and Vauxhall. In some countries, the GM Group distribution network also markets vehicles manufactured by GM Daewoo, Isuzu, Fuji (Subaru) and Suzuki.

GM parts and accessories are sold under the GM, GM Goodwrench and ACDelco brands through GM Service and Parts Operations. GM engines and transmissions are marketed through GM Powertrain.

GM operates one of the world's leading financial services companies, GMAC Financial Services, which offers automotive and commercial financing along with an array of mortgage and insurance products. GM's OnStar is the industry leader in vehicle safety, security and information services. GM Electro-Motive Division manufactures diesel-electric locomotives and commercial diesel engines.

In 2003, GM again set industry sales records in the United States, its largest market, for total trucks and sport utility vehicles. GM became the first manufacturer to sell more than 2.8 million trucks in a calendar year and the first to sell more than 1.3 million SUVs. GM also remained the industry leader in total sales of cars and total sales of full-size pickup trucks.[1]

1.3 Project Definition

This thesis will attempt to answer the following questions, with regards to the warranty process: Why do these failures occur? Are they the failures the same? What can be done to prevent the failures? What can be done to predict the failures? What do other manufacturing companies do to prevent or lower warranty? Why is this particular system in place? What can be down to optimize the system? Are there supply chain management issues?

This thesis will first inspect the current process and the current state of the warranty system. Following the investigation of the current state, this thesis will dissect it and list this issues or concerns with the current state. Lastly, this thesis will give recommendations of how to fix the warranty system.

These tasks will be accomplished by analysis of the warranty system as well as interviews with the stake holders of the warranty system.

[1]http://www.gm.com/company/corp_info/profiles/?section=Company&layer=CorporateInfo&action=open&page=1#

2.0 Background

The first step to understanding the problem is to understand some of the key processes involved. The following briefly summarizes the processes related to the scope of this thesis.

2.1 Vehicle Development Process

Phase Zero

Phase zero begins the actual development process. Phase zero is the concept and the technology development stage when customer research is conducted. Vehicle models are built and packing, engineering, and manufacturing feasibility are determined. This is the phase that begins the development of the product proposal. In order to successfully pass this phase and not be considered a concept vehicle, approval is required by the automotive strategy board.

Phase One

Phase one involves the development of the product and process as well as the validation of prototypes. Upon entry into phase one, the funding is finalized and work commences on the project. Phase one involves much of the design of the vehicle.

Phase Two

The process validation occurs as well as confirmation that all laws and specifications are met. The manufacturing plants are prepped and begin producing pilot vehicles on the assembly lines. This step is the final opportunity to delay or make changes to the program. The automotive strategy board give final approval and authorizes production of the vehicle based upon the success of the piloted vehicles.

Phase Three

The final phase of the product development cycle is the production and the continuous improvement process. The phase lasts indefinitely and is the longest of the four phases for the automotive community as models can usually last many years.

A modeling of the phases is illustrated in the diagram below.

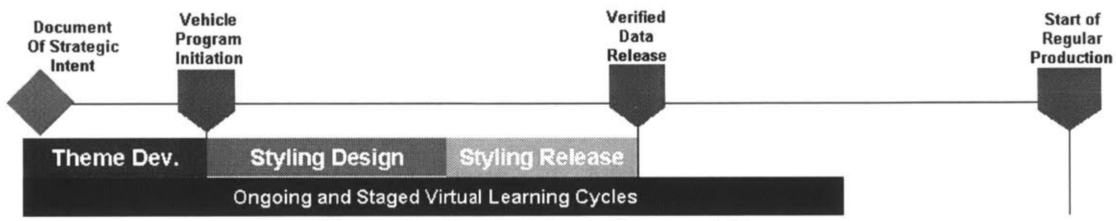


Figure 1: Product Development Process

2.2 Red X

Statistical Engineering (Red X) is the technical problem solving strategy General Motors is currently using to drive Customer Enthusiasm in our products. The technology, pioneered by Dorian Shainin nearly 60 years ago, links engineering sciences, statistics and logic to solve technical problems with a high level of statistical confidence. A Red X project begins with a problem definition and ends with confidence that the problem was fixed. Since 1995, over one thousand Red X projects have been completed.

The General Motors Red X Program encompasses the Right People, on the Right Projects, utilizing the Right Strategy, to respond quickly to the quality concerns of our customers. The process compares the best and the worst vehicles and begins with answering important questions such as are the best people practices taking place and are the production assembly documents being followed. If the answer to each question is yes, a clear problem definition is then determined. The steps to solving a problem not only answers, but also confirms that the answer provided is correct. Red X members must prove that one can turn the problem on and off to confirm that the answer is correct.

<u>What is a problem?</u>

- Anything that deviates from what is considered normal
- All problems share this CONTRAST from normal

<u>Technical Problem Solving</u>

- Technical problem solving is not finding ways to fix problems
- Technical problem solving is gaining an understanding of how problems really work

Words off limits to technical problem solvers:

- I think
- This should
- I have a theory
- I feel This is better
- This might
- Let's try this
- Assuming that
- What if

<u>Red X Process</u>

1) **Listen** to the Customer - Problem Definition

   It begins with customer feedback. Engineers must first understand what the customer doesn't like and identify which projects must be assigned first. In order to do so, data (customer feedback) is organized into information to define which project must be completed first.

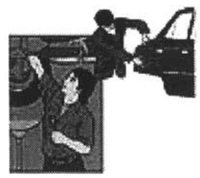
   1. Determine the goal
   2. Convert customer feedback to a common metric based on your goal
   3. Identify potential projects and their impact on your goal
   4. Prioritize the projects to create an assignable projects list

2) **Observe** the Failure - Project Definition
   - There is always a single Red X
   - Nothing else matters until the Red X is controlled
   - Red X Strategies is a disciplined approach to finding the Red X

   What is the Green Y?

- The performance distribution for the event or feature of concern to the customer.
- An example of Green Y is gap in the way the vehicle decklid panels fit together, or it could be a diameter or thickness issue in the build process
- Green Y's are those events/occurrences that happen or fail to happen

Green Y
What the customer cares about i.e. gap between decklid



Red X
Root cause or variable that is causing the greatest variation in the Green Y

3) **Measure** the Contrast - Solution Tree Clue Generation

- Solution Tree - the problem solving "roadmap" for identifying the Red X.
- An appropriate measurement tool is selected to discriminate between the "Best of the Best" (BOB) and "Worst of the Worst" (WOW) For example, the vehicle with the appropriate sized gap in the decklid is compared with the vehicle that has the widest decklid gap. Comparisons are not always conducted vehicle to vehicle. Comparisons can be plant to plant, shift to shift and even day to day.
- Questions are asked that eliminate what doesn't cause the contrast
- Converge on knowledge not solutions. A component search drives further knowledge by understanding the assembly influence and understanding the part influence and analyzing the results.

4) CONFIRM the Major Influence (Red X) - Solution Tree Confirmation

After the Red X candidate has been identified through the use of effective techniques, the next step is to statistically prove this with a predetermined confidence that the Red X candidate is truly the Red X(root cause) using statistical confirmation testing techniques.

5) Implement Control of the Major Influence (Red X) - Solution Tree Implementation

Implementation control is the long term monitoring of the variable measurement of the customer complaint from initiation through implementation of control on the Red X.

Customer Enthusiasm limit:

This is a tolerance or limit set at the beginning of the project where the Green Y needs to be controlled to assure enthusiastic customers. The Green Y is monitored throughout the project. Further it should start as soon as identified in the Project Definition Tree. It should be monitored after the project is complete to assure that the Red X or a new Red X does not come alive.

Red X Certification:

Members of the General Motors team must complete a comprehensive certification program to become Red X certified. The first level of certification is apprentice, next is that of becoming a journeyman and finally, Red X Master.[2]

Certification

Successful completion of a project is only part of the General Motors Red X Program. People drive our business. A comprehensive "people" certification program based on successful completion of projects (application) and the demonstrated ability to teach are included in the program. As projects are completed, engineers can advance through certification levels of Apprentice, Journeyman, or Master. Within General Motors, there are currently over 1,000 Apprentices (one project completed), 500 Journeymen (two projects completed), and 70 Masters (five projects and two coached Journeymen). [3]

2.3 Other Quality Techniques

RedX shares some similarities with the Taguchi method, as it does with most quality methods design around experimental design.

Design of experiments has three widely accepted approaches.

1. Classical
2. Taguchi
3. RedX

Classical

The classical approach is the oldest of the three. This approach uses full factorial. Hence it requires 32 or more experiments to be done! The classical method of design of

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[2] Shainin
[3] Shainin

experiments involves a lot of experimentation. Hence practical implementation becomes difficult.

Taguchi

Taguchi is a system of cost-driven quality engineering that emphasizes the effective application of engineering strategies rather than advanced statistical techniques. It includes both upstream and shop-floor quality engineering. The Taguchi approach was developed by Genechi Taguchi of Japan. Taguchi continued on the research begun by Fisher to develop a practical, systematic approach to designing products and processes. This approach uses fractional factorials and Orthogonal arrays which drastically reduces the number of experiments. Taguchi realized that experiments in which only one parameter at a time is varied are inefficient, particularly when interaction exists between parameters. He developed methodologies whereby all parameters are varied simultaneously to reduce the required number of experimental runs. As the number of necessary experiments required are reduce the task becomes a lot less time consuming.

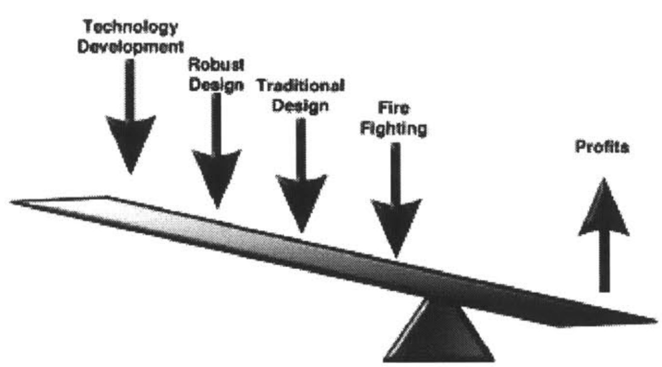

Figure 2: Taguchi Method

Upstream methods efficiently use small-scale experiments to reduce variability and find cost-effective, robust designs for large-scale production and the marketplace. Shop-floor techniques provide cost-based, real-time methods for monitoring and maintaining quality in production. [4]

Taguchi Methods allow a company to rapidly and accurately acquire technical information to design and produce low-cost, highly reliable products and processes. Its most advanced applications allow engineers to develop flexible technology for the design and production of families of high quality products, greatly reducing research, development, and delivery time.

Red X

The Red X approach was developed by Dorain Shainin of the US. The method is often times call Shainin and not RedX. The 7 RedX tools systematically help design processes, solve chronic production problems.

The RedX tools are:

1. Multi Vari Charts
    - Methodology - Positional, Cyclical and Temporal
    - Where and when to apply this technique
    - Case study
2. Components Search
    - Prerequisites, procedure and interpretation
    - Where and when to apply this technique
    - Case study
3. Paired Comparison
    - Procedure and interpretation
    - Where and when to apply this technique
    - Case study
4. Variable Search
    - The 4 stages, procedure and interpretation
    - Where and when to apply this technique
    - Case study
5. Full Factorial
    - Principle of full factorials
    - Procedure and interpretation
    - Where and when to apply this technique

[4] American Supplier Institute

- Case study

6. Better Vs Current
   - Procedure and interpretation
   - Where and when to apply this technique
   - Case study
7. Scatter Diagram
   - Procedure and interpretation [5]

RedX approach systematically pinpoints the Root Cause of a given problem (Red X). These tools are supposed to show variation between good parts and bad parts. Usually only one tool is used once they are able to distinguish between good parts and bad parts.

Comparison

The Taguchi method has more to do with robust design and early product development then does RedX, although the Taguchi method can be used for product improvements as well. It is significant to note that the RedX method concerns variation reduction. You must have a good part and a bad part to you the RedX method. If all of the parts being considered are bad, RedX is probably not the tool that you would want to use. The Taguchi method is a design of experiments whereby all parameters are varied simultaneously. The Taguchi method is can be used to fix or design products.

Several prominent problem-solving models along with a collection of supporting strategies have been introduced during the past century. Although many of these models and supporting strategies have been widely accepted as breakthrough developments, they have yet to realize their full potential for problem solving. This is attributed to the lack of synthesis of the models and supporting strategies and evidenced in the high cost of warranty, recalls, and miscellaneous failure costs.

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[5] Shainin

2.4 Summary

General Motors product development system uses RedX, as opposed to the other quality methods available, for warranty improvements. In the next section, the current state of General Motors warranty system will be analyzed and dissected.

3.0 Current State of GM's Warranty System

3.1 Finding a failure

General Motors follows its product development process to create vehicles. After the vehicles are created, they are then sent to the dealerships. There is a delay of up to 30 – 60 days when leveling the plant manufacturing facilities to arrive at the dealership. After the vehicle arrives at the dealership, the dealer then sells the vehicle to a customer. The mean time from plant to customer is 60 – 90 days.

Following the purchase of a vehicle, the customer drives the vehicle until he experiences a failure. Some failures are reported right away whereas other failures are reported later, if at all. Once a repair is reported to the dealership, the dealership root causes the failure. It is then entered into GM's warranty database. It is coded by a labor code. The labor codes are broken up into subsections of the vehicle. For example, the labor code Z4433 may be given for trouble with the brake system. The warranty verbatim from the customer complaint and the mechanic's root cause analysis are entered into the database as well. The customer's complaints are classified in broad groups. The groups are: noise, operational, warning lights, leaks, or, visual. This classification is made when the vehicle first comes to the dealership before any work is commences on the vehicle. These classifications are given after the mechanic was performed the root cause analysis and repaired the vehicle. These classifications are to better group the warranty problems into recognizable customer dissatisfiers. The rational for these classifications is to group the warranty data into functional group for easier analysis for the RedX process. This allows engineers to determine weather or not the problems is operational, visual, etc. and place on a Pareto chart to help discover the root cause.

Following the completion of the repair, the mechanic must then dispose of the defective parts. If the vehicle is still under warranty at this time the parts are the property of General Motors because the company paid for the repair. The parts are sent to a centralized part facility located in Michigan or discarded. If the vehicle is no longer under warranty, or the repair is not covered by warranty, the parts are the property of the vehicle owner since they are responsible for the repair. The parts are therefore given to the vehicle owner or discarded.

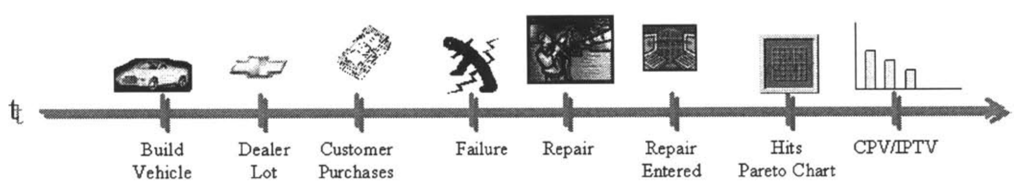

Figure 3: Time Line

3.2 Analyzing failures

Engineers at GM pull data from the warranty database to see failure trends. This warranty is segregated by vehicle line. The warranty data is further segregated via labor codes. The data is then placed in two Pareto charts. One chart is based upon cost per vehicle (CPV) while the other chart is based upon incidents per thousand vehicles (IPTV).

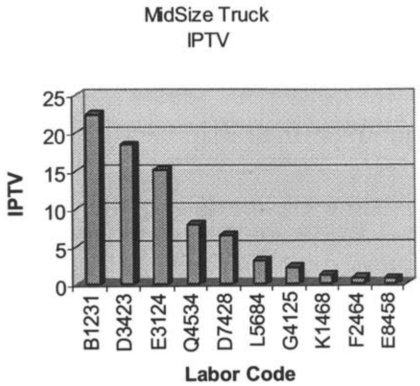

Figure 4: IPTV Pareto

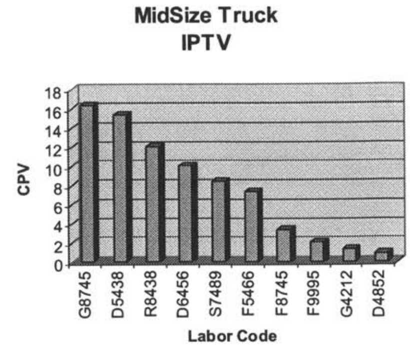

Figure 5: CPV Pareto

The charts are then used to determine which vehicle warranty problem to work on first. There is no one method that is used across the organization. Some vehicle lines use cost per vehicle to work on problems first whereas other use incidents per thousand vehicles to determine which problems to address first. The only common thread is that all vehicle lines place safety issues above either cost or frequency.

3.3 Finding a failure

Once the management team decides which failure to be worked on, GM assigns a warranty engineer to fix the problem. The warranty engineers have two methods to follow:

Order Parts

The Warranty Engineer orders parts from the Warranty Parts Center in Michigan. Once the warranty parts center receives the request for this part, it then starts the process to request this part from the dealership. The arrival rate of these parts varies greatly. Given that some vehicle lines order by frequency of incidents, defect parts could begin to come in as early as three days. Other organizations that order by cost per vehicle may have short or long lead times before parts become available. This is because one engine repair may cost as much as five hundred mirror repair orders. The cost per vehicle would be the same, but the frequency of the mirror repair orders make it more likely to obtain a mirror part quicker.

Finding Parts

Another way that Warranty Engineers find parts is to conduct a search through the search through General Motors' massive fleet. General Motors maintains fleet vehicles for work purposes to facilitate finding common issues with vehicles and to have vehicles available to work on. It is possible to find the same issue with vehicles

3.4 Root cause analysis

After the failure is found, the engineers use the RedX procedure. Engineers are given 30 days to root cause an assigned failure. The first step is to look at the data and try to isolate the problem. This is done using a problem definition tree. A problem definition tree attempts to show that one part of the population has a problem. This can include plants, geographic locations, production dates, production shifts, etc. This is data that can be collected without even touching a part.

Problem Definition Tree

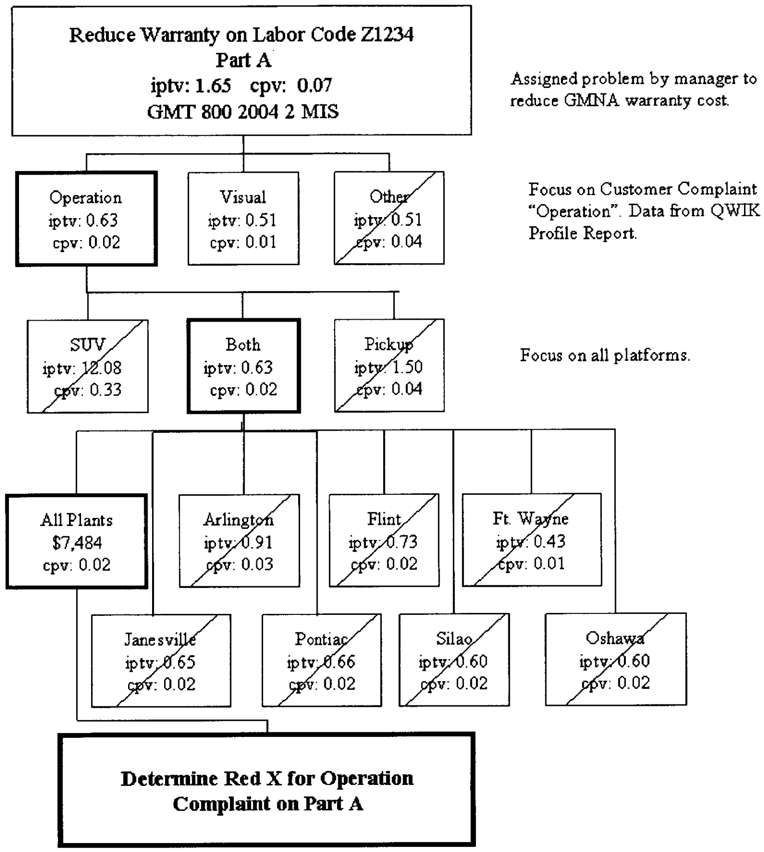

Figure 6: Problem Definition Tree

Next the engineer tries to duplicate the customer failure. After the failure is recreated, the RedX engineer then documents the failure in another database. This database is called the Problem Resolution Tracking System Plus, or PRTS+. This database is a method that GM uses to track warranty issues and their resolution. Following entering this information into the database the Warranty Engineer then proceeds to root cause the failure by a procedure commonly referred to as "splitting the dictionary." This is the RedX belief that if you successively eliminate the good parts from the vehicle, what remains the failure or the RedX. Red X is based upon the belief that all system problems stem from one bad part or the interaction of two parts. The engineer then uses a project definition tree to help him split the dictionary. Figure 7 is an illustration of a project definition tree.

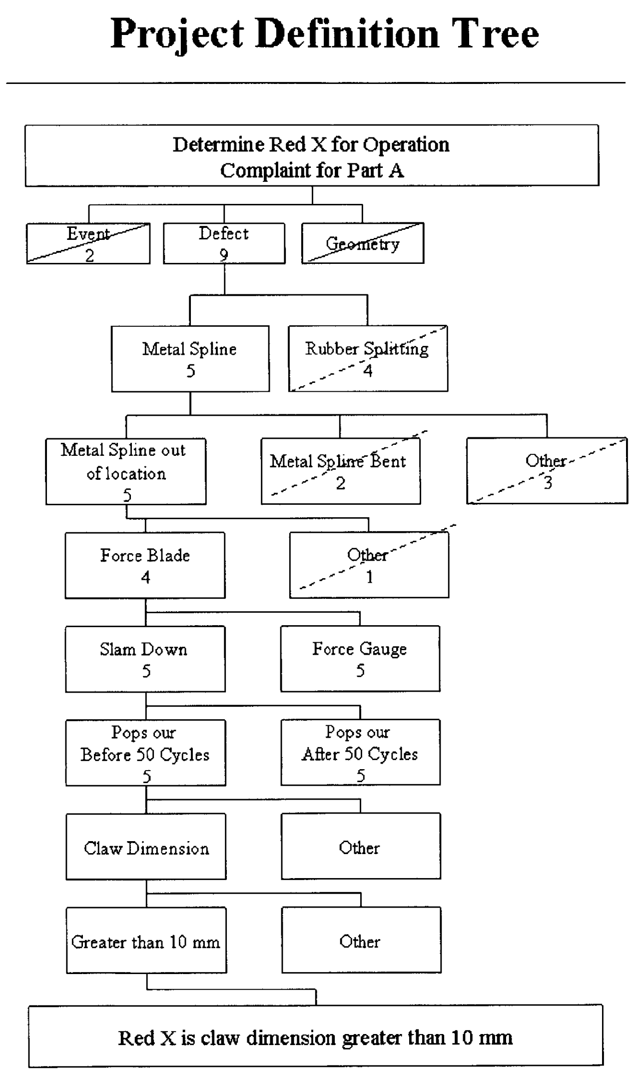

Figure 7: Project Definition Tree

After an engineer determines what the root cause of a failure, various procedures are followed depending on the vehicle line. On some vehicle lines, the engineer who works on the problem is the only person that must agree upon the failure. On other vehicle lines the engineer's manager must also agree with the assessment. Yet another vehicle line the engineers RedX Master must ultimately agree. Finally, on other vehicle lines the Assistant Chief Engineer must agree upon the root cause. Regardless of the method used, once the root cause is entered, the problem then moves to "solution."

3.5 Solution

During the solution phase of a problem, the warranty engineer informs the Designing Engineer of the root cause of the problem. The design engineer then, likewise, has up to 30 days to come up with a solution to the problem. The design engineer may work alone or with the supplier works with the suppliers or by himself to come up with a solution for the problem.

3.6 Implementation

Implementation is the part of the process where the solution is carried out. Implementation time varies greatly. Implementation time can be of a very short duration or can span a period until the next model year.

3.7 Feedback

The final phase of the PRTS+ process is feedback. Feedback is due no later then 180 days after implementation. Feedback is design to close the loop and make sure that the new design is working properly or to maximum efficiency.

3.8 Warranty Database

The warranty database currently has information from various sources. The PRTS+ database has information that the GM engineers have entered with regards to problems that they have detected. The QWIK database has problems that dealership mechanics have entered with regards to customer complaints and their root cause of a single vehicle. The QWIK database also has service bulletins and instructions on repair methods. The input and output of the database is shown below.

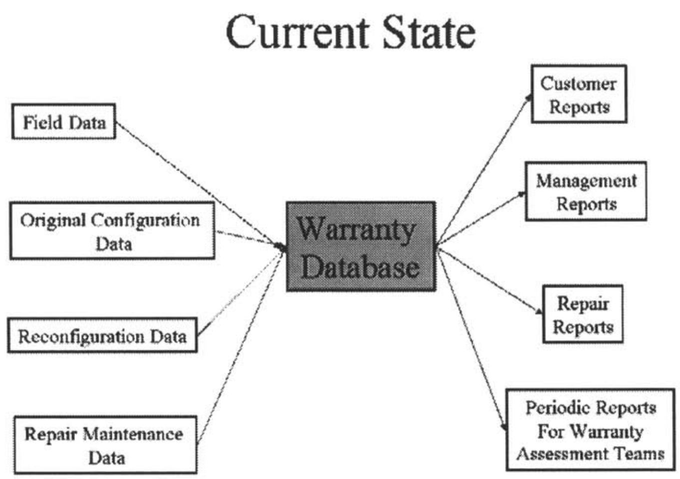

Figure 8: Warranty Database

3.9 Summary

General Motors warranty system is a complex system with many inputs. The warranty system covers issues from finding a failure, to fixing a failure, to eliminating a failure, to ensuring that it does not occur again. In the up coming section, the issues with the current warranty system of General Motors will be discussed.

4.0 Issues with Current State of Warranty System

4.1 Time

The first issue with the current method is time. Too much time passes before it is known that a problem exists. As the following chart illustrates, a minimum of 92 days will pass before a problem that a customer experiences becomes known at General Motors.

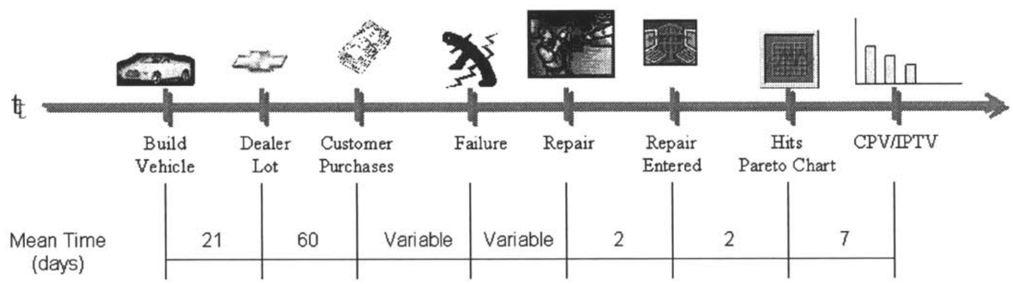

Figure 9: Timeline

The variable time from customer purchase to customer failure is quite wide. The average time is ten months. The mean time between failures to repair is three weeks. Realistically, the timing is may well be over 100 days before a problem is reported. Then add on to that the average 7 days to be assigned a problem, the 25 days to root-cause a problem, and 25 days to solve a problem and the mean time of 60 days for implementation indicates that there is a minimal time of 209 days from when the problem occurs to when it is contained. This minimal 209 days assumes that the problem occurred the day the customer purchased the vehicle and the repair occurred on the same day. Realistically, there would be a minimum of 30 days before the failure occurs and the customer brings in the vehicles for repair(s). If there were a significant problem with a vehicle, it stands to reason, that a customer would not take delivery. Moreover, the dealership is paid to do possible warranty checks before the vehicle is delivered to the customer.

4.2 Defective vehicles are continuously built

General Motors is a labor intensive company with very obligating union contracts. Given the current unions contracts General Motors can not idle plants or produce below 80% capacity because it will still have to pay the union workers at least 95% of their salary whether they work or not. The only economically sound thing to do is to spread this fixed cost over a lot of variable cost to reduce the cost per unit and the price of customer vehicles. Since it takes more than one hundred days to even find that there is a problem, during the interim defective vehicles are still being built. Since production can not be halted it is evident that the vehicles that are still being built are defective and may incur warranty costs in the future. The average General Motors' plant facility produces around 40 cars per hour for two shifts. This means that on the average 640 cars are constructed during a one day which translates to the construction of more than 134,000 vehicles are constructed by the time a problem is contained.

4.3 Root Cause Analysis

Root cause analysis is difficult to determine because of the inability of engineers to reproduce customer failure. One particular customer failure on one vehicle line was only reproducible when the vehicle was driven above 70 miles per hour trying to accelerate to pass a vehicle with less than half a tank of gas.[6] The engineers had difficulties discovering this failure as General Motors' policy requires employees to fill up the gas

[6] Modified from original failure but still shows the relationship

tank when vehicles are returned. The warranty engineer, therefore, always had a full tank of gas and was unable to reproduce this failure. The first step of the RedX warranty process is to duplicate the failure. You must duplicate the customer failure before you can move on to root causing the failure. Some issues are hard or slow to root cause.

4.4 Value Map

Currently, there is a lot of muda in the value map for the warranty process.

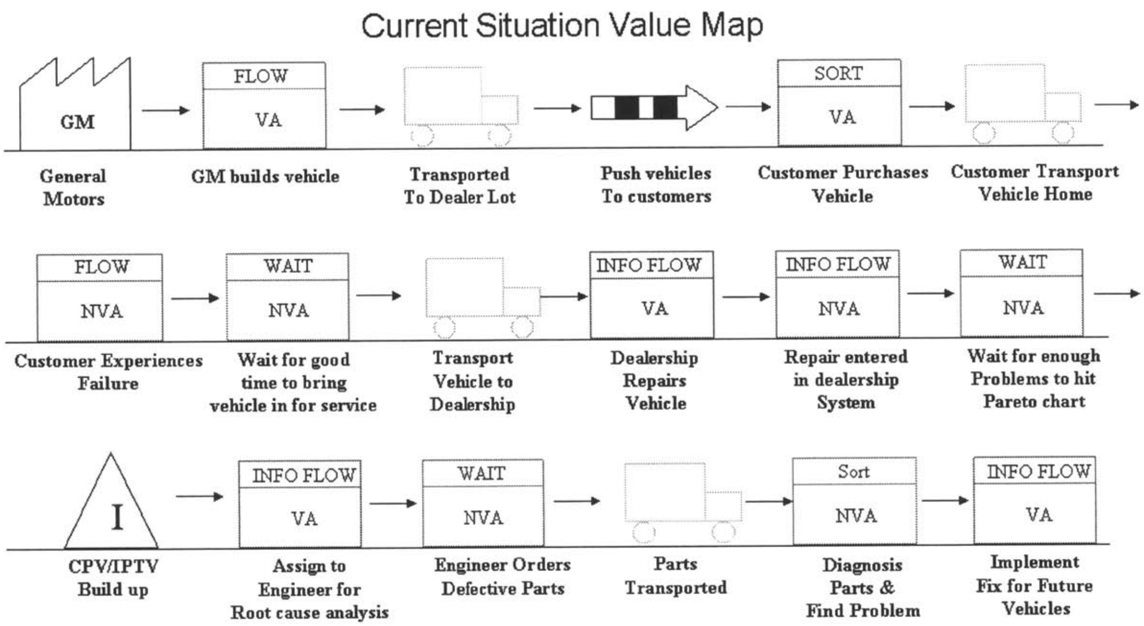

Figure 10: Current Value Map

Whenever one has a push system and is required or obligated to wait for responses, there is usually a way to improve the system.

4.5 Unsystematic Approach

RedX is a good tool to use to root cause failures, however, RedX becomes a crutch for engineers. Since RedX engineers are not assigned to any particular area, it becomes difficult for them to build a level of expertise. For example, in other development areas within General Motors, one works on air induction, chassis control, etc. This allows one to build a level of competence with a specific discipline. For warranty engineers, that is not the case. One must take whatever project is next on the list upon completion of the current project. If this is an area that one has not worked in previously, it becomes necessary for the engineer be educated on the functions that are part that what is attempted to be fixed. This education takes time and can take a week of the required 30 days to solve to solve the problem.

It is significant to note that, when RedX engineers begin their root cause analysis, they try to find the one part that is the cause for the failure. Although RedX is designed to show interactions between parts as possible failures, most of the design of experiments solutions point to a single part. The most experienced RedX engineers are usually the only engineers who do not experience trouble when the object worked on is an interaction between parts. An example of an interaction is when outside rearview mirrors that automatically fold in and out at the touch of a button were being diagnosed for root cause analysis[7]. Every mirror passed the test initially. It was a tolerance stacking problem with the mirror in relationship to the sheet metal that caused the mirror to fail. Having the failed customer part did not provide sufficient information to determine the cause of the failure was. It was necessary for the engineer to see the parts interaction with the rest of the system. RedX procedure, when coupled with General Motors' use of it, is a not a holistic way to solve a problem. In addressing the problem, General Motors only places orders for that one part that fails. However, it can sometimes be an interaction of the various parts. One can not always trace a problem back to a single item.

[7] Modified

4.6 Warranty Performance Metrics

The warranty engineers performance metric differs from one part of the corporation to the other.

Twelve Problems per year

In some parts of the organization you may be required to fix twelve problems per year. The warranty engineers that must fix twelve problems per year now have adapted one of two strategies. Strategy 1: Fix twelve problems early in the year and then relax performance for the remainder of the year because objectives have been met. Strategy 2: Make one fixed problem count multiple times. For example, if an engineer fixes a part and he can assign at least two failure modes to the part, then he can count the single part fixed multiple times. This is known as padding your count.

$1,000,000 per year

In other parts of the organization engineers must save one million dollars per year. Whereas this sounds like a lot of money at first, one powertrain problem can yield the engineer more than a million dollars. Other small problems or low volume vehicles may mean that one must solve 20 or more problems per year to meet the required quota.

No Metrics

In yet another part of the organization, there are no metrics for performance evaluation. It is simply required that the engineers fix assigned problems. As the saying goes, "You can't improve what you can't measure."

30 day deadline

Whatever metrics the various warranty groups have, they still must abide by the 30 day deadline for root cause analysis of problems. The 30 day time limit includes weekends and holidays. On average this means 19 workdays (including holidays) to solve a warranty problem. Given that some of this time may be used towards educating the engineer about the failed parts, this is not a lot of time. As a result, engineers have begun to pad their time. This is accomplished by delaying entering of the problem into the PRTS+ database to add more time to their root cause time. Also, if it is near the end of the year and quotas have been meet, the engineers will delay entering of the problem into the PRTS+ database until the following year in order for the fix to be counted toward the next year's quota. The problem with delaying is that engineers increase the time that defective parts are being assembled in the plants.

Competition

Since vehicle lines sometimes share the same part, sometimes, there are multiple engineers working on the same part. If an engineer enters the request before another engineer in the PRTS+ database, then that is the engineer that is supposed to work on the problem. The PRTS+ database is designed to eliminate the duplication of work; however, since the engineers are in competition with one another to get their metrics done some of engineers "steal" problems from other engineers. They find out what other engineers are working on and how far they are in an effort to make their problems solved numbers increase. Other engineers work is for naught. In an effort to pad their time, when they find a problem, they don't enter it in the database directly. Subsequently, when another engineer enters the same problem into the database, all of the time that they had vested in that problem does not count towards their PRTS+ objective.

4.7 Warranty Structure

Most of the warranty analysis is done by platforms. This is the case because at General Motors vehicle line executives are in charge of an entire vehicle line. The chief engineers report to the vehicle line executives through the vehicle line director. The vehicle line executive's yearly bonus is tied to the success of the vehicle line products. As sales increase so does his bonus, conversely, as warranty cost increase, the vehicle line executive's bonus decreases. It is therefore in the interest of the vehicle line executive to make sure that he minimizes his warranty costs. Clearly, the vehicle line executive has little incentive to minimize the warranty of another vehicle line. Whereas the vehicle line executive would be willing to help other vehicle lines for the sake of the company, that is not his primary focus. As a result, warranty has become an organization of silo groups. There are few people who look at the organization cross functionally. Consequently, a part that is common on two vehicle lines that has the same warranty problem will not be readily noticed.

4.8 Technicians

As with most corporations, resources are limited. This situation is no different for General Motors. Many groups have no technicians while other groups have one or two technicians to help a staff of twenty people. This results in many engineers having to perform their own test. Understandably, this cuts into the time that the engineers could be performing other root cause analyses.

4.9 Corporate Structure

In the General Motors hierarchy, warranty engineers are not viewed highly. This is the situation because when RedX was first introduced to General Motors, it was sold in a fashion of buy our technique and "any trained monkey" can do this. As a result, General

Motors warranty division is composed of a widely diverse set of engineers. Although, some engineers possess PhDs, quite a number of people in the warranty group do not have bachelors degrees. The result of diverse grouping and the lack of undergraduate degrees, coupled with the fact that warranty problems should be designed out of a product, warranty engineering has not been highly regarded in the company. Furthermore, warranty engineering does not have a set career path as does a number of other areas of General Motors. Lastly, when GM hires people, the GPA requirements are not as high for this group. Once you factor all of these things together, one gets a clear perspective of how the organization views the warranty group.

4.10 Communization

The warranty group is not communized in its approach to warranty issues. Different groups have different metrics. Different vehicle lines also have different ways to solve problems. Some warranty groups are allowed to take vehicles home overnight to simulate customer driving conditions whereas others are not allowed this option. This in itself is an excellent way to provide workers an opportunity to drive in a non stimulated environment to obtain real data. These groups are able to root-cause more problems because of more seat time in vehicles. Moreover, these differences breed problems amongst the various warranty groups.

4.11 Designers not involved

At General Motors, design engineers do not have access to the warranty database. This is due to the marginal cost savings that General Motors receives by restricting access to the database. Oftentimes, the designer is not aware that their parts have a problem until the warranty engineer calls him. The reason for this is that the design organization is a forward looking organization. Their performance metrics are getting future parts out without any regard to fixing past parts. Quite often, the designer in charge of the product is not the designer who released the product. The designer therefore does not know that part of the history or how the part interacts with the surround systems or noise factors.

4.12 Solution is not always validated

The design engineers' job is future products. As a result, it is often necessary for the design engineer to question the warranty engineer regarding what to do to fix the problem. In as much as the warranty engineer is usually on to the next problem, he gives the designing engineer a quick solution or none at all. Subsequently, the design engineer will enter a solution into the database and then go on with his core responsibilities of designing future products. The new solution is often times not validated which results in the problem reoccurring.

4.13 Summary

There are many issues with General Motors warranty system. Chief amongst these issues is the lake of a systemic process and time to discover failure. The following section will examine some of the solutions to the challenges that General Motors faces.

5.0 The Fix

5.1 Time

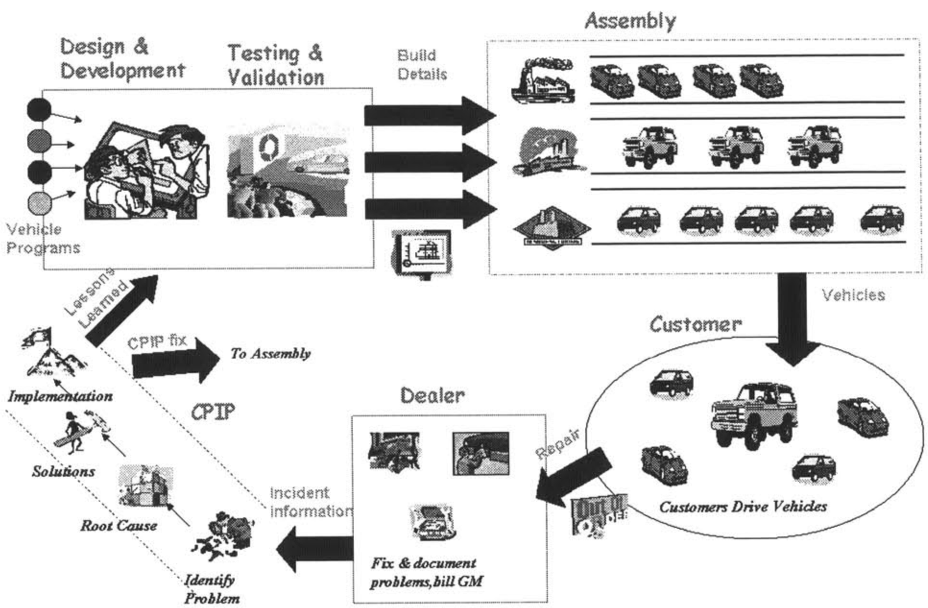

Figure 11: Current Procedure[8]

The above diagram illustrated the warranty process. You can look at this problem as a supply chain management problem where knowledge of the defect is the delivered product and the supply chain is the customer, the dealership, and the warranty database.

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[8] Agarwal, "Cost-Benefit," 8

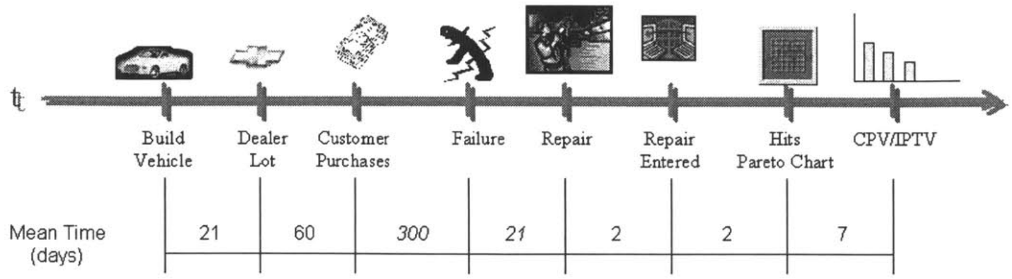

Figure 12: Timeline

The major problem is the time that is spent waiting for the knowledge of the failure to be sent to General Motors so that engineers can be assigned to solve the problem. If you take this time line and separate it in various pieces, it becomes easier to work with. Let $X_1 + X_2 + X_3$ be the total time for the problem to be known to General Motors, as shown in figure 13.

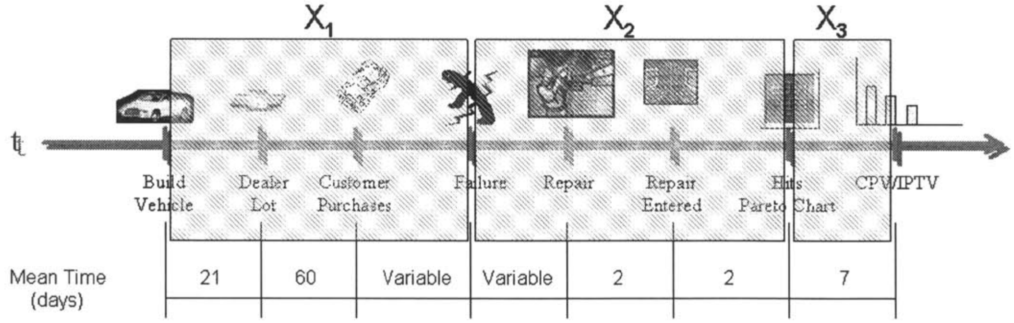

Figure 13: Timeline

Since time = $X_1 + X_2 + X_3$, the easiest way to minimize the time is to minimize the individual components.

<u>X_1</u>

X_1 failures are in the hands of the dealerships and the assembly plants. If a failure were to occur at this stage, before the customer takes delivery of the vehicle, then the only cost effective prevention is to have dealerships and plants do quality checks prior to vehicles leaving there site. Although this is done currently, it would be beneficial to emphasize this necessary step.

$\underline{X_2}$

X_2 can be reduced with the technology present in vehicles today. With telematics it is possible to transmit failures or problems of the vehicle to a centralized database. If this were done, it would become unnecessary to have customers bring in vehicles to dealership to determine the failures. 85% of the warranty work that is done by General Motors could be detected via diagnostic trouble codes. These diagnostic trouble codes would enable General Motors to root cause most problems. The earlier the trouble codes are discovered, the quicker the problem can be eliminated.

Once the diagnostic trouble codes and driving conditions have been found, warranty engineers can then duplicate the failure mode on General Motors' fleet vehicle. Based upon the previous example, engineers would have been able to know that trouble code Z2222 was triggered on many vehicles. Then the engineers would have looked at the driving conditions of the customers. This would have told all engineers that the speed of the vehicles were all above 70 mph and that during acceleration a throttle diagnostic trouble code was tripped. Engineers could also tell fuel level, tire pressure, oil pressure, and even location and heading. This data is enough to root cause the problem without the presence of the customer vehicle, but with the present of comparable vehicles. Ninety percent of General Motors' warranty problems are solved by reproducing the failure with

GM vehicles or in GM plants. Only a small percentage of trend warranty issues need the actually customer vehicle. This method would also solve problems that are interaction with other parts as long as they were diagnostic computer detectable problems. While this telematics fix would not work on warranty problems that can not be detected by computer (i.e. water leaks), it will work all other problems. These problems account for 85% of General Motors' warranty problems and would go a long way to reducing warranty detection and root cause time.

$\underline{X_3}$

A person must run this task every week to see how the corporation warranty numbers are going. This can and should be automated so that these numbers are constantly available. Furthermore, it should be set up that the entire corporation looks at warranty by cost, frequencies, and safety across vehicle lines, vehicle platforms, suppliers, and the entire company.

5.2 Defected vehicles are continuously built

After a defect is found, vehicles are continuously built. A quality spill is a function of the number of vehicles affected and the time to fix the spill. The number of vehicles affected, in turn, is a product of the vehicles produce and the time to identify that there is a failure. This is illustrated in figure 14.

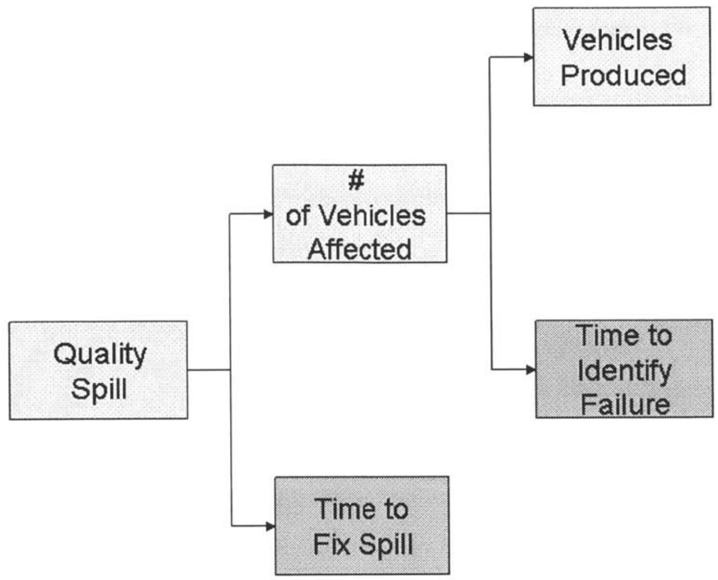

Figure 14: Quality Spill Dissection

By the cummunitive and distributive property, the equation reduces to the following:

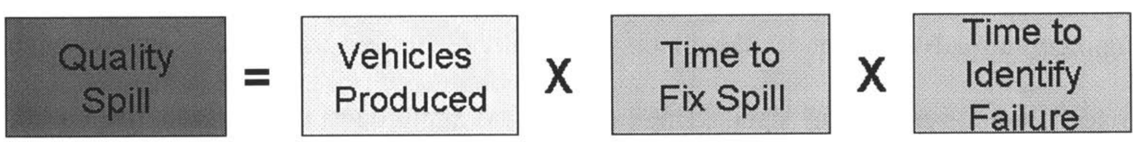

Figure 15: Quality Spill Make Up

This implies that the quality spill is directly proportional to the vehicles produced and the time inputs. Since vehicles produce is a matter a union contracts and sales, it becomes easier to focus on the time inputs. By reducing the time to fix spill and the time to identify that spill has even occurred then one is able to reduce the defective vehicles built. The easiest way to reduce time is by the methods shown in the previous section.

5.3 Root Cause Analysis

Root cause analysis is oftentimes difficult too determine because it is challenging to produce the failure of the customer. Many times it because the noise factors present during the customer's failure are not present during the duplication procedure. Other times it is due to the fact that interaction of parts, rather than a single part, is the cause for the failure.

Most vehicles continuously record data via the data recorder. This is most commonly known as the "black box." This would be of great use in root causing problems. These data recorders can be programmed to record any trouble codes and triggered to transmit the codes, along with the relevant information, to a centralized data facility. The one failure mention previously concerning a vehicle that had to be driven above 70 miles per hour while trying to accelerate to pass a vehicle with less than half a tank of gas to reproduce that failure is a good example. This type of failure is hard to recreate without knowing the exact components leading to failure. Having access to the diagnostic equipment already present in the black box and the rest of the vehicle would have provided some very useful data. Engineers would have been able to tell the speed, heading, and all the other vehicular gauge readings. The engineers would have been able to look at the data and realized that this was common on this type of vehicle. The data recorder would have shown the loss of throttle and the vehicle conditions present along with the diagnostic trouble codes that the vehicle emitted. Engineer could have easily duplicated this problem on fleet vehicles and solved the problem before many vehicles were affected. This warranty issue is an example of a challenging issue to duplicate. A lot of issues are easy to root cause once engineers can duplicate the issue. This is one of the first steps of the RedX process. A lot of the engineers' time is spent trying to duplicate customer failures so that they can root cause the issue. This method would allow easier duplication which, in turn, would enable quicker root cause analysis.

5.4 Value Map

The current value map calls for many periods of waiting as shown in the below value map.

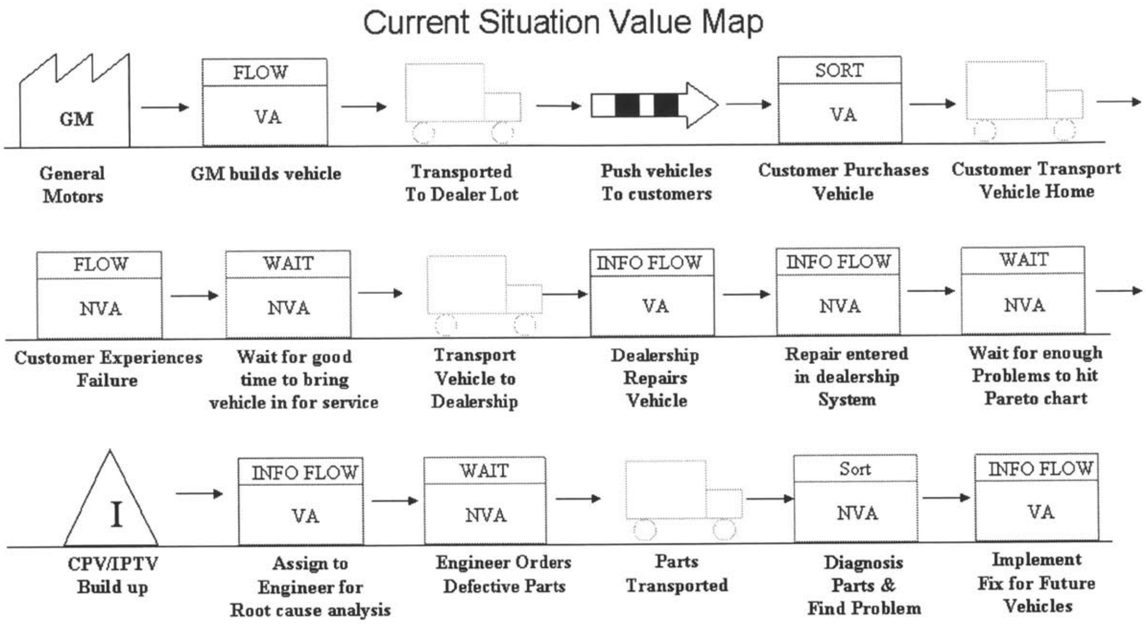

Figure 16: Current Value Map

A significant amount of time can be eliminated by connecting to a vehicle via telematics to download error codes. With this information, engineer would be able to root cause problems without ever seeing the vehicle or receiving parts. It would be possible for engineer to discover problems before customers brought vehicle into dealership and, in same cases, before the customer became aware that there was a problem. The value map for this proposal is shown below:

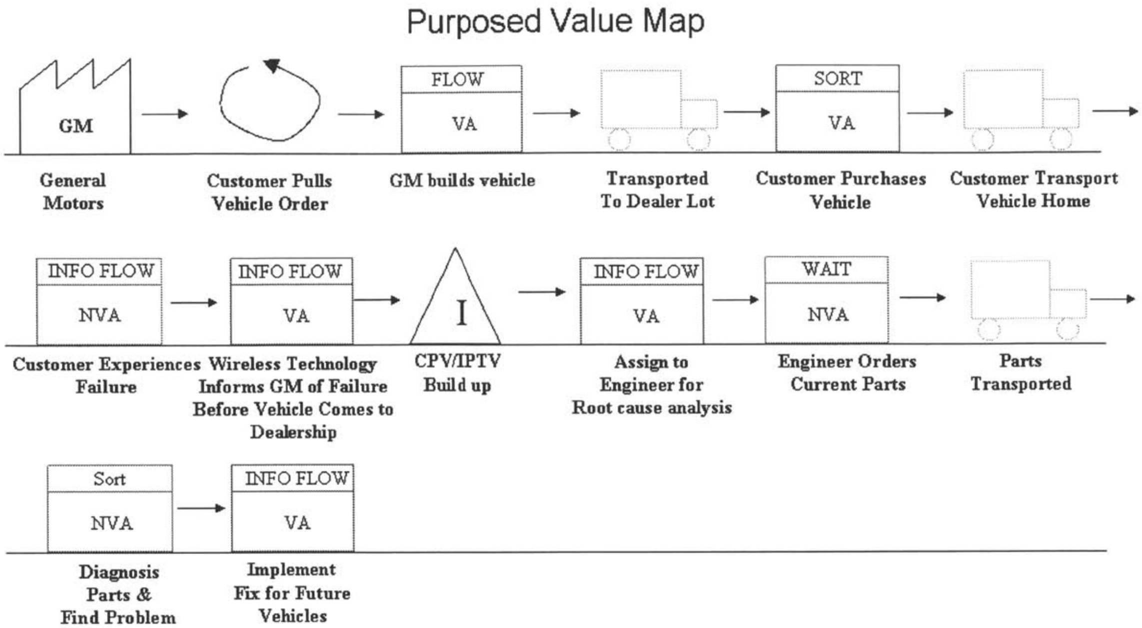

Figure 17: Purposed Value Map

If this approach is adopted, then X_2 of the time equation can be reduced. As it now stands X_2 is equal to variable failure time + 2 days + 2 days. This is a mean time of 49 days. X_2 can be minimized to 7 days by checking the fleet of General Motors owned and operated vehicles on a weekly basis.

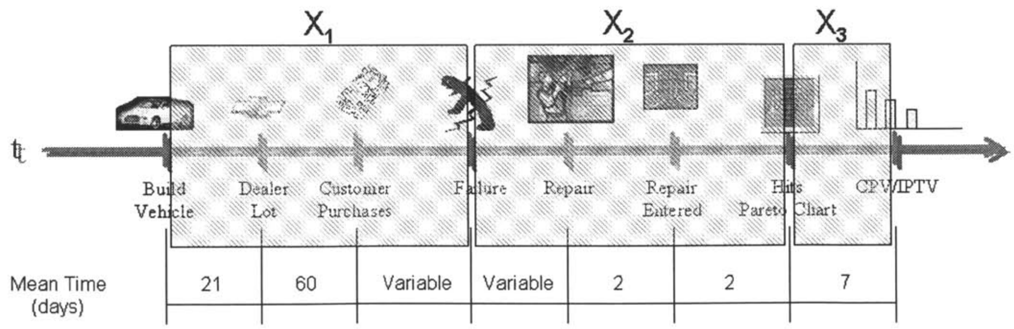

Figure 18: Timeline

5.5 Unsystematic Approach

RedX is a great tool for solving problems. Sometimes the manner in which RedX is practiced at General Motors is a very non-holistic way a solving problems. Engineers have gotten into the habit that RedXes are always a single part and oftentimes forget that RedX can also be the interaction of multiple parts. While RedX tools do allow one to root cause parts and interactions, it is difficult to do so with the method that General Motors employs. Warranty engineers order single parts and therefore they are trying to find out what on that part is damaged or malfunctioning. Warranty engineers must be cognizant of the fact that just because they have a part in their hand, the damage could be anywhere within the system.

Furthermore, it should be pointed at that the goal of RedX is variation reduction. Since RedX is quite simply a collection of design of engineer experiments that eliminate variation, it should be obvious that one needs variation in order to utilize the process. One needs a good product (BOB) and a bad product (WOW). If all of the available products are bad or defective, then one can not use RedX to solve the problem.

The entire warranty process does not look at the approach in a systematically and efficiently way. General Motors is solving its warranty problems with a tunnel vision approach. The engineers need to look for interaction amongst parts as well as interaction among the rest of the engineer organization. Warranty engineers and design engineers should be in the same group.

5.6 Warranty Performance Metrics

The warranty performance metrics are not conducive to a collaborative work environment. Although General Motors promotes team work, the manner in which the warranty engineers' performance is measured tends not to promote team work. The warranty engineer's performance metric should include the full life of the problem, not just finding the root cause of the problem. This full ownership of solving the problem and working in a team atmosphere would be more conducive to problem solving. True ownership of the part and the solution for the warranty problem is still in the hands of the design engineer. The design engineer and the warranty engineer should be responsible for solving the problem. If this was a shared problems with shared metrics, then a true since of teamwork would evolve between the two organizations.

5.7 Warranty Structure

While it is necessary to perform warranty functions by vehicle line, more attention should be focused on the fact that problems can occur that are shared by multiple vehicle lines. For example, a key fob (remote for unlocking vehicle doors) is shared across many vehicle lines. If there is a problem with key fobs, the cost may not be great across one vehicle line, but if all vehicle lines with the same key fob have a problem, the cost may become astronomical. However, if one only looks across vehicle lines, one would not readily discover this problem.

Furthermore across functional team should immediately analyze problems to determine if they are a trend or random occurrence. An illustration of this approach is shown in the below figure.

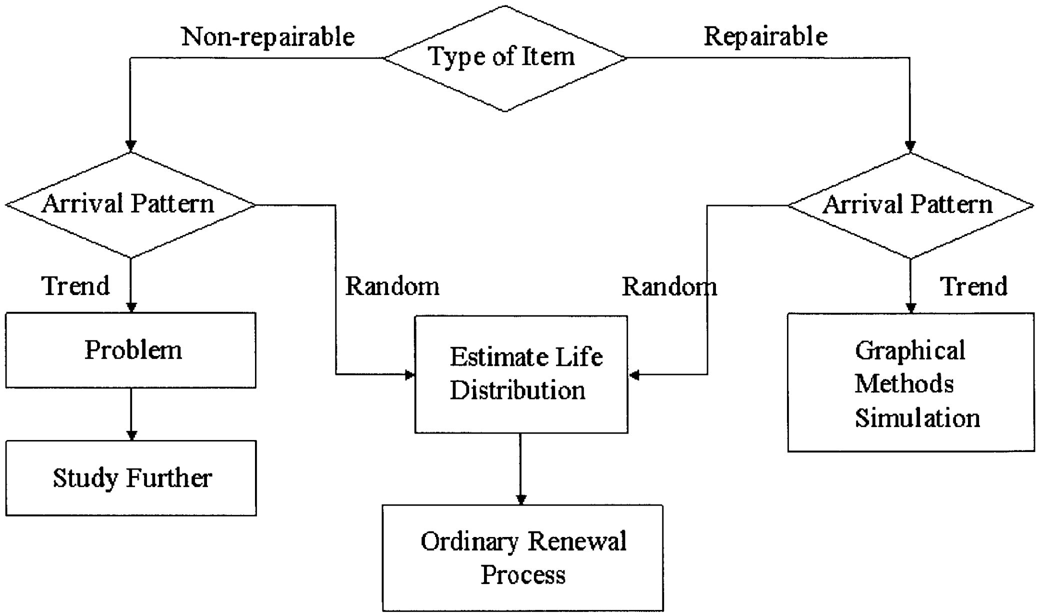

Figure 19: Warranty Process Structure[9]

By following this approach, it becomes clear which problems to work on and which problems require further study.

5.8 Technicians

Increasing the number of technicians available will make it easier for engineers to complete more work. It takes a considerable amount of time to swap parts and systems. If technicians were available to assist the engineer or perhaps perform some of the task for the engineers, it would free up a considerable amount of time. As a result, their output or productivity would be increased. One engineer would be able to do the work of two simply with a shared technician. This would mean that groups could get by with more lower paid technicians headcount and less higher expensive engineers headcount.

[9] Brennan, 91.

5.9 Corporate Structure

The corporation needs to realize that although warranty cost is not desirable, it is a necessary part of the business. The corporation also needs to understand that the morale in the warranty groups is low because of the manner that the group is considered within the organization. If the corporation were to promote warranty engineers or increase their standards for acceptance into the organization, the rest of the corporation's opinion of the warranty organization would be heightened.

Another organization change to consider is one in which the warranty engineers and the design engineers are in the same group. This was there is no separate organization, just one commingled group. The benefits are many. Designers would be more accountable for their own parts. Designer would be more cognizant of failures modes that similar parts have had. Furthermore, institutional learning could be enhanced with one unified group.

5.10 Communization

All warranty groups are not created equally. The warranty group's metrics are different from one program to the next program. The work perks are different from one group to the next as well. These differences create fiefdoms and dissent within the organization. General Motors should create one standard within the warranty organization.

Currently, if one vehicle line is performing well on warranty cost and another vehicle line is performing poorly, the poorly performing organization s not permitted to borrow resources from the better performing vehicle line. This should be changed. General

Motors promotes RedX as a centralized problem solving skill, yet the link the skill by vehicle lines and not by function. This should be a cross functional operation.

5.11 Designers not involved

Designers need to be involved with the full life of their parts. The design organization encourages moving around in order to be able to design more parts. It is a good objective to create well rounded designers, however, the drawback of this strategy is that designers do not stay in position long enough to see the life of their parts. Consequently, designers design parts and then leave for another position within General Motors. As a result, when problems arise the new designer does not know the part history or how to fix the problem. There is no accountability for designing poor products. The designers usually do not even know how to fix their parts because they are new to the problem. Designers also are focused on future tasks, not on a task that was done by the predecessor or possible a predecessor one or two steps removed. Designers do not even have access to the warranty database to enable them to check up on their parts to see if they are performing efficiently and efficiently.

Toyota designers remain in one area for more than ten years. It is common to work at Toyota and have done the same function for one's entire career. Toyota designers also receive an email alert if the part they designed has been repaired in the dealership. The very next day that a part is repaired by a dealer, the Toyota engineers are made aware of it which enable the engineer to take the appropriate course of action. Likewise, General Motors designer should have access and be required to check on their parts periodically. If it is cost prohibitive to have each designer have access to the database, then there should be one access point per design group. The designer's performance metric should be set up to create accountability for their parts.

5.12 Solution is not always validated

The solution that the designers come up with is quite often not validated. Consequently, the problem resurfaces a few months later and must go through the warranty process again. It is common to see problems go through the warranty procedure multiple times. If the solutions were validated prior to being accepted, this would eliminate most problems. The feedback of the process is designed to show that the solution is working, but oftentimes this is not really focused on because this does not the represent core responsibility of any party involved although it is a step in the RedX process.

6.0 Conclusion

There exists a wide variety of time to discover defects in the field. Reducing the measurable standard deviation of time from introduction of a vehicle to the field to assigning engineer for root cause of a problem to implementation of the solution is the key to solving the problem. There is not real time data transfer from the field to the corporation. If this link did exist, the corporation could fix these problems almost as soon as they occurred instead of months later.

To successfully fix the issues, General Motors must become a part of the global telematics market and increase its capability to receive live data. General Motors must also work on their internal issues and conflicts as well. General Motors must also think holistically when solving its problems. General Motors tunnel vision approach to warranty obviously is not working. Warranty elimination is a process that must be a corporate-wide issue and not a departmental or organizational issue.

If General Motors is to survive and thrive in the coming decades, then they must minimize their mean time to failure discovery for the sake of warranty costs, which go directly to the bottom line, and for the sake of perceived quality.

Glossary

Assistance Chief Engineer – Reports directly to the chief engineer is usually in charge of one product line

Automotive strategy board – Group of executives that determine which vehicles should be developed and manufactured and which vehicles should be terminated.

BOB – The Best Of the Best part/assembly/component made in a process as determined by the Green Y. BOB represents one extreme of the process distribution that is opposite the WOW extreme. Typically this is not the nominal value.

Chief Engineer – Chief engineers report to vehicle line executives. Chief engineers are usually in charge of more than one product line. For example, the Buick La Sabre and the Cadillac Deville are built on the same product line and there is one chief engineer for each one

Continuous Process Improvement Process – The process of continuously improving products once they have already been released.

Data Recorder – Also known as the infamous black box, the data recorder continuously records what the vehicle is doing. The recorded data includes speed, direction, and acceleration.

Diagnostic trouble codes – DTC are error codes that the vehicle has in its memory on the vehicles processor. These codes are stored whenever the vehicle senses that an error has occurred

Green Y – The response the customer cares about. It is either a failure mode or a performance distribution and is typically a technical specification. It is green because that is the color of money - the more enthusiastic the customer is about the product, the more money the company makes.

Muda – Literally translated, muda means waste. Specifically, muda is any human activity which absorbs resources but creates no value.

Platforms – Although there is much debate, both in General Motors and external to the company, about which constitutes a platform, a platform are the components that can be common amongst many different vehicle lines. Platforms usually share the same underbody and basic components that the customer is indifferent to.

PRTS+ – Problem Resolution Tracking System Plus is the database that engineers use to record warranty problems. There are four steps recorded in the database. They are root cause, solution, implementation, and feedback.

QWIK – Quality with Information and Knowledge is the name for the database that houses the information inputted via the dealerships. This database contains customer verbatims and mechanics root cause. This database also contains that contact information of the involved parties.

RedX - The root cause or variable that is causing the greatest amount of variation in the Green Y. The Red X causes non-random patterns in the data. It is red to alert danger of excess variation in the process or product.

Signature Analysis - Signature Analysis (SA) is a lab resource management tool in that it provides a formal method of reducing the number of these repetitive failures requiring full analysis. Two statistical models are presented, both of which assign a confidence level to any number of units with the same failure characteristics (i.e., signature) and same failure mechanism, allowing the statement "I am A% sure that greater than B% of other parts with this signature will also have this failure mechanism". One model is for use when the failing population size is finite and known, and will be referred to as 'finite population analysis' (FPA).

Taguchi - The Taguchi method of design of experiments is a statistical tool based on the systematic approach of conducting minimal number of experiments using orthogonal arrays. Traditionally, this method has been used to predict the significant contribution of each design variables and the near optimum level combination of the design variables by conducting a real time experiment.

Vehicle Line Executive – An executive that is in charge of all aspects of a vehicle line. This include engineering, marketing, finance, purchasing, etc.

Warranty Engineer – Engineer that uses RedX strategies to solve assigned problems.

WOW The Worst Of the Worst part/assembly/component made in a process as determined by the Green Y. WOW represents one extreme of the process distribution that is opposite the BOB extreme.

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