A System Perspective on Warranty Problems within a Supply Chain

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ABSTRACT

Warranty is important financially to American manufacturers, especially automotive companies. Carmakers and suppliers must work aggressively to improve their warranty management approach as warranty cost often equals or exceeds their investment in engineering. This thesis focuses on studying warranty management in a supply chain from a systems perspective. Warranty data in the automotive industry, focused upon a "Tier one" supplier, is analyzed to obtain general warranty trends and typical failure types. Following the data analysis and hypothesis formation, a sequential series of surveys and interviews within the supplier are conducted in attempt to determine the root causes of warranty failures. A major finding of the study is the lack of a cross-company and long-term approach for dealing with warranty. Other root causes (though not as deeply imbedded as that noted first) include the lack of design discipline, design knowledge, and resources in the product development process. In addition, unclear accountability, poor communication, and lack of a supplier management process delay the warranty resolution process. Furthermore, the culture and mindset in an organization is a critical element in effective warranty management. A reactive warranty firefighting mindset is inadequate to attack the significant warranty issues. Based upon solving the root causes found in the research, the thesis provides five specific recommendations. These recommendations appear likely to be useful to a wide variety of automotive companies as well as manufacturers in other industries.

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1. Introduction

1.1 Motivation and Research Objectives

Manufacturers in the United States spend a total of nearly $24 billion per year on warranty claims [1]. In the automotive industry alone, which includes carmakers and suppliers, about $12 billion in warranty claims are processed annually. The average portion of revenues that is spent on warranty is about two percent for the automotive manufactures. This often matches or exceeds the total spending on engineering including product development and can exceed profits in many years. With these financial implications, there is no doubt that many companies have worked aggressively to improve their approaches to warranty management. The benefits of warranty reduction are far more than just cost savings. Fundamental quality improvements can save warranty costs but also can boost revenues, promote company image, increase customer satisfaction and loyalty, and drive up the long term profitability and growth of the company. Indeed, the last twenty-five years of automotive history shows that the winners have had the best quality, warranty, and performance.

Warranty management is a business process that includes a series of activities: warranty registration, warranty claims processing and settlement, failure detection, warranty problem solving, knowledge sharing and giving feedback back to the design process. Companies have realized that effectively managing warranty is extremely difficult especially when other entities are involved, such as intermediate customers and suppliers. Understanding of the root causes of warranty issues can be hampered by technical issues, process issues and/or cultural-political issues. This greatly increases the difficulty of focusing the effort and moving in the right direction.

There are two major objectives for this research. The first one is to determine the major issues related to warranty in a typical automotive supplier. We will use data analysis, surveys, and interviews to collect information. That information will be screened and analyzed to lead to understanding about the root causes of the issues. The second objective is built on the achievement of the first objective. After we determine some possible root causes of the warranty issues, we will try to make some suggestions to address some of them. We will apply the knowledge and tools that we learned from the MIT SDM program, especially the system thinking, to address those issues. Since warranty is such a complex subject, even trying to approach it is a big challenge. Nonetheless, we hope that our effort is of some value and that's the most important objective of this research.

1.2 Warranty Definition and History

Many consumer durable goods, such as cars, computers, electronic devices, and appliances, include a manufacturer's warranty to insure product quality and reliability.

The definition of "warranty" is "***a written guarantee of the integrity of a product and of the maker's responsibility for the repair or replacement of defective parts***" per

Webster dictionary. In January 1975, the US Federal Government enacted the "Magnuson-Moss Warranty - Federal Trade Commission Improvement Act (25,515). It is "An act to provide minimum disclosure standards for written consumer product warranties, to define minimum Federal content standards for such warranties; to amend the Federal Trade Commission Act in order to improve its consumer protection activities; and for other purposes." In the Act, terms related to warranty are defined below:

Consumer product - any tangible personal property which is distributed in commerce

Supplier - any person engaged in the business of making a consumer product directly or indirectly available to consumers.

Warrantor - any supplier or other person who gives or offers to give a written warranty or who may be obligated under an implied warranty.

Implied warranty - means an implied warranty arising under State Law in connection with the sale by a supplier of a consumer product.

Service Contract - a contract in writing to perform, over a fixed period of time or for a specified duration, services relating to the maintenance or repair (or both) of a consumer product.

Warranty terms and coverage are industry dependent. Consumer appliance manufacturers usually offer much longer warranty than computer manufacturers.

Some warranties pay the entire repair cost while others only cover the cost of parts, not the service. The scope of this study focuses on the industry that is affected by warranty the most – the automotive industry. Therefore, a clear understanding of the special characteristics of automotive warranty is necessary.

1.3 Automotive Warranty

In the auto industry, warranty starts when the vehicle is delivered to the dealer. Warranty has been one of the most significant considerations when people shop for automobiles. Therefore, marketing needs have traditionally been the main factor to determine the warranty terms. The manufacturer supplies a vehicle with many different warranties. In the passenger vehicle industry, which usually includes passenger cars, sport utility vehicles (SUV), pickup trucks, and minivans, warranty is covered by the vehicle manufacturers, such as General Motor Corp. Depending on brand name, usage purpose, and specific component groups, warranty coverage may vary. For instance, typical warranty coverage for a passenger vehicle is 36,000 miles or three years from the original "in-service date" as shown in Figure 1.1.

Often selected component groups, such as the power-train system that includes the engine and the transmission, have extended coverage (typically 5 years and 50,000 miles). Also, luxury brands normally have longer warranty coverage to promote customer satisfaction and brand images. Historically, vehicle manufacturers paid the entire warranty bills without sharing them with component suppliers, although up to

70 percent of the total components are purchased from suppliers. In recent years, automotive manufactures have begun to rely more strongly on their suppliers. The suppliers are facing a new challenge as the auto firms are now moving to transferring part of the warranty cost to suppliers if they are responsible for the failures. The trend of increased warranty sharing is expected.

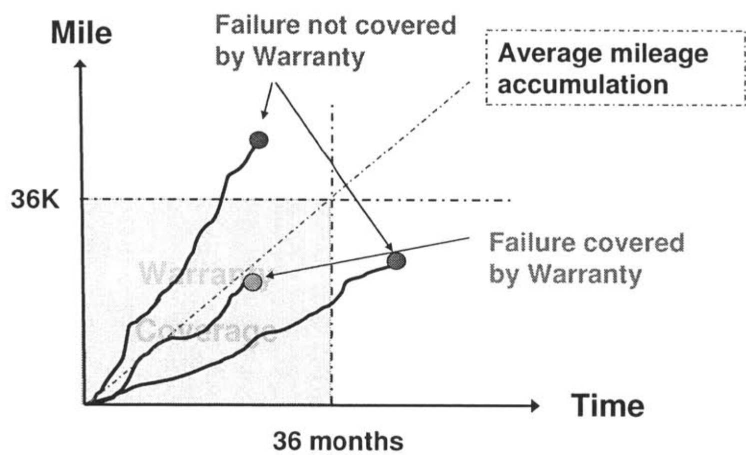

Figure 1-1: Typical warranty coverage for passenger vehicles

Commercial vehicles, which usually include on-highway commercial trucks, buses, couches, and special purpose vehicles like fire trucks, ambulances, garbage trucks, are mostly owned by the fleets or transportation companies. Those vehicles have different warranty terms compared with passenger vehicles, which are usually directly owned by consumers. One special characteristic of commercial truck warranty is a much longer warranty coverage period. It is not surprising to see warranty coverage of 500,000 miles for the on-highway trucks. A longer warranty is desirable since most of these trucks are driven for more than 200,000 miles a year. Another important characteristic is that for most commercial truck components, the warranty is provided directly by the automotive suppliers that build those components, rather than the vehicle manufacturers. It is very common to see that engines, transmissions, suspensions, axles, and brakes are directly covered by the supplier warranty agreements. This fact brings both benefits and shortcomings to the commercial vehicle suppliers. On one side of the coin, suppliers have more direct access and control of the warranty claims, shorter lead time to identify new failures, and thus quicker response to problem solving or design change which eventually leads to a lower accumulated cost. On the other side of the coin, suppliers are also directly impacted by big warranty campaigns such as recalls. In such cases, there is no buffer zone provided by the automotive manufacturers. Therefore, some small suppliers can be placed in severe financial jeopardy. The scope of this thesis focuses on automotive suppliers in the commercial vehicle industry. However, suppliers with both kinds of business could learn by examining the commercial vehicle business side as the trend in passenger vehicle warranty could lead to a situation resembling that in commercial vehicles today.

1.4 Warranty vs. Quality vs. Reliability

Warranty to the customer is a guarantee of service and repair without charge. To the manufacturers, warranty is a direct measure of product quality. If a product has to be sent back for warranty repairs frequently, neither the customer nor the manufacturer will consider it a high-quality product. Nowadays manufacturers rely more on warranty data for both financial and engineering analyses. Analysts use warranty data to predict future liability and estimate the annual accrual for financial report. Engineers use warranty data to identify unforeseen failures and assess product reliability.

Reliability, by definition, is the "probability that a system performs its intended function at predetermined life". Warranty data often contains information on all incidents reported during the warranty coverage period. The product failure behavior, including warranty failures, can be modeled by a "bathtub curve" that is widely used in reliability engineering field. Figure 1-2 shows a typical "bathtub curve".

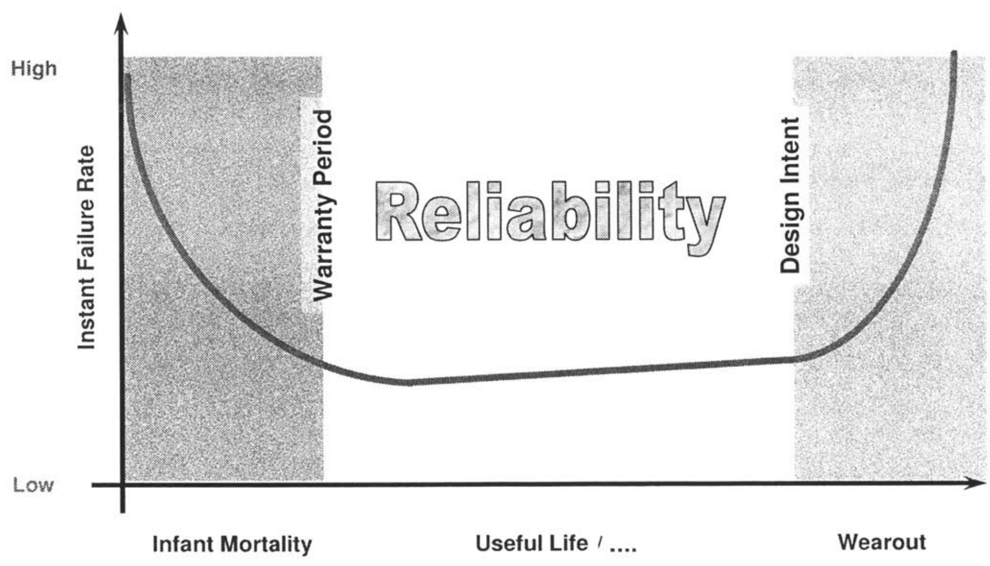

Figure 1-2: The bath-tub curve of warranty and reliability

The X-axis of Figure 1-2 represents the entire life span of a product, while the Y-axis shows the instant failure rate. The warranty coverage period of automotive systems is always shorter than the design intent life. Indeed, most failures seen in warranty period are infant mortality issues, which mean the failure rate is decreasing over time. When the failure rate stabilizes, the product starts to reach its useful life period, where most failures are random. After a product reaches its designed life, the probability of failure starts to increase dramatically due to wear out. Warranty and reliability are interrelated and both could be viewed as "quality over time". From the bath-tub curve, warranty can be described as reliability in "short-term".

Many papers have been published to develop mathematical models to assess reliability using warranty data and to predict warranty cost using reliability testing results. Discussion of these and other literature results are in the next section.

1.5 Literature Review

A great number of books, articles, internet resources, and technical papers are available for warranty and quality management. Three major areas of research can be found in this field:

(1) Warranty planning, data reporting, and cost prediction using statistical analysis

(2) Warranty reduction through Total Quality Management (TQM) and Six-Sigma methodology.

(3) Warranty prevention through concurrent engineering, lean manufacturing, and Toyota Production System (TPS)

Planning warranty policy, reporting warranty data, and estimation of future warranty cost have received great attention from many researchers. Reference [1] is an excellent website for general warranty figures and trends across all industries in the US. Detailed information can be found including annual warranty spending and accrual of major American companies, analysis of new warranty regulation trends, and case studies of successful warranty reduction for many industries. The specific warranty information and facts for the automotive industry is described well in [2]. Brennan [3] established the criteria for good warranty policies for customers and suppliers and presented real-world case examples to illustrate basic warranty principles, requirements, tradeoffs, costing, planning, and management. Blischke and Murthy [4], [5] overviewed basic warranty concepts and techniques for analysis; history of warranty, and warranty in marketing. They also provided a format useful to engineers, statisticians, as well as managers having responsibility for establishing warranty policy, administering the warranty program, or estimating warranty cost. Sahin and Polatoglu [6] discussed theories of warranty and preventive maintenance, and investigated what exactly better quality means, how it impacts warranty policies and costs for the manufacturers, and how it effects placement and maintenance strategies and costs for users. Abernethy [7] listed all latest methodologies developed for warranty analysis from statistical and reliability analysis. More in-depth automotive warranty data analysis using reliability methods, particularly Weibull distribution for life data, have been discussed in [8] - [12]. These studies emphasized technical solutions to specific automotive warranty characteristics, such as two-dimensional (time/mileage) warranty limits, incomplete and unclean warranty data, and combination of both infant mortality and random failure rates. Some articles [13] - [15] discussed non-technical ways to manage and reduce warranty claims including providing advanced warranty tracking system and promoting communication between customers and supplier(s).

Warranty can be dramatically reduced if the root causes of failures are captured early and effective corrective actions are applied. A number of books and papers are available in the fields of Total Quality Management (TQM) and Six-Sigma methodology, which have been widely accepted by industries as the best quality management and problem solving processes. Evans and Dean [16] presented an overview of the key principles of total quality and linked those concepts to traditional management practices and organizational models in management theory. Evans and Lindsay [17], Pyzdek [18], and Breyfogle [19] provided comprehensive reference guides to the five-step process of Six-Sigma: Define, Measure, Analyze, Improve, and Control. Both basic concepts and advanced statistical tools, from design of experiment (DOE), response surface method (RSM), Chi-square contingency tables, and analysis of categorical data are well explained. Non-technical issues in quality management are also studied by some researchers. Lagrosen [20] explored the impact of culture on quality management and found that the cultural dimensions of uncertainty avoidance and individualism-collectivism have an influence on the values of TQM. Montes, Jover, *and* Fernandez [21] provided a framework for studying the relationship between TQM and organizational performance. They also revealed that TQM contents have to be consistent with business orientation and environmental uncertainty in order to be effective. Hansson, Backlund, and Lycke [22] reviewed the literature and found that obtaining management and employee commitment are crucial to successfully implementing TQM and other quality improvement tools. Nwankwo, Obidigbo, and Ekwulugo [23] discussed effective warranty and quality management from logistic and supplier quality management points of view.

Modern product design and manufacturing processes can help to prevent warranty and other quality issues. Many companies have already started to use concurrent engineering and robustness design processes to improve efficiency and reduce mistake(s) in the product development. A good reference on how to establish concurrent engineering is [24], written by Fleischer and Liker. Taguchi [25] emphasized the importance of robust design methods in product development to prevent fire fighting. Kennedy [26] and Feld [27] introduced product development process for lean enterprise and explained why Toyota product development system is four times more productive than what is used by most other companies. A handful of books are available about Toyota's secret of success – the lean manufacturing, which has been widely regarded as the benchmark of modern production system. [28] and

[29] are among the first English books to introduce the history and mindsets of the Toyota production system. Womack, Jones and Roos [30] wrote the famous book, "Machine That Changed the World", to draw an in-depth analysis of Toyota's practice and uncovered the specific manufacturing techniques behind Toyota's success. Liker [31] - [32] further revealed the essences of lean manufacturing and fourteen management principles behind Toyota production system.

From the brief summary of the literature above, one can realize that the entire warranty process is a very large-scale system. The system is composed of various internal and external elements of the company affected. Internal elements include the product development process, the manufacturing process, warranty reporting system, finance and accounting activities, company organization, policy and culture, and resources. External elements are customer relationships, supplier collaboration, market conditions, and competition. All these elements are interrelated and interact with each other. To successfully address warranty issues, a systems approach needs to be applied.

2. Warranty Status

The overall warranty picture for American manufacturers, automotive companies and suppliers are discussed in this chapter. All data presented in this chapter are collected from public sources including Form 10-K financial statements, annual reports, company official websites, and resources listed in the references.

2.1 American Manufacturers

Nearly $24 billion dollars are spent annually by American manufacturers honoring their product warranties, which on average, account for 1.9% of their product revenue. More than nine companies are spending a million dollars a day on warranty expenses. The aggregate of some 750 manufacturers' warranty reserve funds stands at $33.6 billion at the end of 2003, up roughly $1.26 billion from the balance at the beginning of the year [1]. Among all warranty claims, the automotive industry accounts for half of the total, while computer and telecommunication equipment industries take up a quarter. Figure 1-1 shows the percentage of shares for different industries in terms of warranty claims in 2003.

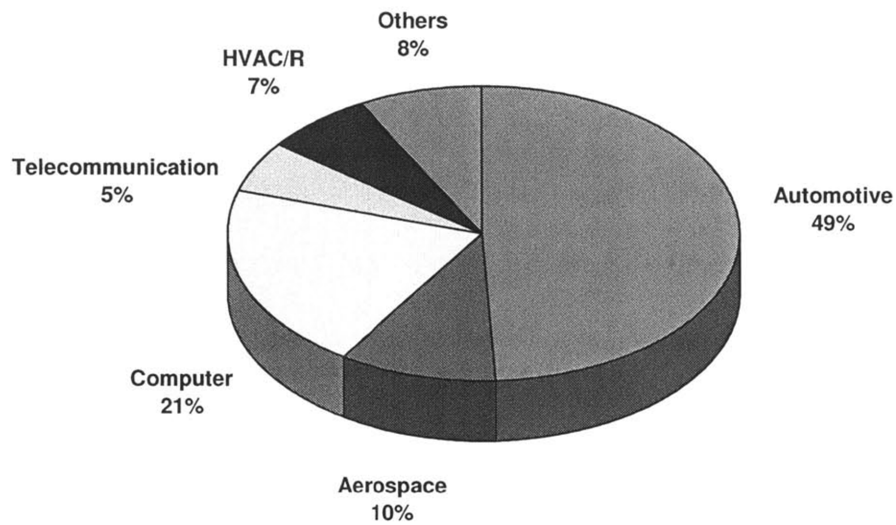

Figure 2-1: Warranty shares of different industries

The automobile, truck, engine, and parts manufacturers not only pay more for warranty claims, their average share of sales spent on warranty is also higher than other industries. Compared to automotive manufacturers, the HVAC and airframe manufacturers exhibit a lower rate of claims as well as a lower percentage of sales in warranty accruals. The computer and telecommunications manufacturers experience above average claims and accrual rates. However they keep less in their reserve funds than automotive manufacturers. This trend is basically determined by the relatively rapid obsolescence of their products. While a 10-year warranty on a passenger car is a desired selling point, on a cellular telephone such a long warranty would be absurd [1].

2.2 Warranties in Automotive Industry

2.2.1 General Trend

Automakers, the biggest warranty spenders across all industries, face a staggering $12 billion annual bill to fix vehicles covered by warranty. According to AMR research, warranty costs shave one percent to three percent off revenues for most automakers. It has been a huge financial burden and for some companies, warranty costs are wiping out profits. The situation is being worsened by a surge in product recalls. Analysis shows that in 2003, recalls associated with 529 brands of 19.5 million vehicles are issued, which greatly impacted the automakers that are already struggling to boost slim profit margins.

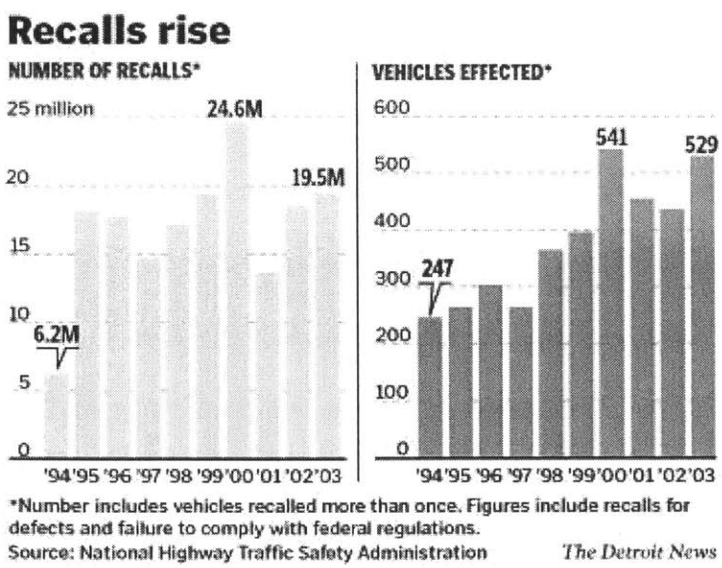

Figure 2-2: The impact of recall in automotive industry

Among all companies in automotive industry, the two big OEMs (Original Equipment Manufacturer), General Motors and Ford Motor Company, are the top two warranty spenders with 4.4 and 3.5 billion dollars warranty bills in 2003, respectively. Figure 2-3 shows the top ten warranty spenders in automotive industry for year 2003 in terms of dollar amount. However, there are not just GM and Ford. There are numerous other types of vehicles and markets, and numerous automotive system/components suppliers to those OEMs who each have their own warranty figures and trends. Warranty is not only a function of product quality and reliability, but also a function of a company's place in the supply chain of the automotive industry since typical warranty claims and amount spent by suppliers are only one tenth of those OEMs, such as Ford, GM, Caterpillar, Deere, Navistar, and Paccar. Those suppliers that have the closest relationship with their customers see the highest claim rates. It is probably because of a combination of effects of expected business relationship, closely watched purchasing arrangements, prompt supplier recoveries, and relatively ease of pinpointing the cause of a specific failure and tracing it back to a given supplier's design or manufacturing responsibilities. The detailed differences of warranty claims and accruals are explained in the next section.

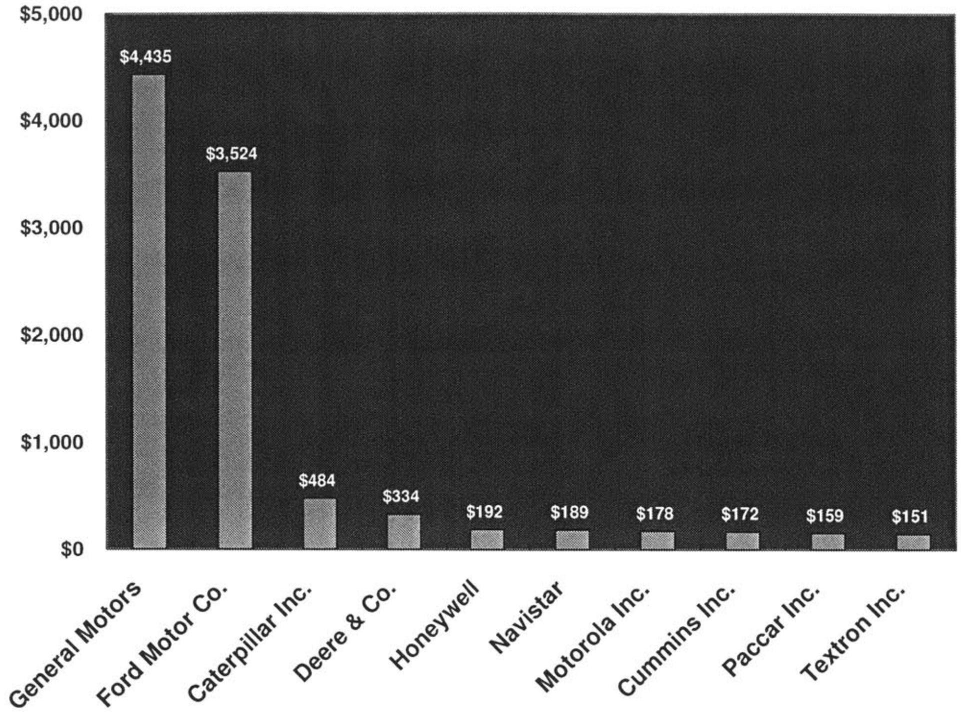

Figure 2-3, Top ten warranty spenders in automotive industry in 2003

2.2.2 Automotive Suppliers vs. OEMs

An OEM (original equipment manufacturer) is usually defined as a company that uses product components from one or more other companies to build a product that it sells under its own brand name. Automotive OEMs are more than just passenger car manufacturers. All US-based manufacturers also produce trucks, buses, recreational vehicles, fire engines, ambulances, garbage trucks, construction equipments, farm equipments, riding lawn mowers, motorcycles, all-terrain vehicles, golf carts, and other types of motorized vehicles. The companies that provide components or sub-systems directly or indirectly to OEMs are called suppliers. However, in the automotive industry, the line between the two is far from definitive. Some companies manufacture their own automobiles as well as systems such as engines and transmissions for other OEMs, while others are more general suppliers to the OEMs but still, in some special cases, build specialty vehicles such as golf carts. In the supplier world, the companies that provide products directly to OEMs are also referred as the Tier one suppliers. Those companies that provide components directly to the Tier one suppliers, thus indirectly supply components to OEMs are referred as the Tier two suppliers. Some suppliers might be both Tier one and Tier two depending on the customers of their products or services. A common rule to simplify the confusion between OEM and supplier is to find out if the company's brand name is outside the vehicle or not. If yes, then the company is OEM. For example, Ford Motor Company may purchase electrical system from Visteon. However only the Ford blue oval appears on the front or back sides of the vehicle as the brand name. Visteon logo is only stamped on the electrical control box and cannot be seen by the customers.

The analysis done by Warranty Week [1] identified 44 OEMs and 107 suppliers in the automotive industry that are also American companies. The claims and accrual rates for the 44 OEMs is at the range of 2.4% to 2.8%, as Figure 2-4 shows.

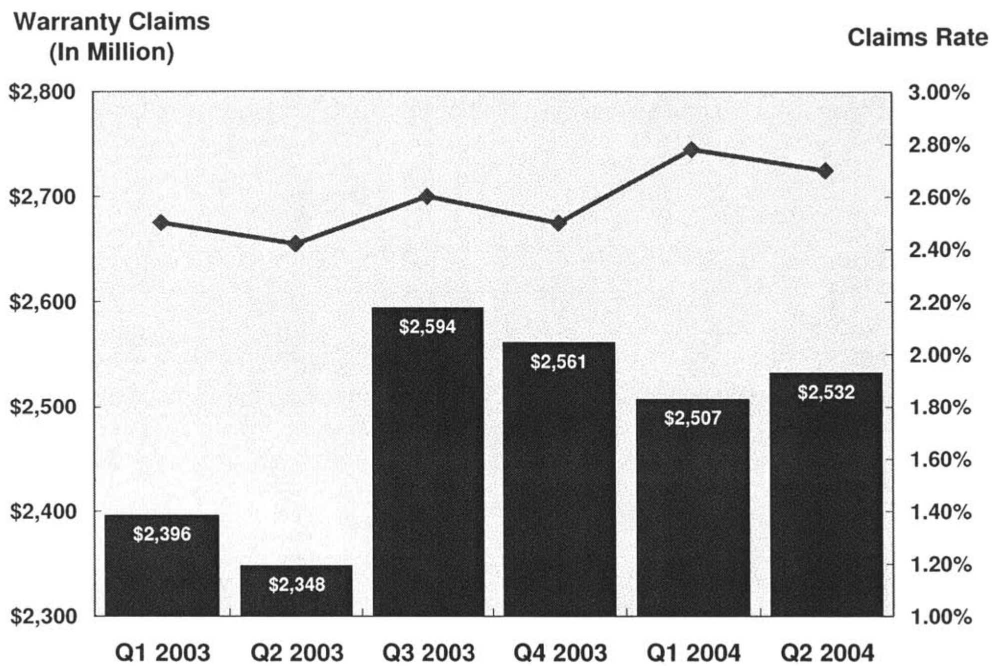

Figure 2-4: Automotive OEM warranty claims and claim rates

Warranty cost and claim rate for OEMs have been trending higher since the first quarter of 2003. As mentioned earlier, a surge in product recalls is perhaps the primary reason. But the overall trend lines are actually fairly stable while the offset zero on the scale of the chart makes it look like a big jump.

Automotive suppliers seem to follow the trend of OEMs in terms of warranty claims and claim rates, although the actual figures are lower as indicated in Figure 2-5. The typical warranty claims and accrual rates are in the 0.5% to 0.7% range. The suppliers of minor automotive components such as brakes, mufflers, tires, shocks, interiors, sunroofs, lights, audio, climate control, glass, and paint are more accustomed to seeing claims and accrual rates in the 0.2% to 0.4% range, which are much lower compared with major system suppliers that manufacture engines and transmissions.

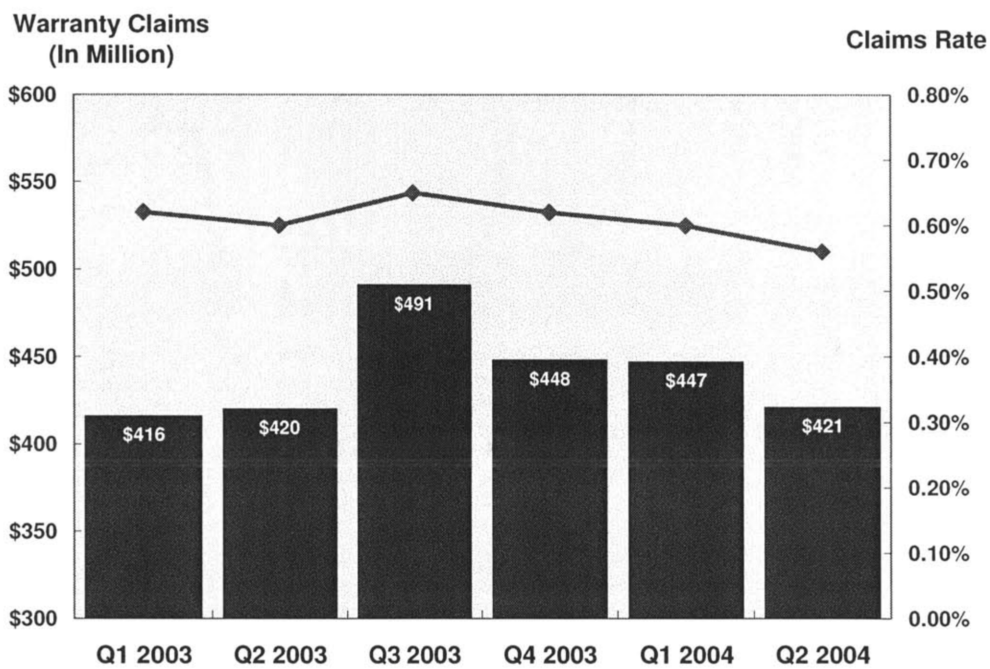

Figure 2-5: Automotive supplier warranty claims and claim rates

Due to the reason that in the commercial vehicle market suppliers usually provide their own warranties directly to the customers, the big drive-train manufacturers do not follow the OEM vs. supplier model. They are seeing claim rates not far below those seen by the OEMs they supply. For instance, when a drive-train supplier sells a tractor axle to Freightliner for use in an on-highway 18-wheeler, the ultimate customers receive their warranty directly from the axle supplier, not Freightliner. Figure 2-6 shows the warranty trend of commercial truck suppliers from first quarter of 2003 to the second quarter of 2004.

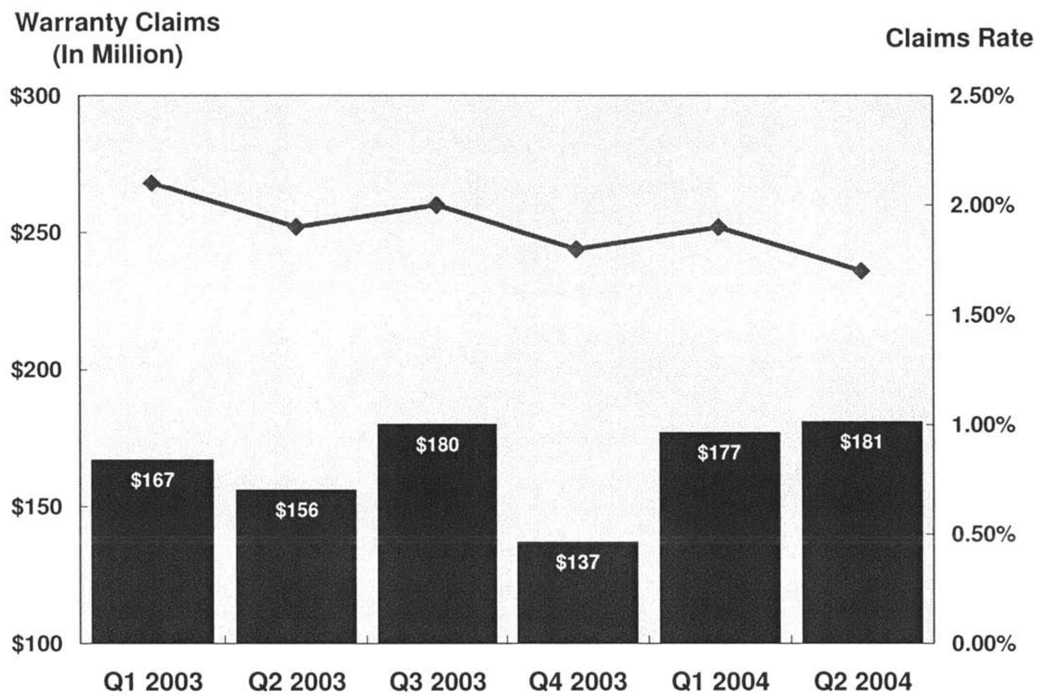

Figure 2-6: Commercial truck supplier warranty claims and claim rates

2.2.3 Automotive Suppliers

As mentioned in section 2.2.2, automotive suppliers see different warranty trends and claim rates depending on the types of system and component they manufacture.

Suppliers that provide critical systems, such as engines, transmissions, axles, and suspensions, are encountering a similar figure as OEMs, while suppliers that manufacture the rest of the components enjoy a much lower warranty cost. The primary reason is that OEMs pay the final bill when there is a warranty claim. However, in recent years there is an increasing trend for OEMs to transfer warranty liability to suppliers who are traditionally not responsible for the warranty of their products. This trend may put automotive suppliers that have less negotiation power in the quoting phase to a worse financial situation if big warranty, or even recalls, occurs. Of course, many automotive suppliers provide both critical and minor components, thus the warranty results of these suppliers are somewhere in the middle. Figure 2-7 shows the comparison of warranty claims rates for suppliers whose products are mainly drive-train components and those whose products are mainly brakes, shocks, and exhaust.

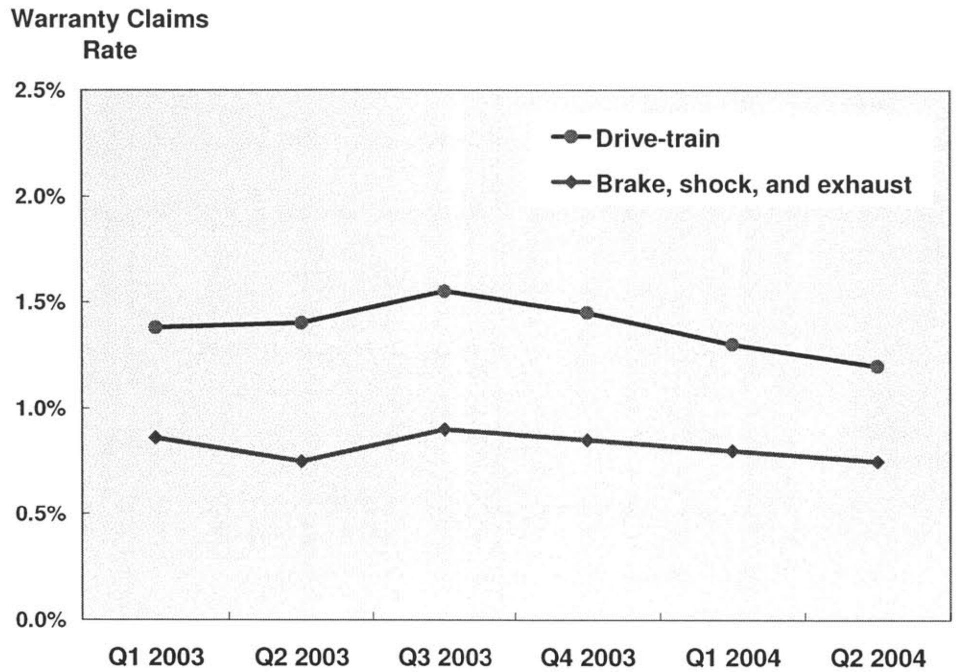

Figure 2-7: Comparison of warranty claim rates between drive-train suppliers and brakes, shocks, and exhaust suppliers.

Within the drive-train category, there is a further difference in warranty claim rates depending on the subsystem. It is obvious that the engine makers encounter a much higher warranty claim rate than those who manufacture axles, brakes, and suspensions. On average, engine makers see a warranty claim rate of 2.8% while suppliers that manufacture axles, brakes, and suspensions, have around 0.8%. This is mainly because a lot of newer technologies are emerged in the engine design than the traditional designs of axle, brakes, and suspensions. Some immature technologies cause potential failures in the real world. In addition, an engine failure is much more severe and expensive to fix than failures caused by most brakes and suspensions. Three suppliers that manufacture axle, suspension, and brakes for the commercial vehicles are compared in terms of warranty claims and rates for year 2003. Figure 2-8 indicates that all those three suppliers have very similar total warranty cost and claim rates.

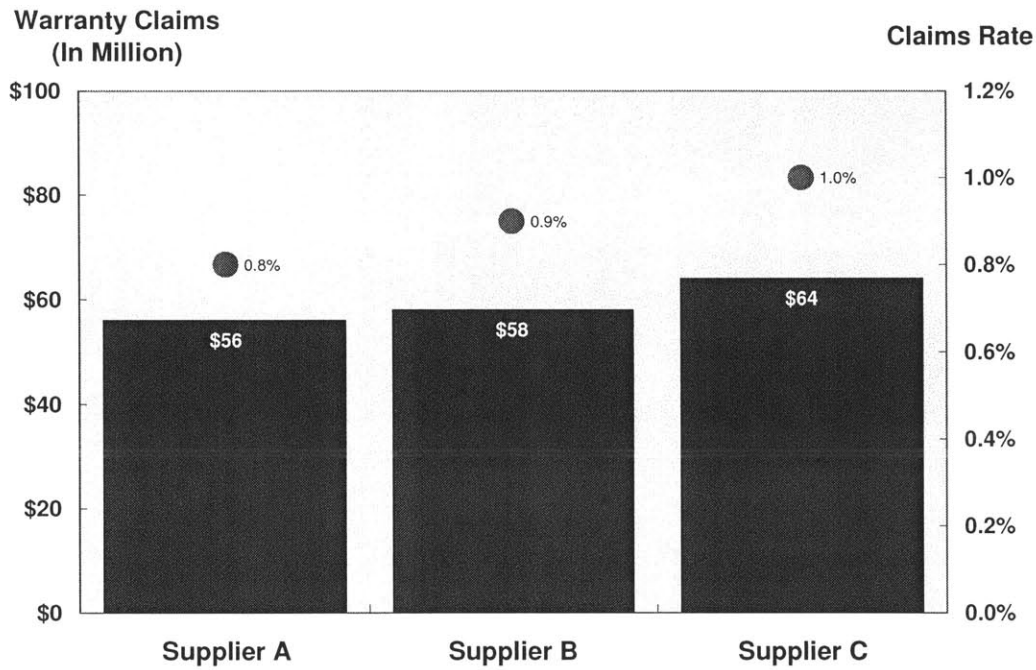

Figure 2-8: Warranty claim rate of three automotive suppliers

3. Warranty at an Automotive Supplier

3.1 Introduction

The supplier studied in this thesis is a multi-billion global supplier of a broad range of integrated systems, modules and components to the motor vehicle industry.

Starting from this point, the information used in this research primarily relies on data and interviews collected from this automotive supplier. All presented warranty numbers, trends, and interviews are altered to protect proprietary interests of the supplier. The overall observations, conclusions, and recommendations are still applicable from the academic point of view.

3.2 Warranty Process Flow

Figure 3-1 shows a typical warranty process in an automotive supplier. The process follows a timeline as indicated by the arrows. It proposes to use multiple functional groups to control the warranty. Different colors are used for the easy identification purpose as the following:

- Value chain responsibilities are in the green blocks
- Production responsibilities are in the blue block
- Warranty administration responsibilities are in the pink blocks

- Financial responsibilities are in the black blocks

- Problem solving responsibilities are in the red blocks

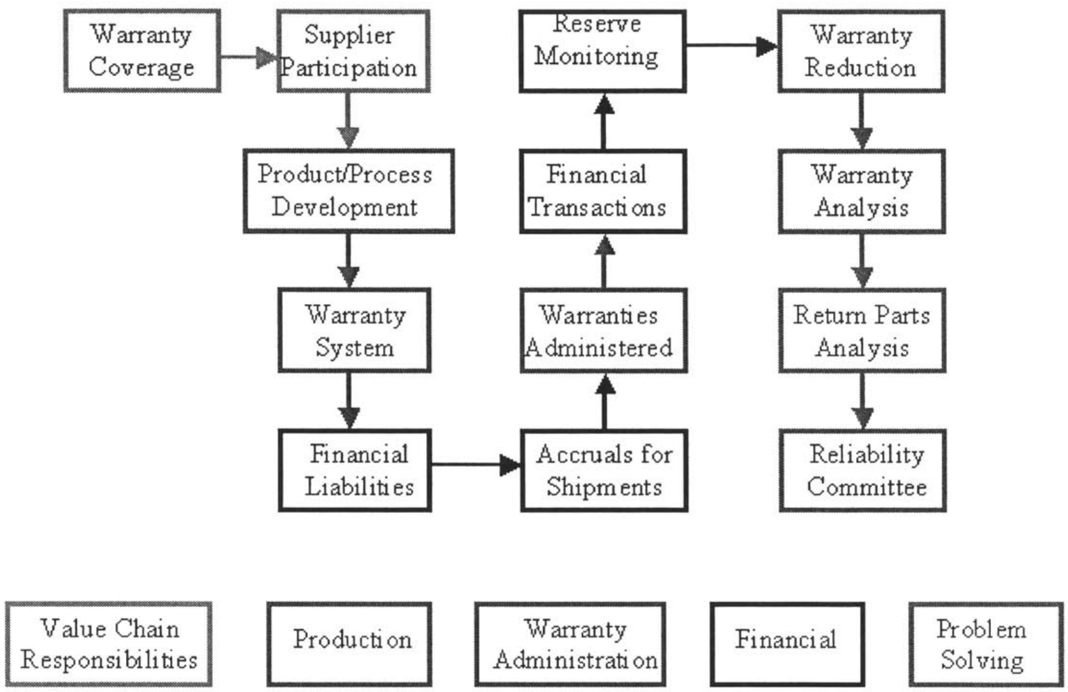

Figure 3-1: Typical warranty process in an automotive supplier

Detail descriptions about each activity are in the following:

(1) Warranty Coverage: OEM Sales negotiates long term agreements (LTA) with major customers and these LTA include warranty coverage conditions - OEM Sales may negotiate additionally special warranty extensions with major fleet customers - or - competitive equalization (CE) warranty giveaways - OEM Sales also publishes

extended vocational warranty coverage and advantage plan purchased warranty options to the marketplace each year.

(2) Supplier Participation: Purchasing negotiates and includes supplier warranty responsibility in contracts. Historically these have been generic. More emphasis placed on key commodity partners can help drive liability mitigation and improved performance.

(3) Production/Process Development: Warranty feeds the development cycle via Failure Mode and Effect Analysis (FMEA) and is integral to the test and validation plan.

(4) Warranty System: Warranty repair failure mode coding and specifications for selecting parts for return and analysis are designed into the administrative systems. This is an ongoing evolution. As product field performance surfaces new issues, new codes are added as required in order to streamline top problem scoping and part return flags can be set to acquire sample-failed parts for root cause analysis.

(5) Financial Liabilities: Quality establishes product warranty accrual rates each cycle based on historic warranty performance and known future contributing factors such as administrative, product design, or manufacturing process changes.

(6) Accruals for Shipments: Rates are built into plant standards and accumulated into reserves as products are shipped.

(7) Warranties Administered: Dealers call into warranty reporting system before repairing a product. System personnel help diagnose, recommend the proper repair, and approve the claim as warrantable. Claim details are captured and recorded into warranty databases. Digital photographs are often attached to the claim. Parts may be requested to be returned to the centralized return facility for further root cause analysis. In addition to warranty, sales also administer product support payments associated with related safety campaigns and retrofits. Annual budgeted discretionary sales policy payments are also processed thru these systems.

(8) Financial Transactions: Headquarters warranty systems feed accounting systems to issue customer payment for approved claims. These payments can be either credits to customer receivables, cash thru accounts payable, or parts shipped by aftermarket distribution. The claim value is charged against appropriate divisional warranty reserves that were funded by plant accruals.

(9) Reserve Monitoring: Quality monitors the adequacy of warranty reserves each quarter by comparing actual warranty paid to forecast expenses based on the accrual rate model. Reserve balances are adjusted quarterly as surplus or deficit indications exist.

(10) Warranty Reduction: Engineering and Quality steering committee reviews top warranty problems and assign the appropriate design or manufacturing team to address the issue. Teams utilize problem-solving discipline.

(11) Warranty Analysis: Interactive web based warranty analysis tools are available to employees. Trend analysis, Paretos, early warning, and detailed claim drill downs are some of the available options.

(12) Part Returns Analysis: the company centralized parts return facility analyses material for problem solving teams, often in conjunction with divisional engineering or suppliers as the situation requires.

(13) Reliability Steering Committee: Long run views of underlying systemic issues found by field reliability problem solving teams are addressed by the executive steering committee and corporate systems addressed accordingly.

The corresponding functional groups for all activities are captured in the following matrix (Table 3.1). It has a format similar to the House of Quality as it was developed by the quality group. It is a fairly well developed structure with well-defined details as explained in above. It builds up a good foundation for further continuous improvement work.

Warranty Process		Warranty Coverage	Supplier Participation	Product / Process Developed	Warranty System	Financial Liabilities	Accruals for Shipments	Warranties Administered	Financial Transactions	Reserve Monitoring	Warranty Reduction	Warranty Analysis	Part Returns Analysis	Reliability Committee
Functional Lead / Participation	Sales	X	x		X			X	X		x	x	x	x
	I.T.				x			x	x			x	x	
	Product Management	x	x	X		x					x			X
	Procurement		X	x							x			x
	Engineering	x		X	x	x		x			X	X	X	x
	Quality		x	X	x	X	x		x	X	X	X	x	X
	Finance					x	X		X	x				

Table 3.1: Warranty process/functional group matrix

Figure 3-2 shows the architecture of a typical warranty reporting system that is designed to reduce the time to find the new warranty issues and improve customer satisfaction.

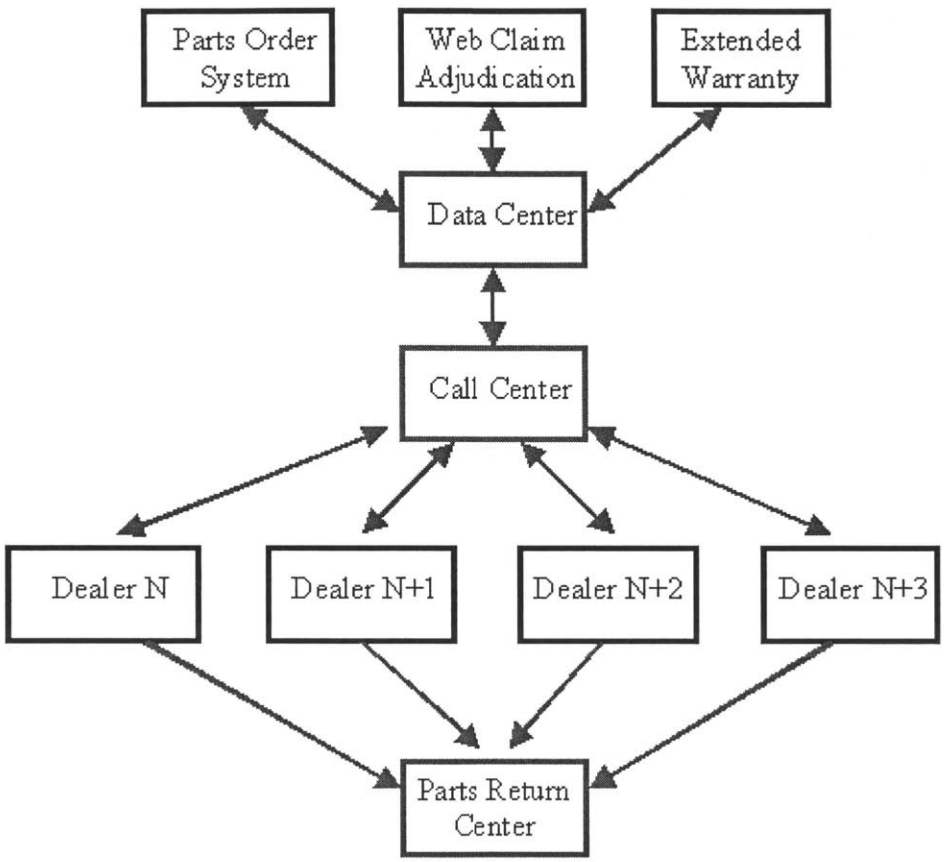

Figure 3-2: Architecture of warranty reporting system

3.3 Categories of Warranty Failures

3.3.1 Major Categories

The automotive supplier studied directly covers the warranty for the end users, thus has its own warranty database. The warranty data for the past five years have been collected, analyzed, and then grouped into four major categories: Design, Manufacturing, Supplier, and Customer. The categories minimize overlap and ambiguity while providing a framework for analysis of warranty failures that are reported by the warranty database. We used a top-down and a bottom-up approach to create the data categories used. The top-down approach is based on a brainstorming session, which drew on our experience and discussion with internal warranty experts. The bottom-up approach is used to create subcategories within the major categories after careful examination of the failures in all products. The definitions used for the failure categories and subcategories used in this research are listed in Table 3.2.

Category	Definition	Examples
Design	Any failure that is caused by insufficient design such as inadequate requirement, specification, reliability, analysis, test validation, robustness, and design discipline.	An axle that cracks prematurely. A seal that leaks under extremely cold environment.
Manufacturing	Any failure that is introduced by a manufacturing process due to inadequate capability or process failure.	Contamination in a plating bath causing early corrosion. Axle diameter out of tolerance.
Supplier	Any failure that is due to the use of supplier material, component, or subsystem not meeting the agreed specifications, quality and reliability requirements.	An undersized bolt breaks under normal driving conditions
Customer	Any failure that is caused by customer abuse and misuse.	30,000 lbs rated suspension is installed on a 40,000 lbs truck.

Table 3.2: major categories of warranty failures

For each failure, a thorough investigation has been done by product and quality experts to determine which category that a specific failure belongs to. For some failures, multiple categories may be assigned based on subjective estimate of percentage on each category. Finally, all failures are organized and then summarized in Figure 3-3.

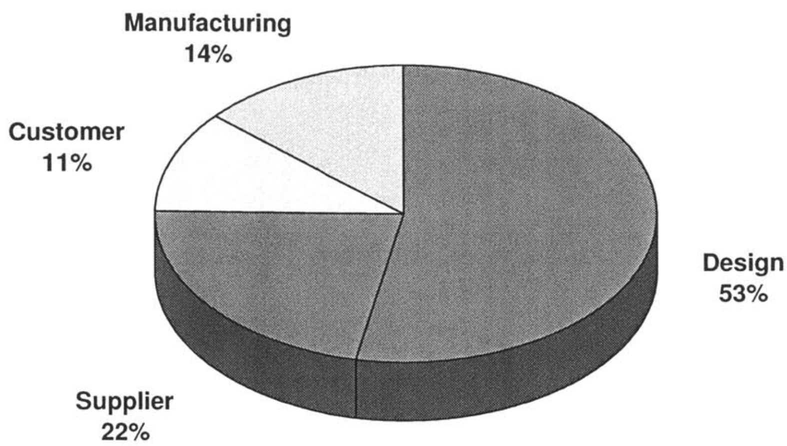

Figure 3-3: Percentage of each failure category

As we can see from Figure 3-3, Design related failures account for more than half of the entire warranty claims. Following Design related failures is the Supplier, which is responsible for almost one quarter of the total. Two relatively minor categories are Manufacturing related failures (14%) and Customer related failures (11%). This analysis helps to show a clear picture of the entire warranty problem and indicates a direction of where the most effort should be put in to reduce warranty claims. There is no doubt that design related issues should be addressed first to maximize improvement. However, it is obvious that these four major categories are fairly general and not detailed enough for more sophisticated analysis. A further breakdown of each major category is illustrated in the following section.

3.3.2 Sub-categories

To better understand which particular portion of the process causes most warranty issues, each major failure category was further broken down into sub categories where applicable. Some minor subcategories that have negligible number of claims are not included in this study for simplicity.

Four subcategories identified for design related failures are:

1. Design Knowledge
2. Test Validation
3. Specification/requirement
4. Design Discipline

Manufacturing related failure, which has a much lower share compared with design related failure, has two subcategories:

1. Process Validation
2. Process Capability

Supplier related failure is the No. 2 for the entire warranty claims and consists of three subcategories:

1. Supplier Competency

2. Supplier Black-box Design

3. Supplier Process Capability

Customer related failure contributes the least to the total warranty and can be divided into two subcategories:

1. Customer Misapplication

2. Customer Misuse/abuse

Table 3.3 lists all sub categories with definitions.

Category	Sub Category	Definition
Design	Design Knowledge	Failure caused by lack of design knowledge, outdated design guideline, incomplete/simplified design analysis, and lack of understanding on robustness engineering
	Test Validation	Failure caused by lack of understanding on lab test duty cycles, usage conditions, failure modes, and insufficient test facilities and samples
	Specification/Requirement	Failure caused by incomplete/wrong product specification, reliability target, and lack of understanding of customer requirements
	Discipline	Failure due to insufficient design discipline, neglect of certain design/test/analysis stages and design review
Manufacturing	Process Validation	Failure due to lack of process/manufacturing validation before mass production
	Process Capability	Failure due to lack of process control and capability
Supplier	Supplier Competency	Failure due to insufficient supplier knowledge, competency, and engineering support
	Supplier Black-box Design	Failure caused by the lack of understanding and validation on supplier's parts due to supplier black-box design.
	Supplier Process Capability	Failure due to lack of process control and capability of supplier's operation
Customer	Customer Misapplication	Failure caused by applying the wrong system to application at customer site
	Customer Misuse/Abuse	Failure caused by misuse/abuse of the system by the end user such as vehicle driver

Table 3.3: Sub categories of warranty failures

Figure 3-4 shows the Pareto plot of all 11 subcategories. It is interesting to see that the top three subcategories are all design related failures, while number four and five are both supplier related failures. This analysis further confirms that a lot of issues in the product design process and supplier cooperation must be addressed to significantly reduce the warranty cost. The remaining sections of this chapter further break down the subcategories to show a clear picture of each major category.

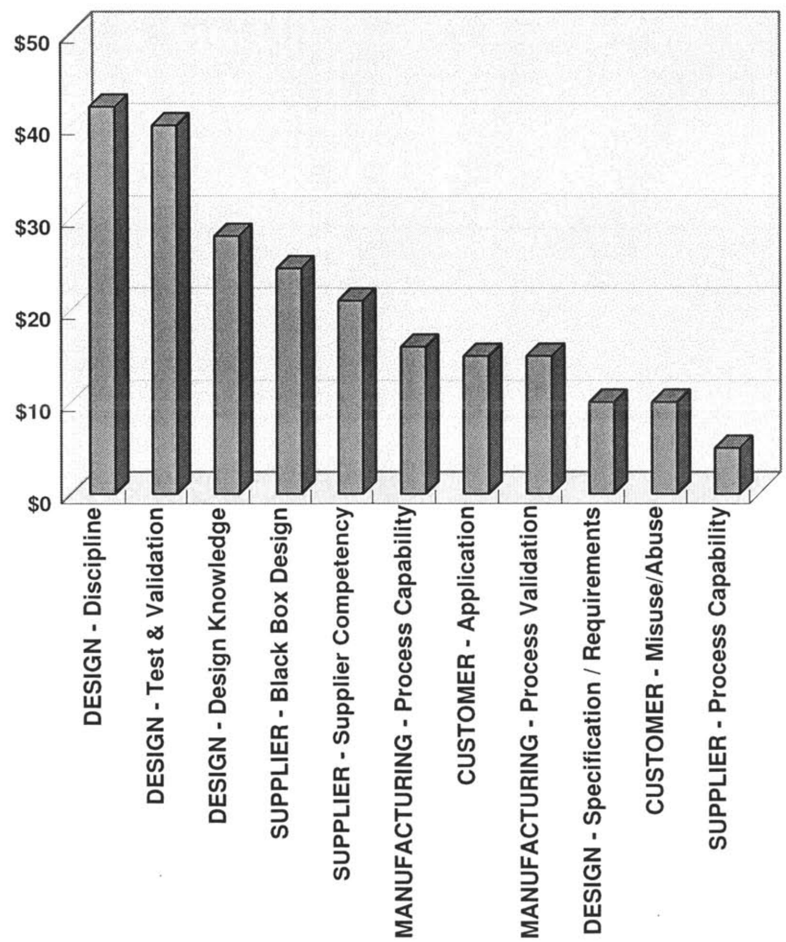

Figure 3-4: Pareto plot of 11 subcategories

3.4 Design Related Failure

Figure 3-5 shows the breakdown of four subcategories under design related failures. As mentioned before, the failures because of design issues account for more than half of the total warranty claims. More important, the top three subcategories across all major categories are all design related. They are (1) Design Discipline, (2) Test and Validation, and (3) Design Knowledge.

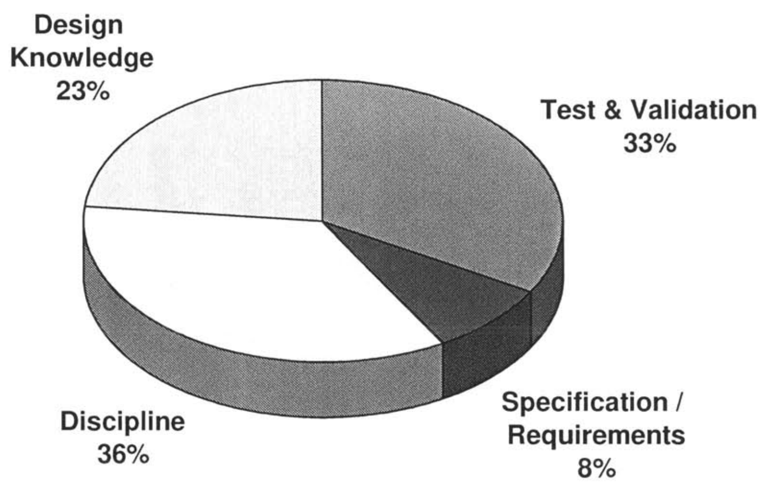

Figure 3-5: Break down of design related sub categories

Lack of design discipline is related to many issues such as skipping important design phases, canceling or delaying design reviews, and ignoring adequate testing before design release. Some of the reasons may be of time pressure and budget constraint. Others can be cultural or political issues within the organization. It is unfair to blame design engineers or project managers without really understanding the root causes of design failure. The time for a company to bring a product from the conception stage to delivery to customers determines a company's success. Therefore, nobody can afford the risk of delaying the projects. However, the quality and reliability of the products cannot be compromised despite having less time to develop and test them.

The second top design related issue, lack of test and validation, might also have many root causes such as lack of understanding the failure modes or customer usages. Lack of design knowledge is not caused by single reason either. In order to further reveal all potential root causes, in-depth questions were asked in the surveys and interviews described in the next chapter.

3.5 Supplier Related Failure

Supplier related failure contributes to more than one fifth of the total warranty claims and is the second largest category. Within this category, the failure due to supplier black box design, which means the company has very limited information and control on supplier parts, is one of the two major subcategories as shown in Figure 3-6. The other one is supplier competency, which indicates that in many times suppliers are not capable enough to design high quality products, or are not willing to support engineering activities. Supplier capability is not a concern based on the analysis. The results are in line with the fact that most suppliers provide commodity components, not custom design, to the company studied. As a result, the company has less control in supplier design. In addition, suppliers may think their products are good enough to meet the applications. Assuming they have the mature manufacturing process, they do less engineering support. The root causes of the supplier related failures were also further investigated in the surveys and interviews.

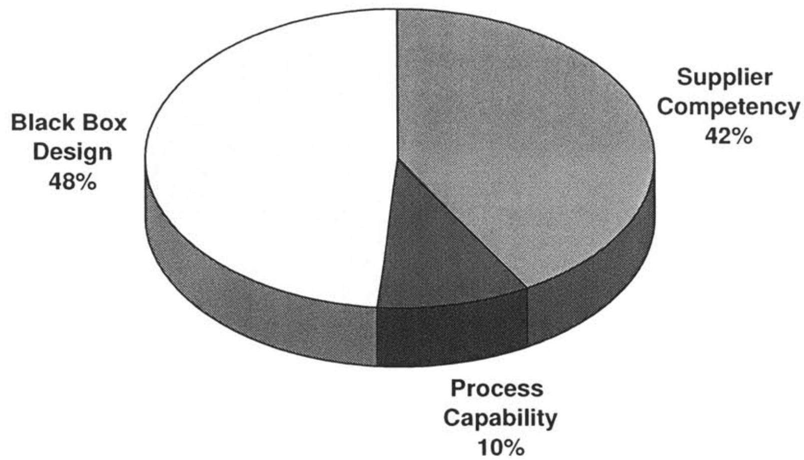

Figure 3-6: Break down of supplier related sub categories

3.6 Manufacturing Related Failure

Manufacturing related failure accounts for fourteen percent of the entire warranty claims. This result actually surprises us since we would expect more failures since such suppliers are generally seen as major manufacturing and assembly companies. It seems that the adoption of Shainin problem solving and Six-Sigma process improvement methodologies in recent years has made significant impact. The surveys and interviews shown in the later chapters further confirm this point. Within this category, the two subcategories are split half and half as shown in Figure 3-7. Most of the reasons that cause the lack of process validation could relate to lack of validation testing in design related failures. The reasons causing the lack of process capability are more complicated. Questions are asked in the surveys and interviews to either explore our above hypotheses and/or reveal the root causes.

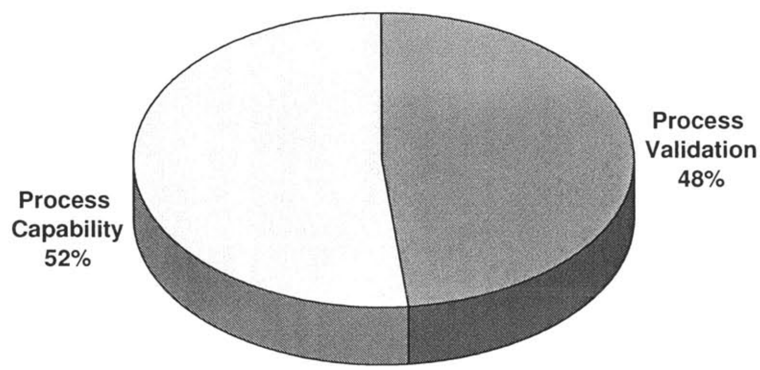

Figure 3-7: Break down of manufacturing related sub categories

3.7 Customer Related Failure

Last but not the least is customer related failure, which contributes to about one tenth of the total warranty claims. Sometime it is really hard to separate customer related failure from design related failure since customers do have some impact on the product development process. Furthermore, it is usually difficult to confirm that a failure is actually caused by customer misuse or abuse purely based on warranty reports. We identified several cases that customers put under-rated systems on a platform which is designed and rated to be operated under tougher load and/or environmental conditions. Customers from time to time misapply systems without consulting the company although they usually have been warned. Those cases sum up to sixty percent of total customer related failures as shown in Figure 3-8. It is generally difficult to prevent this type of failures since they are mostly out of the company's control. Together with the fact that this category is the least significant across all major categories, customer related failure is removed from the focus of this research.

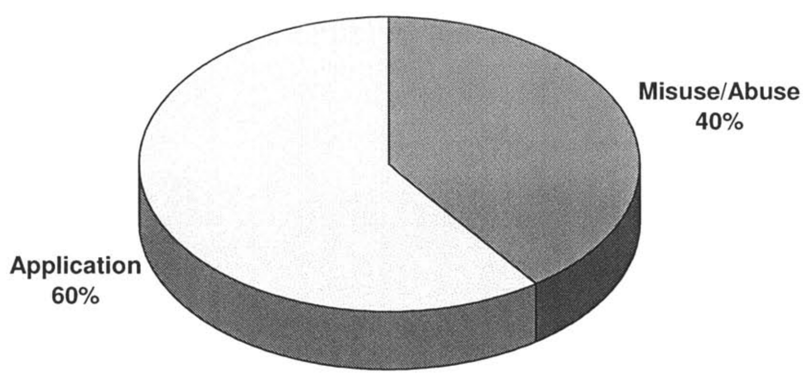

Figure 3-8: Break down of customer related subcategories

4. Surveys and Interviews

The warranty data analysis in chapter three concludes that most failures are caused by product design and suppliers. Furthermore, design discipline, knowledge, test and validation are the worst three areas followed by supplier black-box design and competency. Manufacturing process and customers, on the other hand, appear to be less significant. These findings help us to narrow down our focus on warranty root causes identification. In this chapter, we elaborate the two surveys and a series of interviews at the supplier site to reveal the root causes of warranty issues. The surveys are designed to test hypotheses raised in our analysis in chapter three as well as our thoughts, which cover various aspects of the warranty system with the emphasis on product design and supplier management. The interviews are used to confirm our conclusions from two surveys and to learn additional findings that are missed in the surveys.

4.1 Surveys

4.1.1 First Survey

(1) Hypotheses, demographics and survey questions

During the process of the research, especially the warranty data analysis stage, a series of hypotheses has been raised in terms of possible causes of most warranty problems. These hypotheses support the five aspects of system issue and cover many functional areas including engineering, administration, quality, operations, procurement, and information technology (IT). The first survey, composed of 14 multiple-choice questions, was designed to test these hypotheses using a broader range of opinions. Table 4.1 shows the details of each hypothesis and the question number(s) associated with it.

The questions of the first survey are listed in Table 4.2. All questions except for number 11 are multiple-choice questions with scale of “strongly disagree”, “disagree”, “neither disagree nor agree”, “agree”, and “strongly agree”

	Hypothesis	*Associated Question(s)*
A	Significant resources have been devoted to warranty reduction activities.	1
B	Additional resources (experienced engineers and testing budgets) are needed for quicker and more effective warranty resolution.	2, 3
C	Lack of use of data and fact causes subjective judgments on the effectiveness of corrective actions.	4
D	Engineering knowledge and experience are not adequate. As a result, some design related warranty issues happen.	5
E	Problem solving methods (Six-Sigma, 8D) are adequate to solve warranty problems caused by manufacturing.	6
F	Current warranty data tracking system is effective and efficient to provide early warning of warranty issues	7
G	Current cross-functional warranty reduction team approach is effective to resolve warranty issues	8
H	Some product development stages are skipped to meet time-to-market requirement.	9
I	A reactive mode dominates warranty reduction process. A proactive approach (i.e., promoting Design for Six-Sigma and Design for Reliability) should be used in product development to prevent warranty issues from happening.	10
J	Current accountability of warranty issues is not clear (i.e., who owns the warranty process? Who should lead the warranty reduction team?)	11
K	Analysis has to be based on supplier testing result due to lack of internal testing capabilities.	12
L	Instead of proactively solving warranty issues, supplier tends to hide warranty problems.	13
M	A Lessons Learned database has not been formally established.	14

Table 4.1: Survey hypotheses

1	What percentage of your work time is devoted to warranty related activities?
2	Current resources (Manpower) in your department are adequate for warranty issues.
3	Current resources (Manpower) in your department are being effectively utilized.
4	For design related warranty issues, there is sufficient engineering knowledge and experience to resolve problems.
5	More simulation and physical testing are needed to objectively determine the effectiveness of design-related warranty corrective actions.
6	For manufacturing related warranty issues, current Six-Sigma and 8D problem solving tools are adequate to resolve problems.
7	Current warranty reporting system is effective and efficient in providing early warning of warranty issues
8	Cross-functional warranty reduction teams are the best approach to promptly resolve warranty issues.
9	On Time Delivery is more critical than the rigid product design process, therefore, some product development process (PDP) may be skipped.
10	In addition to the reactive approach, warranty issues should be reduced proactively by applying Design For Six-Sigma and DFX (Design For Reliability, Manufacturability, Serviceability) in the new product development process (PDP)
11	Current warranty reduction activities include data collection, analysis, root cause identification and problem solving. With the addition of proactive warranty prevention in product development process (PDP), which of following function is the most appro - Product Engineering - Advanced Engineering - Operation - Quality - Reliability - Procurement - Sales - Other – Please specify
12	For supplier related warranty issues, the company does not usually have internal testing capability on supplier components.
13	For supplier related warranty issues, suppliers tend to disguise problems instead of proactively solving them with help from the company.
14	Lessons learned from warranty issues are documented and shared with other teams

Table 4.2: Questions of the first survey

An overall picture for the full warranty system is in the focus of this study so we need to interview people from all different functional areas as shown in Table 3.1. As a result, the survey was sent to more than 100 selected people from all related functional areas. All of those people are specially identified to ensure they have solid knowledge and experience of warranty issues. In order to get a higher response rate, the length of the survey is carefully controlled. The name of the person who takes the survey is not required, while the functional area and job title (either manager or employee) are required inputs. The percentage of number of people from each functional area is shown in Figure 4-1. Among them, about 80% are management level people such as chief engineers, project managers, and directors of functional areas, while the rest are engineers and analysts.

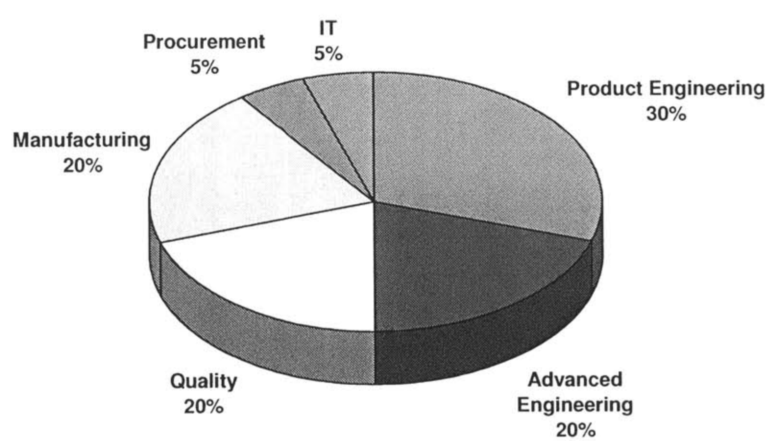

Figure 4-1: Percentage of each functional group survey participant

(2) Results of the First Survey

Details of all survey questions and results are shown in Appendix A.

Question (1) is designed to get a general figure of time spent on warranty by people surveyed. It is interesting to see that half of the people spend more than 30% of their work time on warranty, regardless of their functions. The result confirms Hypothesis A that a lot of resources have been devoted to warranty reduction activities for a typical automotive supplier.

Question (2) and (3) are related and both are designed to test hypothesis B, which indicates that additional resources, both manpower and testing budget, are required to resolve warranty issues. The results of these two questions indicate that some departments lack resource while others have sufficient resources to address warranty issues. In addition, most people believe current resources are utilized efficiently. This result indicates that how to utilize resources is not a concern, while how to balance resources among teams needs to be considered.

Sometimes, a corrective action is implemented without sufficient testing. People simply hope it works but unfortunately it does not. Question (4) is designed to test the hypothesis C that more objective facts based on data and testing result should be used to judge the effectiveness. The survey result clearly confirms that more testing, instead of guessing, should be used to determine if a re-design or corrective action will solve a warranty problem.

Question (5) tests what the perception is about adequacy of engineering experience and knowledge to resolve design-related warranty issues, which is the top major category of warranty failures. This question is different from resource related questions by asking about the quality instead of quantity of resources. From the results of the survey, most people tend to believe that current engineering knowledge and experience are fairly adequate, although some do think improvement is needed. Additional questions are asked in the follow-up survey to test the knowledge level of specific quality/reliability improvement methods, such as Design for Six-Sigma, robust design, and reliability engineering.

For manufacturing related warranty failures, question (6) is designed to test hypothesis E which states that current problem solving and avoidance methodologies, such as Six-Sigma and 8D process, are adequate and effective. The result suggests that these methods work well. This conclusion confirms that advanced problem solving tools reduce warranty issues caused by manufacturing.

Question (7) is designed to assess the effectiveness of current warranty reporting system. It is assumed that the current warranty administration process is effective and efficient to provide early warning on warranty issues. The survey result shows an overwhelming agreement. We conclude that with the help of modern information technology, the warranty reporting system provides prompt and sufficient information for warranty issue identification.

The current organizational approach on warranty problem solving is in the form of cross-functional team, rather than dedicated team. Question (8) is designed to test if this approach is the best way. Most people agree that current cross-functional team organization is the most effective and productive approach.

Question (9) is derived from warranty failure data analysis, in particular, the subcategory of "lack of design discipline". It is believed that some product development stages, such as test and validation, have been skipped to ensure on-time-delivery. Question (9) is designed to test if people think they should do it. The result shows that most people feel quality should not be sacrificed for faster product development. Since people do not think it should be done but it nonetheless is common, additional questions are raised in the follow-up survey to uncover more details about why it occurs.

Question (10) assumes that a proactive warranty prevention mode should be applied to actively reduce warranty issues. Several modern quality/reliability improvement methods in new product development process are mentioned to explain what we mean by proactive approach. It is not surprising to see most people surveyed believe the current reactive fire-fighting mode is not very effective and more attention should be brought to a proactive way.

Question (11) follows question (10) by asking which functional area is most appropriate to lead the entire process if the proactive warranty prevention approach is adapted in addition to the current reactive activities. This question is derived from hypothesis J, which states that current accountability of warranty process is not clear. The survey result confirms that people do not have consensus on which function should lead. However, the top three picks are product engineering, the quality department, and the reliability engineering department. The accountability issue is further analyzed and discussed in the interview section of this thesis.

Question (12) and (13) address supplier related warranty failure, which is the second major category. Result of question (12) confirms our hypothesis that automotive tier one suppliers usually do not test components purchased from tier two suppliers. Question (13) indicates that some tier two suppliers try to hide warranty problems, which can only make things worse later. The potential reasons that cause the lack of supply chain management is further discussed in the interview section.

Well-established lessons learned database is essential to warranty reduction since very often the same mistake happens again. Question (14) is designed to check if the company has such system that encourages people to share knowledge and lessons in resolving warranty issues. The result indicates that current lessons learned are not well documented and shared, thus a better infrastructure needs to be constructed.

(3) Statistical Analysis of First Survey Result

As mentioned before, survey respondents are composed of both management level and employee level personnel. A further statistical analysis is conducted to test if management people have different opinions from employees. For each question, the survey result is grouped by management and employee, and statistical t-tests are conducted to compare the difference between mean scores. Table 4.3 shows four statistical values: the mean scores of total respondents, of employee only, of management only, and the associated p-values.

		Total	Employee	Management	p-value
2	**Current resources (Manpower) in your department are adequate for warranty issues.**	2.7	2.7	2.7	0.842
3	**Current resources (Manpower) in your department are being effectively utilized.**	3.8	3.8	3.8	0.877
4	**More simulation and physical testing are needed to objectively determine the effectiveness of design-related warranty corrective actions.**	4.1	4.5	4.1	0.122
5	**For design related warranty issues, there is sufficient engineering knowledge and experience to resolve problems.**	3.3	3.5	3.3	0.726
6	**For manufacturing related warranty issues, current Six-Sigma and 8D problem solving tools are adequate to resolve problems**	3.8	3.8	3.8	0.912
7	**OnTrac is effective and efficient in providing early warning of warranty issues.**	3.7	4.0	3.7	0.455
8	**Cross-functional warranty reduction teams are the best approach to promptly resolve warranty issues.**	4.1	4.2	4.1	0.797
9	**On Time Delivery is more critical than the rigid product design process, therefore, some PDP stages may be skipped.**	2.3	2.5	2.3	0.825
10	**In addition to the reactive approach, warranty issues should be reduced proactively by applying Design For Six-Sigma and DFX (Design For Reliability, Manufacturability, Serviceability) in the new product development process (PDP).**	4.1	4.0	4.2	0.142
11	**For supplier related warranty issues, the company does not usually have internal testing capability on supplier components**	3.3	3.7	3.2	0.330
12	**For supplier related warranty issues, suppliers tend to disguise problems instead of proactively solving them with help from the company.**	3.4	3.2	3.5	0.575
13	**Lessons learned from warranty issues are documented and shared with other teams**	2.7	3.0	2.7	0.589

Table 4.3: Mean scores and p-Values of first survey questions

The mean score is the average of individual response in a one-to-five scale indicating "strong disagree", "disagree", "neutral", "agree", and "strong agree", respectively. P-value of 0.05 or less suggests statistical difference between two mean scores. From the results we conclude that there is no evidence that management people give different opinions from employees. The conclusion is further confirmed after we conducted face-to-face interviews. This is consistent with the lean organization of this particular automotive supplier; most management people spend a significant amount of time on front line work.

4.1.2 Follow-up Survey

After the first survey, we realize that some aspects of warranty issues, particularly in the crucial product development process, are still unclear. For instance, questions in the first survey do not answer why people skip important product development stages as they have answered that they should not. Furthermore, based upon the findings from the first survey, we began to realize that broader organizational and cultural related questions may have to be addressed in order to improve the system. As a result, we conducted a follow-up survey to be answered by product development people. The questions are listed in Table 4.4.

1	The company decisions are often made in such a way that treat the project's on-time-delivery as more important than rigid product development stages. A) Strong agree B) Agree C) Neither agree nor disagree D) Disagree E) Strong Disagree
2	If decisions are made to prioritize time ahead of quality, what are the reasons that decisions are made in that way? A) Incentives to complete on time are strong and immediate while quality results are slower (and uncertain) to show up B) Lack of project management skills C) Insufficient product engineering resources D) Lack of accountability when system later fails E) Pressure to fit customer schedule F) Some stages in PDP have no added value G) No warranty concerns from similar/prior products H) Lack of knowledge with some of the PDP stages I) Suppliers cannot meet their schedule J) Others – please specify
3	How do you grade your knowledge level of quality/reliability improvement methods such as statistics, robust design, Design for Six-Sigma, and reliability engineering? A) Very good B) Good C) Medium D) Poor E) Very poor
4	Relative to how often there could be benefit to using these quality/reliability improvement methods, how often do you actually use them? A) Always B) Almost always C) Sometimes D) Seldom E) Never
5	What are the reasons that keep people from using these tools? A) Not enough time B) Lack of experience and understanding of the tools C) Not required by customer D) Not required by product development process (PDP) E) Others – please specify

6	Current test validation is not adequate due to which of the following reasons: A) Not enough time B) Lack of belief in the importance of test validation C) Lack of correlation between field performance and lab testing D) Insufficient knowledge of potential failure mode E) Insufficient lab equipment/facility F) Lack of test samples G) No customer requirement on testing H) Others – please specify
7	What are the reasons why the company does not perform internal testing on supplier components? A) Budget constraints B) Suppliers testing is trusted C) Lack of communication with suppliers D) Component is not part of company core competency E) System test already covers component failures F) No warranty concerns from similar/prior components G) Others – please specify
8	What actions can help to reduce the time to resolve warranty issues? A) Improve communications between operation and engineering B) Improve accountability on warranty issues C) Improve reward system D) Others – please specify
9	How do you grade the current company reward system to promote employee efforts to reduce warranty? A) Very good B) Good C) Medium D) Poor E) Very poor
10	How do you grade the current company reward system in terms of increasing employees' relevant technical knowledge and capability? A) Very good B) Good C) Medium D) Poor E) Very poor

Table 4.4: Questions of the second survey

Question (1) and (2), following question (9) in the first survey, are designed to further reveal reasons for skipping certain product development stages. Results of question (1) shows that two thirds of people surveyed agree that the company decisions are often made in such a way treating the project's on-time-delivery as more important than following rigid product development process. Furthermore, answers to question (2) reveal that the top reason is "the pressure to fit customer schedule". The next two most important reasons given by the respondents are "incentives to complete on time are strong and immediate while quality results are slower (and uncertain) to show up", and "insufficient product engineering resources". "Lack of accountability when system later fails", "no warranty concerns from similar/prior products", and "lack of knowledge with some of the product development stages" are also chosen by some respondents.

Question (3), (4) and (5) are related to question (5) of the first survey, which ask if engineering has sufficient knowledge and experience on quality/reliability improvement methods. More specifically, question (3) asks respondents to self-evaluate their knowledge on advanced methods including statistics, robust design, Design for Six-Sigma, and reliability engineering. Without surprise, all people rate them either "medium" or "good", which is consistent with the result of question (5) of the first survey. Question (4) goes one step further by asking how often people actually use those methods. One fourth of the people surveyed use these tools almost always. More than half of them sometimes use these tools, while one fifth of them seldom applied these tools in their daily work. This result surprises us since we observe a much lower usage rate of these methods. When asked why some people do not use these tools, the top reason raised is "lack of experience and understanding of tools". Combined with result of question (3), we conclude that people with good knowledge on these methods use them more often than people that do not understand them well. Additional training is desired to promote better implementation of these methods. The second reason of not using these tools is "not enough time", which indicates a lack of resource. Some people also mention the reason of "not required by customer". This finding indicates that a reactive quality/reliability improvement culture dominates the company surveyed. Detailed questions are asked in the interviews to explore this conclusion further.

Question (6) and (7) are engineering test/validation related. Result of question (6) reveals the root causes of insufficient test and validation during product development process. The top two reasons are "lack of correlation between field performance and lab testing", and "insufficient knowledge of potential failure mode", both of which are knowledge related. The third reason is "insufficient lab equipment/facility", which is resource related. Question (7) asks why the company does not perform internal testing on supplier components. The top reason appears to be "supplier testing is trusted", followed by "system level test, which is done at the company, already covers component failures". Combination of results from questions (6) and (7) suggest that a lot of real world failures, including supplier components, are not detected in testing because engineers do not know the right specifications (load, duty cycle, environment, setup, etc.) which are derived from known failure modes and reasonably accurate field-lab correlation.

Question (8) gives respondents the opportunity to offer suggestions that can help to reduce the time to resolve warranty issues. Most people believe that improving accountability on warranty issues would be the most effective solution. Other solutions include better communication between operation and engineering, and a better reward system on warranty reduction activities.

Question (9) and (10) are designed to assess the two reward systems, promoting employee efforts to reduce warranty and increasing employee's relative knowledge and capability. The result shows that people are not satisfied with either reward system. Only nine percent of all respondents believe the current system to reward warranty reduction efforts are good, while the rest rate it either "medium" or "poor". Ratings of current reward system for increasing employee's relative knowledge and capability are even worse. Eighteen percent of the respondents rate it "very poor". It is clear that the company needs to improve its reward systems to encourage employees to both improve their skills and to focus on warranty reduction activities.

4.1.3 Survey Conclusions

A list of preliminary conclusions, as shown below, are drawn from the results of two surveys and summarized according to five aspects. All conclusions are to be explored further in the individual interviews.

- Product development related:
  - The product development process is not followed (i.e., some stages are skipped to ensure on-time-delivery) due to tight customer schedule pressure and the fact that incentives to complete project are immediate while quality results are slower to show up.
  - Inadequate test/validation due to insufficient knowledge on both potential failure modes and correlation between lab test and field test. And lack of time makes it easier to avoid finding out about the failure modes and correlations
  - Insufficient understanding and experience on advanced quality/reliability improvement methods as well as lack of time keep engineers from using these tools.
- Resource related:

- Inadequate test lab equipment and facility causing insufficient test/validation.
- Lack of incentives discourages employees from working on warranty issues and from improving their relevant knowledge and capability.
- Insufficient manpower in certain key functional areas.
- Unbalanced resource among functional areas. Some teams have extra capacity while others are overwhelmed by workload.
- Current lessons learned database needs to be improved to promote knowledge sharing.

• Supplier related:

- Usually supplier's components are not evaluated since the company purchases black-box designs and hope they are good enough.
- Some suppliers tend to hide warranty problems until it gets worse and uncontrollable.

• Warranty organization related:

- Poor communication between engineering and operation causes delayed implementation of corrective actions.

- Cultural related:
    - Reactive warranty fire-fighting mode dominates the entire warranty reduction process.

4.2 Interviews

4.2.1 Background and Demographics

Although the two surveys described above gave us a lot of statistical data and information about the root causes of warranty, the written format of the survey limited us from getting more detail and broader understanding about this very complex subject. In order to get the deeper understanding, direct interviews were used to support and confirm our survey findings and to begin to explore improvement actions. The interview results were also analyzed to obtain understanding of the key warranty "System Issues". The interviews questions include the five aspects determined in the survey conclusion and open section to let interviewees to give free opinions. All interviewed persons were assured to keep their statements as confidential information to build up a trust with them for an open-mind discussion.

In each face-to-face interview, we asked the interviewee to provide the following information:

a) Identify the areas that they are familiar with in terms of warranty related issues.

b) Describe warranty related issues in their identified areas.

c) Provide details or reasons for the existence of those issues.

d) Make comments or suggestions to resolve those issues if they could.

A large amount of information is collected from the interviewees, who are experts from across all functional areas. Their positions included vice president, directors, chief engineers, managers, senior engineers, and specialists working in the quality, engineering, purchasing, and sales groups.

4.2.2 Results and Discussion

Since a large amount of information was collected from the interviews, it is most effective to combine similar comments and organize the interview results according to the five aspects of warranty issues as described in section 4.1.3. We reproduce here the interview results grouped by these five categories.

Product development related quotes

- "Our product development process is the best engineering process developed so far. We need to follow it. There are two reasons for not following the process: (a) Lack of knowledge or education; (b) Know it but don't do it either because of personal or management/leadership failure."

- "Our engineering errors can contribute to warranty. We allow engineering to operate in vacuum. Design with only inputs from design group (not listening to other groups). There are tremendous amount of changes from prototype to product launch. During this time, try to meet requirements with less involvement from manufacturing and quality."

- "Cost reduction eliminated some component features. Then those eliminated features caused new problems."

- "We need to have a centralized reliability group. Need to incorporate reliability with design."

- "We made a mistake in relocating engineering to the plants. We don't have common platforms. Engineering is separated into groups and regions. Information and the best designs and practices are not shared by different groups. We need to eliminate silos."

- "We put our engineers to react to warranty issues but they should do the engineering work that they are good at. This would prevent warranty in the first place."

- "Lack of knowledge and use on Design for Manufacturability sometimes make the part hard to manufacture within spec. Manufacturing sometimes makes process change without informing product engineering.

The results of these issues are warranty problems then both sides start to blame each other."

- "In design, we need to include the warranty cost. We might need to change our engineering process. We don't validate our products all the time."

- "Lack of validation is the biggest issue on our warranty. We need to do better job in continuous validation in production. Need to do better job and more field testing to get correlation data."

- "Test support working with dealers can get more information and identify root causes for engineering."

- "Inadequate samples and time for most reliability testing due to the lack of knowledge on statistics and limited time and budget. Engineers do not know that one or two parts to pass the bogey will only give a very limited confidence on reliability."

- "Outdated testing specifications: the new application is much more severe than two decades ago. Time and funding constraints. Last month we have to start production and shipment before the completion of lab testing since the lab just could not finish all required tests on time."

- "Lack of use of FMEA: a lot of failure modes are not identified thus no corresponding tests are developed. Sometimes we cannot even duplicate failure modes happening in the field."

- "We do not really understand the correlation between lab testing and field performance, i.e., we do not know how long the part is going to last even though it passes the lab test. We need to put more effort to gain the knowledge on the correlation between lab test and field performance, especially for systems that are new to the company."

- "Very few samples are tested to failure. Most parts are tested to bogey then we think it is okay, which is apparently not statistically valid."

- "Engineers still think reliability is just data analysis after testing is done. A lot of advanced reliability tools, such as reliability growth, FMEA, DOE, are either overlooked or abused. More technical training is needed."

- "Validation and testing should include both hardware and analysis. Analytical models (simulation, FEA) are not adequate enough due to the lack of accurate inputs. Nobody really knows where the test specification comes from and why we test three samples to 100,000 cycles."

- "We do our best as we can. We do a good job in product development and a poor job in product verification. No one is responsible for validation of production parts. Plant doesn't have budget and resources to do in- production testing."

- "The Reliability target is not clear for most products and not developed based on warranty allowance. Therefore in design, product engineers do not know the target they are shooting for."

- "Every time when we make design changes, we have to have validation tests. We have to have independent validation, not just by supplier."

Supplier related quotes

- "Supplier parts are like black box to us. We buy supplier made parts as black box without knowing detail. We have no control of supplier engineering and quality related issues. We trusted supplier without verification. We rely on supplier to tell us about their products. Need to develop knowledge about the parts made by the suppliers."

- "Supplier didn't do good job in two areas: (a) PPM of out of box parts as received; (b) Reliability. Supplier had bad process, poor quality control. Supplier manufacturing can't meet specs. Supplier had design flaws. Suppliers don't fully understand our application conditions."

- "Supplier parts are not adequately tested. Lack of product/process checks. We need to do trust verification of suppliers. Key characteristics were not monitored effectively."

- "Supplier can do a good job in the initial development and demonstration work. But they can fail in production or after production for a while. We need to do ongoing performance testing of supplier parts."

- "Need to get in early product development process with supplier. We need to give supplier clear definitions about our requirements and pre-select multiple suppliers instead of just one who gives the lowest quote."

- "Sometime, we don't know what to say to our supplier (less understanding about supplier). We need to have our own experts and capabilities to challenge supplier's validations."

- "We push supplier to cut cost and it affect the supplier quality we received. They always under our pressure to reduce cost therefore they might not tell us many things they know well. Both sides are responsible for this issue. We put supplier into a corner and we don't have a trust relationship with them."

- "Supplier is a significant factor in our warranty issue but not the major factor. We have to have an open communication, open cooperation, and open understanding of cost with our suppliers."

- "We don't have a vender (supplier) warranty recovery system even today. We need to ask vender to be complied with warranty."

- "Only recent years we start to concern about warranty. We have good process on suppliers but we don't follow it closely. The way we identify warranty is too complicated to be used by most people."

- "We need to have an adequate budget to do warranty reduction work such as reliability, testing, global communication, etc."

Cultural related quotes

- "We have all different cultures to do work at different groups and locations."

- "We react to problems and do fire fighting. We need to change this culture."

- "We react to problems and do fire fighting. We reward fire fighting. People respond to the reward system. Some people even created fire then solve it later to make them look like hero. We need to reinforce good behaviors, don't reward wrong behaviors."

- "Need to get feed back on changes to know how effective the changes are."

- "We do have good process but we don't follow it. We don't have up front planning. We need to do a better job on communication."

- "Our process doesn't capture all input information that related to warranty. We need to have living documents to track changes and progress."

- "Some people use lack of resource as excuse for not doing anything. We can use available resource to do just 20% of required work, not necessary to do 100%. Some validation work is better than no validation. People say we have no software to do the work but we don't have software long time ago (we still did a lot of work that time)."

- "We need to pick up top four issues based on Pareto chart and really work on solutions. After we agree on a targeted warranty reduction number, we need to insist on the completion date and dollar amount."

Resource related quotes

- "We need to have an adequate budget to do warranty reduction work such as reliability, testing, global communication, etc."

- "Every group has resource issue. We could be more effective with additional resources. Resource is always an issue for engineering. Everyone is resource constrained including manufacturing. Everyone say this is the No.1 issue."

- "Engineering resources (manpower) need to be re-analyzed then distributed evenly. Some departments apparently have more people than needed while others are suffering in getting enough people"

- "Extreme shortage of skilled and experienced engineers in quality and reliability function. Inexperienced workers at plant."

- "Lack of testing budget. Labs need more capital investment. Lack of internal test vehicles, have to rely on customers."

- "Very weak manufacturing/industrialization engineering organization leads to poor launch in production."

- "Instead of putting three engineers in one project, we throw three projects to one person, and then human errors happen. More manpower is needed."

- "Dedicate team to warranty will be a good investment. We need to use resources to change our culture."

Warranty organization related quotes

- "We don't have a centralized reliability group to analyze the warranty issues. We need statistical analysis of test data. Problems are resolved reactively and ineffectively due to the lack of use of statistical tools such as Six-Sigma."

- "Purchasing negotiated the lowest price without considering warranty. Purchasing dug a hole for us in our top warranty issue. Warranty is linked with our constant battle on cost. Purchasing is constantly looking for low cost suppliers. We buy parts from suppliers who offer the lowest price."

- "Supplier selection is not focused on engineering support/relevant experience of suppliers, the top criteria seems to be the price. Engineering judgment needs to have a higher weight. Need engineering to participate in the purchasing process (it's happening now)."

- "Engineering cannot start to work on a program before there is a business case. This usually leads to tight product development time. So when something is wrong, we have to choose the quick fix/short-term solutions that may cause warranty problems later on."

- "We are not certain that we got high quality supplier. Plant is caught in the middle. We might late to prepare our manufacturing because we are late with supplier selection."

- "Cost, warranty, and technology are the three most important things that we have to deal with. There are many other things but those three are mandatory items. Warranty needs to be included in the purchasing process. We need to consider warranty in both terms of cost and case numbers."

- "Lessons learned need to be more effectively documented and shared within the whole company. Knowledge should also be transfer to junior engineers before senior ones retire: we have seen too many repeated mistakes."

- "Meeting should be done after we review the supplier provided information. We are constrained to communicate with suppliers."

- "Top management should be committed to warranty reduction activities and communicate their support to lower levels. Top management should enforce and promote the use of statistical methods and tools in design, testing, and process improvement."

- "Achievement on warranty reduction should be better recognized and rewarded."

- "We need a centralized group to coordinate and manage warranty problems. A centralized reliability group should be leading all reliability and warranty activities. We need people accountable for finding ways to improve. This issue is a broad system issue so the central group is the existing corporate management and making someone else seem to be responsible may be a mistake."

- "Warranty targets should be given to engineering not purchasing or sales department. In this way quality and reliability can be put to a higher authority over price. Whenever there is intent of supplier change, engineering needs to approve based on reliability and testing concerns."

- "Top management needs to clearly define the function and responsibility of each engineering department. Sometimes it seems like several departments own one activity then efforts are duplicated."

- "Frequent reorganizations within all functional groups make it extremely hard to focus and communicate. Last year for one of my products, I have been working with three different plants, we buy and sell plants so frequently and products are moved from plant to plant everyday."

4.2.3 Internal Interview Conclusions

Generally speaking, the interview results provided confirmations and additional detail information about the root causes as exposed by the survey. We got not only root cause statements on each issue but also the supporting evidence to assure no biased opinions would influence the conclusions. In summary, the interviews identified the following additional root causes of the warranty issues that were not uncovered in the surveys:

- People need to change their mind to accept a proactive warranty prevention approach.

- Unclear accountability on warranty issues. Sales department gives warranty target but engineering is responsible for warranty correction activities.

- The purchasing department selects supplier components based on price, not quality.

- Suppliers cannot provide adequate engineering support when product fails due to the lack of knowledge and capability.

- Warranty needs to be included in the purchasing process. Warranty needs to be considered in both terms of cost and case numbers.

Furthermore, a higher-level conclusion has been identified as the lack of system approach in dealing with warranty. One characteristic found that indicates a lack of a systems approach is that each functional group has its own focused areas and performance goals thus warranty approaches and concerns are conducted and prioritized separately. For this reason, the boundary, interface, and interaction among functional areas are poorly handled. A second characteristic that indicates a non-systematic approach is the short-time focus of most efforts and trade-off decisions. Warranty occurs over the life-cycle of the products and its influence on corporate success is fundamental and long-term. Consequently, a lot of efforts lead to only minor achievement.

Because all the people interviewed have many years experience in their specialized areas and all are heavily involved in the warranty reduction activities, we also received many valuable comments and suggestions about how to deal with above issues. The interviews give us a strong feeling that teamwork with some improvement in process would reduce warranty to a much lower level for the company. We can use the survey and interview results as the guidance for our search for solutions in the next chapter.

5. Recommendations

5.1 Use Pull System to Replace Push System on Warranty

It is well known that the so called fire-fighting mode means that people wait to receive warranty data before doing anything. No action will be taken if there is no report on warranty although the warranty issues could exist for sometime. If a warranty related issue is detected very late in production, there will be a lot of accumulated warranty losses no matter how hard people try to address the issue. The following chart represents a push system used in the current warranty reduction process. When a warranty issue is reported by the users such as customers, the information shows up in the warranty database. Then the quality group would contact the engineering and suppliers to inform them of the existence of the issue. If the issues are persistent or significant enough, a warranty reduction team is formed to resolve them. Normally a so called 8D process will be used by the team to find the root causes of the issues, generate solutions, and verify the solutions using a controlled turn on-off approach. Then the new solutions will be implemented in production.

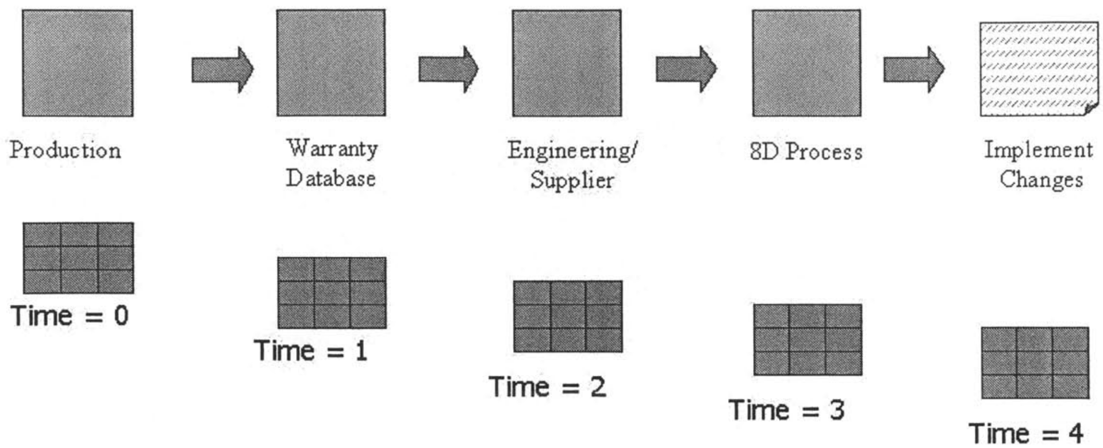

Figure 5-1: Current push system used to resolve warranty.

Disadvantages associated with the push system are the following:

- It takes a long time to complete a warranty reduction cycle (find warranty issues, understand root causes, create and verify solutions, and implement changes).
- Misunderstanding of the root causes of warranty under tight timing pressure can cause repeated, expensive and ineffective fixes.
- It promotes the fire fighting culture that is not adequate for warranty prevention.

This kind of push behavior has also been observed in different functional groups as exposed by the surveys and interviews. Some of them are listed in the following.

- Purchasing pushes to use low-price supplier and does not correlate this with later increases in warranty costs.
- Finance pushes to reduce spending.
- Engineering pushes to get products in market quick.
- Validation pushes to get full testing capability.
- Supplier pushes warranty responsibility to their customers.

Since the push system operates in sequence and the people using the system under a lot of pressure to keep thing moving fast, it creates the tendency to ignore the inputs provided by people who are outside of the push system. Therefore, it has risk to make quick decisions without utilizing all available information. To resolve the push system related issues, we propose to use a pull system as expressed by Figure 5-2.

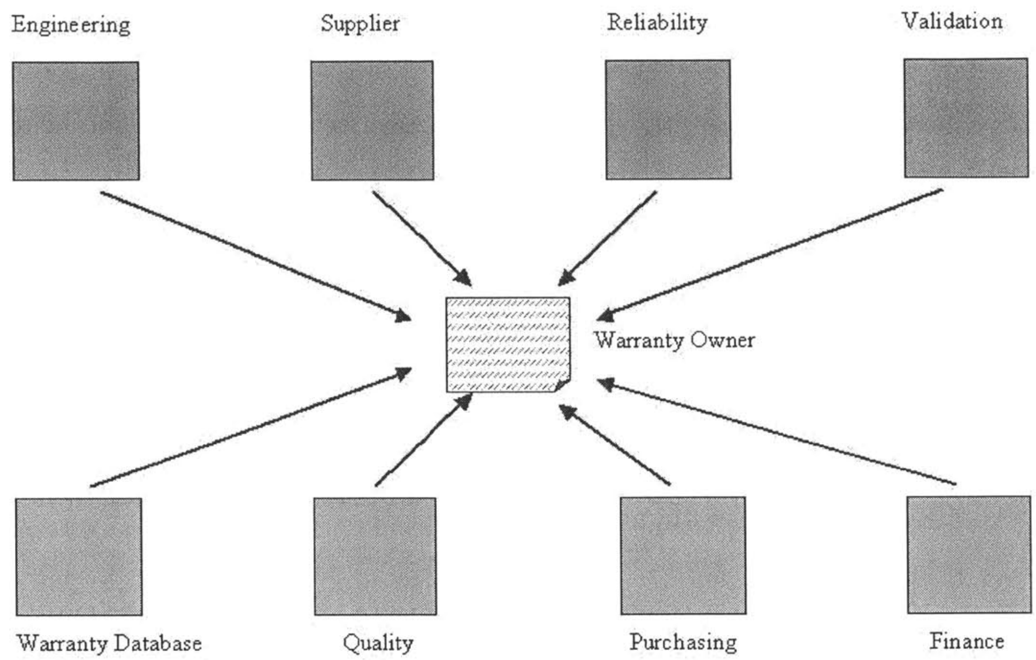

Figure 5-2: Proposed pull system to resolve warranty.

Instead of taking actions in sequence, the new pull system uses all available input information to receive early warnings and make quick decisions. When any functional groups find warranty related issues, they will be connected to the warranty team organizer/owner who is responsible for the warranty. The owner will assess the input information to make sure that the new issues will be addressed before even reaching the production phase. If the engineering group, for example, finds the candidate supplier doesn't have the capability to produce good products, the warranty owner will inform the purchasing group and supplier to work on the issue and generate a solution. It creates an opportunity to significantly reduce supplier related warranty in production.

In contrast with the push system, the pull system provides the following advantages.

- Shorten the warranty reduction process.
- Stimulated communication to find the issues and solutions early
- Build early warning and proactive culture on warranty
- Build team work among functional groups and suppliers

5.2 House of Warranty (HoW)

One major issue identified in the surveys and interviews is that even though the company has the procedures to guide the warranty reduction processes, problems can still happen when the procedures are not followed for various reasons. To deal with this issue, we propose to apply the concept of the House of Quality (HoQ) that is well explained in the system engineering. We go even further to create a new term of House of Warranty (HoW) in this thesis study. The layout of HoW is shown in Figure 5-3.

Warranty Attributes	Relative Importance	Engineering PDP process	Enhance validation/reliability	New resource model **	Decision Making Process	New warranty pull system *	Purchasing Process	Leveraging supplier resource	Finance number include warranty cost	Leading/responsible group or person	New reward model ***
Robust design	10	X				X					X
DOE/validation/reliability	10	X	X	X		X				X	
Resource	7			X	X			X			
Cost	5			X	X	X	X		X		
Communication	10					X					
Quick response to warranty	10			X	X	X				X	X
Long-term fix of warranty issues	8				X	X		X	X	X	X
Early warranty warning	10					X				X	X
Supplier warranty recovery	10						X				
Maintain good products	8	X	X		X		X		X	X	X
balance between engineering & sale	5				X	X			X	X	X
Accountability	6									X	X

Process Characteristics

Figure 5-3: Concept of the house of warranty (HoW).

As one can see that the HoW has some content that are not considered in the HoQ such as the pull system, resource management, reward system, etc. The key concept of the HoW is to use the system approach to deal with warranty. HoW might not be owned by the quality group as the HoQ does. Any group who claims to be responsible for warranty such as the purchasing or the engineering group could own the HoW.

To emphasize that HoW is a new system to deal with the fire fighting culture, some processes such as 8D are not listed in the top level architecture of the HoW. As an important functional unit, HoW is not organized on a temporary basis. It is operated in a long-term basis with stable resources and budget (we will discuss the budget model in more detail later). HoW specifically identifies accountability as a key attribute. HoW offers a new way to reward the warranty prevention culture (we will discuss the reward model in more detail later). In contrast, the 8D process is built on a temporary basis under the urgent request. 8D process puts efforts on quick problem solving and rewards the fire fighting mode.

There are many details about the creation of the HoW. Figure 5-3 shows only the top level architecture of the new warranty system. There are sublevel rooms for each functional group such as the main room for the HoW owner, engineering room, quality room, validation and reliability room, purchasing room, finance room, supply chain room, marketing room, etc.

5.3 Model for Leveraging Suppliers

Based on the value chain or the supply chain theory, suppliers play a key role in the warranty control process. It's hard to maintain a good warranty-control system without full involvement of the suppliers in the dynamic business environment.

Therefore, we propose a new model to give a qualitative indicator to be dynamically adjusted based on the capability and performance of the suppliers. The following chart illustrates the concept behind our model. The message is to work with supplier and leverage their resources and know-how to reduce the spending from the company side. We believe that building a trust relationship with carefully selected suppliers is necessary to assure a long-term successful process on warranty control.

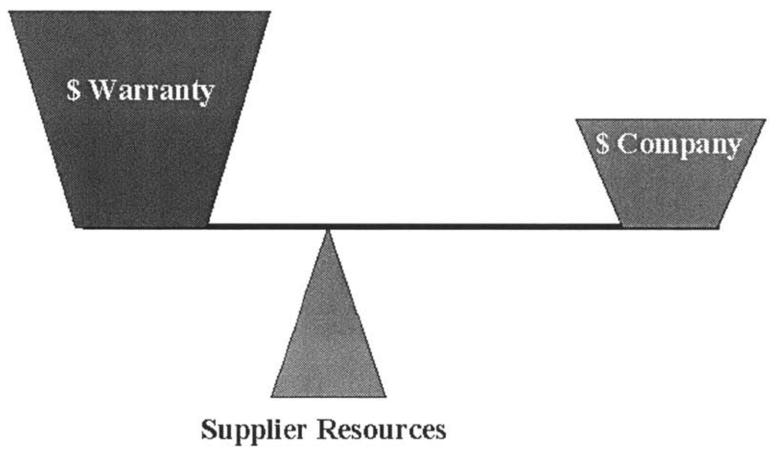

Figure 5-4: Concept to leverage supplier resources in warranty reduction.

As expressed in the surveys and interviews, lack of resources at the company side is a big issue for not been able to perform many warranty reduction related activities. On the other hand, suppliers make many products for the company and they normally have the best knowledge about their products. Therefore, the ideal way to control supplier parts related warranty is to get suppliers involved in the whole warranty control process from concept design to production. This requires a close working relationship with the suppliers. As implied in Figure 5-4, let supplier fully utilize their resources to provide all required services such as design, validation, manufacturing, etc. At the same time, the company needs to spend a small amount of resources to monitor the supplier activities using approaches such as design reviews, auditing tests, field tests, reliability prediction, etc. Since all those company-performed activities are small-scale compared to what the supplier does, it significantly reduces the consumption of the company resources.

In order for this concept to work, we do have special requirements about the suppliers and the company as outlined in the following.

- Supplier validation capability has to be specified by the purchasing contract.
- The suppliers need to agree on full validation by either testing or simulation of their products whenever they receive requests from the company based on warranty early warning data.
- Company will not do full validations of supplier parts to reduce cost.
- Company will perform monitoring tests of the supplier parts before and after production to generate early warning data for the pull system.

The financial impact of above concept can be visualized in the following chart. For a given warranty reduction project, the cost for a company performed full validation could be seen as the dotted constant line in the chart, which is too expensive to be sustainable over the product life cycle. Our proposed partial validation will cost only a small portion of the warranty and it is always less than the full validation cost.

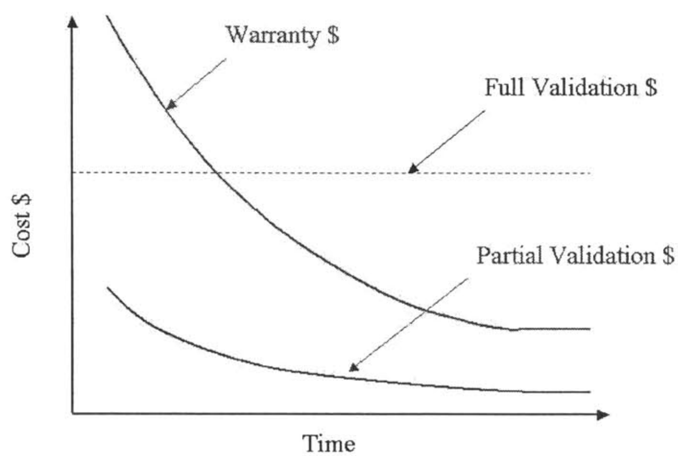

Figure 5-5: Assumption on warranty and validation costs change over time.

We also develop a math model to determine the partial validation budget based on the warranty cost.

Partial Validation $ = FUNC1(Warranty $; Purchasing $)

For example, assuming the warranty cost is $2 million per year for the supplier made products and the purchasing cost is also $2 million per year, our model predicts a budget of $0.15 million for performing partial validation related activities. Figure 5-6 shows our model prediction of the partial validation budget based on the change of the warranty cost.

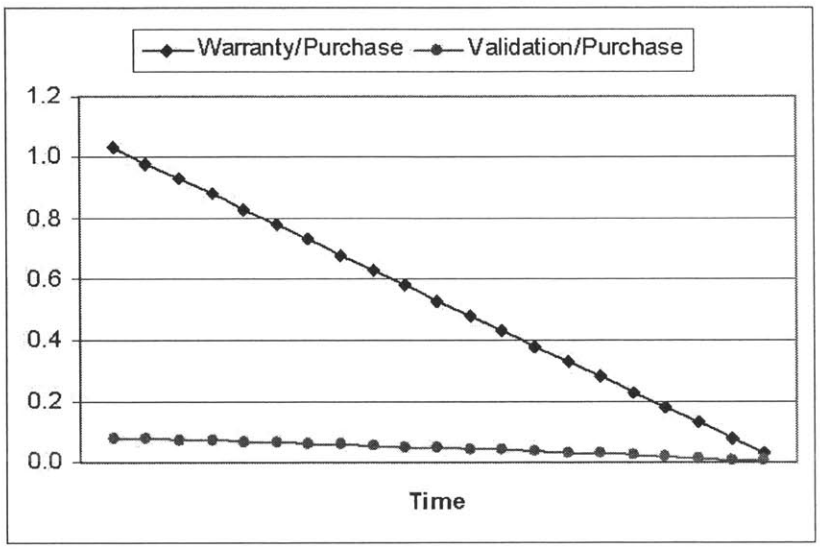

Figure 5-6: Model prediction of validation budget change.

5.4 Reward Model

As discovered in our surveys and interviews, the current fire fighting mode is influenced by the reward system. For example, people could be hired to solve same problems repeatedly. But there is no system to reward warranty prevention. Since people do react to the reward system, we propose a new reward system as shown in the following chart to help build a new culture on warranty control. It indicates that the reward payment is linked with the warranty reduction. When the warranty cost is very high, the reward will be very small or near zero. The reward will be increased with the reduction of the warranty. When the warranty is reduced to the lowest level, the reward will reach the highest level. This is significantly different from the reward system for the fire-fighting mode in which the reward is linked with the number of problem solving activities.

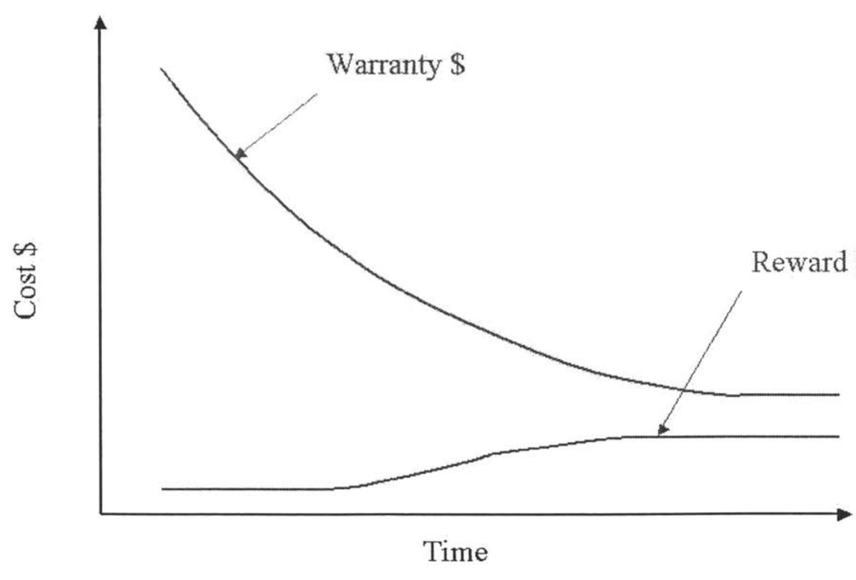

Figure 5-7: Assumption on new reward change with warranty.

We also develop a math model to determine the reward based on the warranty reduction.

Reward $ = FUNC2(Warranty $; Validation $)

For example, assuming the warranty cost is $60,000 per year for a product and the validation cost is $7,600 per year, our model predicts a reward of $1,300 per year. The following chart shows our model prediction based on the changes of the warranty and validation costs.

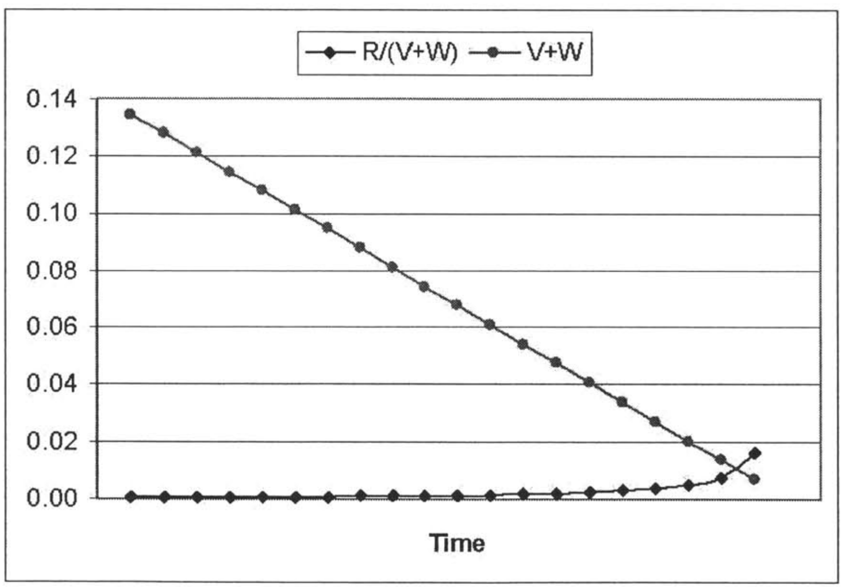

Figure 5-8: Model prediction of the reward budget.

5.5 Dynamic Management of Resources

Because of limited resources, we can never get the amount of manpower and budget we want for all warranty reduction related activities. This is even more difficult with the growing competition in the low-margin automotive market. How to address resources related issue is another key challenge for this study. Besides the strategy to leverage supplier resources, we also tried to apply the system dynamics principle to model the resource management here.

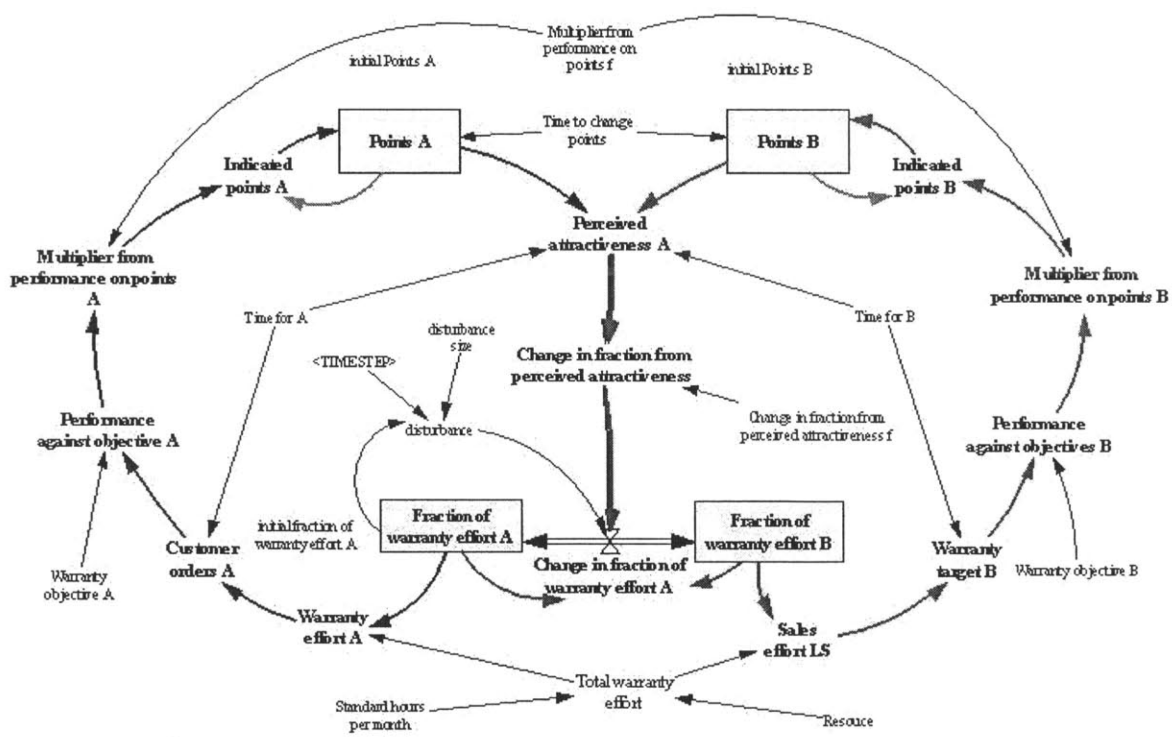

Figure 5-9: System dynamics model of resource management for two different projects.

To simplify our discussion, we assume there are only two warranty reduction projects for a given group who is responsible for both projects. We identify those two projects as A and B respectively in the system dynamics model shown in Figure 5-9. Without going through details of above model, we will say the key point is to keep a dynamic balance on manpower sharing between two projects in the same operational group. It requires a break down of the conventional fixed department structure. Although the two HoW owners need to be relatively stable to maintain long-term control of the key warranty issues, the team members can be dynamically adjusted based on the changing warranty status. It is more desirable when two warranty reduction projects have similar content. For example, the group of people who have skills on gear technologies can handle two different gear warranty projects for different applications. The amount of manpower will be dynamically adjusted based on the warranty trend of each project.

6. Summary and Future Work

6.1 Summary

This joint thesis covered a wide range of topics on warranty by taking advantage of two students' effort. It is organized in the following four major parts:

- Part one explains the importance of warranty to the manufacturing industry and thus why it was chosen as our thesis topic.

- Part two identifies major warranty issues and the warranty process at a tier one automotive supplier.

- Part Three reviews results of two surveys and a series of interviews done within the company to understand the root causes of warranty issues.

- Part four makes recommendations to address the warranty issues recognizing the root causes identified.

Parts one and two give a general description of the warranty issue in the automotive industry such as the warranty history, difference of warranty from quality and reliability, the evolving nature of warranty responsibility in the automotive supply chain and the key role of warranty and quality in determining corporate success in this industry. The specific automotive supplier case is then developed and gives an overall view of managing warranty. The case demonstrates that warranty has direct impact to the company's bottom line regarding financial performance, market share, customers, and stakeholders. Warranty failures collected were also grouped to categories. Parts three consists of detailed information collected from two surveys and interviews of key personnel. The purpose of this effort was to attempt to reveal root causes of the company's inability to be as successful as it desires in decreasing warranty costs. The conclusions of the study are grouped to five categories:

Product development related:

- The product development process is not followed (i.e., some stages are skipped to ensure on-time-delivery) due to tight customer schedule pressure and the fact that incentives to complete projects are immediate while quality results are slower to show up.
- Inadequate test/validation due to insufficient knowledge on both potential failure modes and correlation between lab test and field test.
- Insufficient understanding and experience on advanced quality/reliability improvement methods keep engineers from using these tools.

Resource related:

- Inadequate test lab equipment and facility

- Lack of incentives discourage employees from working on warranty issues and from improving their relevant knowledge and capability

- Insufficient manpower in certain key functional areas.

- Unbalanced resource among functional areas.

- Current lessons learned database needs to be improved to promote knowledge sharing.

Supplier related:

- It is hard to evaluate supplier's component performance due to black-box design.

- Purchasing department selects supplier component based on price, not quality

- Some suppliers tend to hide warranty problems until it gets worse and uncontrollable.

- Suppliers can not provide adequate engineering support when product fails due to the lack of knowledge and capability.

Warranty organization related:

- Poor communication between engineering and operation causes delayed implementation of corrective actions.

- Unclear accountability on warranty issues. Sales department gives for warranty target but engineering is responsible for warranty correction activities.

Cultural related:

- Reactive warranty fire-fighting mode dominates the entire warranty reduction process.

All findings listed above can be viewed as the first level of conclusions. A higher level conclusion is the finding of lack of system approach in dealing with warranty. One characteristic found that indicates a lack of a systems approach is that each functional group has its own focused areas and performance goals thus warranty approaches and concerns are conducted and prioritized separately. For this reason, the boundary, interface, and interaction among functional areas are poorly handled. A second characteristic that indicates a non-systematic approach is the short-time focus of most efforts and trade-off decisions. Warranty occurs over the life-cycle of the products and its influence on corporate success is fundamental and long-term. Consequently, a lot of efforts lead to only minor achievement. The overall conclusions drawn from both the surveys and interviews can be summarized in a Cause-and-Effect diagram, as shown in Figure 6-1.

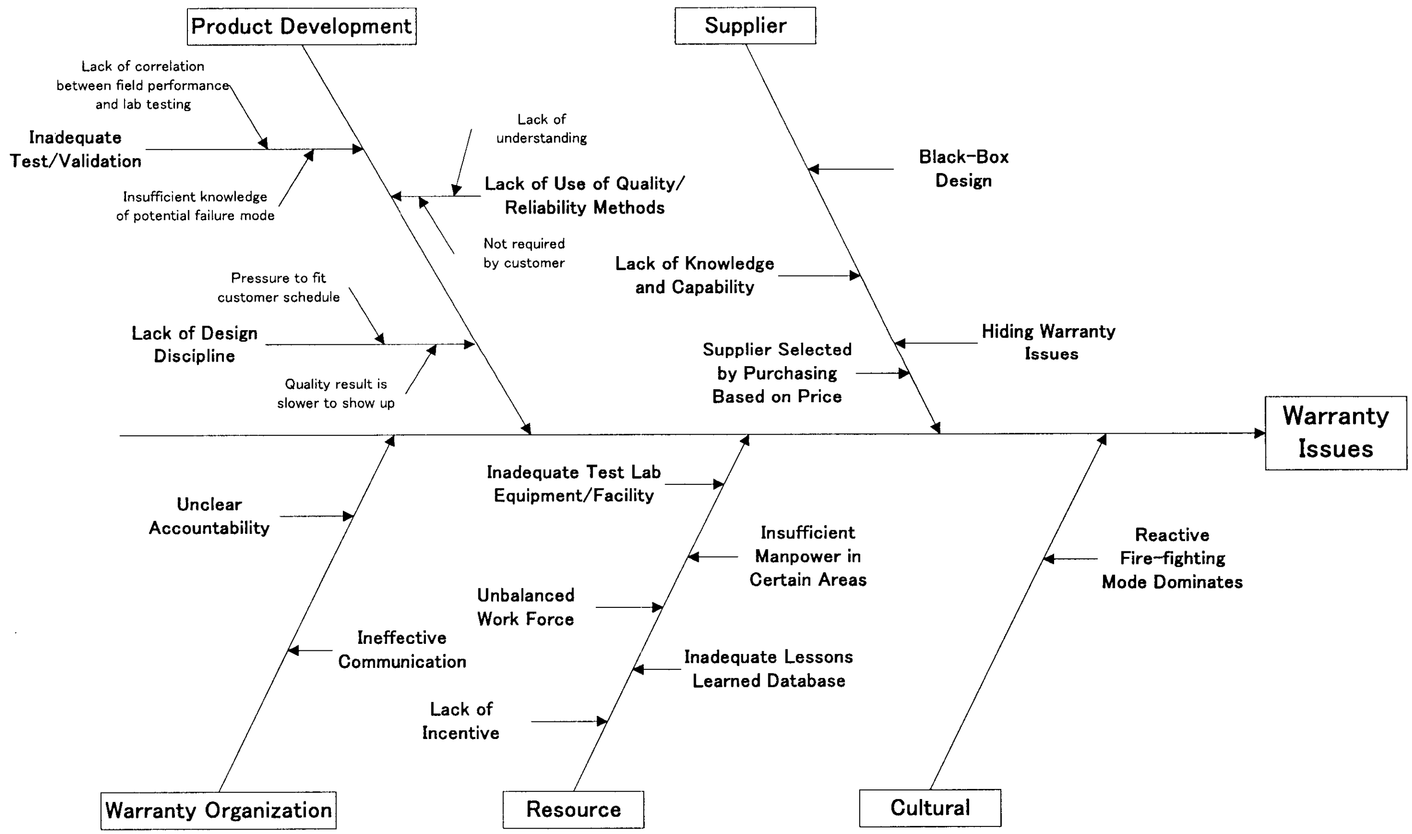

Figure 6-1: Cause-and-effect diagram to summarize warranty root causes.

Part four of the thesis describes our suggestions for improving warranty-related performance at this case study company. As a short-term suggestion to address the warranty issue immediately, we proposed to use a new pull system to replace the current push system. The current push system is built on the current fire-fighting culture. It has disadvantages such as taking a long time to find issues, root causes, and solutions. It has higher risk of failure because activities are carried out in sequence. It is suggested that the new pull system will help build up a new warranty prevention culture. It stimulates communication among different functional groups to find issues and solutions early. It reduces overall time for the warranty reduction process because of better teamwork.

Using the concept of House of Quality (HoQ), we develop a new concept we call the House of Warranty (HoW). HoW is broader than HoQ because it addresses issues such as resources and accountability. HoW has many sub houses to display required details of each functional group. For example, the sub house of engineering can address design, manufacturing, validation, reliability, testing, etc.

Supply chain management is a major issue in the case study company. Our recommendations are aimed at changing the basic mode of working with suppliers. Instead of pushing suppliers into a corner and incentivizing them to hide the truth, we suggest working with suppliers and leveraging their resources and expertise to help reduce warranty. We developed a model to adjust spending on warranty reduction activities based on the financial impact to the business. The key concept is that resources will not allow 100% validation but maintaining a minimum level validation strategically placed will help significantly in warranty prevention and thus also aid in building the essential new warranty culture.

Everyone wants more resources but the low margin of the automotive business makes it impossible to add more staff as desired. We propose using a system dynamic model to adjust resources based on the financial impact of different warranty products. For example, a given organization can have a fixed structure to maintain the stability of operation but the size of a product team could be dynamically adjusted. A key factor in the model is the warranty/person ratio. Other factors could be the warranty trend, customer needs, supplier content, etc.

Accountability is a complicated issue and we suggest using a reward model to address it. Instead of rewarding people for their fire fighting behavior, we suggest rewarding personnel or teams that have kept their warranty in a continuous downtrend. The lower their warranty is in comparison with the past one or two year history, the more the person or the team will be rewarded. When the warranty trend is in the increasing direction, the reward will be reduced or eliminated. In this way, the incentives will align in helping foster a new culture of warranty prevention.

6.2 Future Work

We have tried to use three lenses to study the warranty related issues. Despite some suggestions outlined here, we know that we can't resolve all warranty issues by this thesis study. Our proposed suggestions are at the initial stage without verification in practice. We feel that more creative thinking is needed to generate more effective strategies based future study and accumulated new information. It needs a broader teamwork and takes time to see things through to lasting change.

Since all our surveys and interviews are carried out at the supplier site, we feel it will be more beneficial to extend the survey and interview to an outside OEM company like Toyota. The information collected from Toyota will give us the opportunity to review the warranty issues from the view of a well established company.

Among many things we thought about for future study, we feel we have to address the maturity of the company. From the organization point of view, it's very important to have a people focused culture. We all know that people is the most important asset for any successful enterprise. But the business condition changes and culture-political issues make it difficult to address this topic. We hope further study will find out where the company stands at in the following chart regarding the maturity of the organization. We also hope some fundamental changes will make the identified issues becoming obsolete completely.

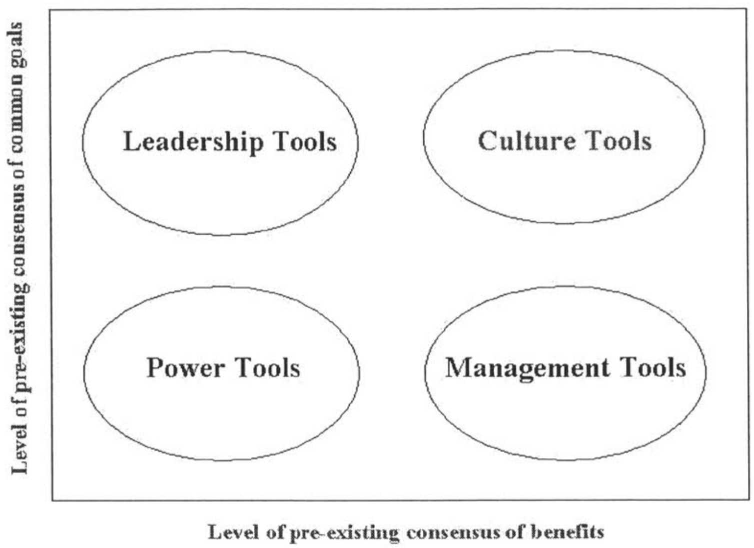

Figure 6-2: Four categories of tools of agreement (from C. Christensen and H. Stevenson [33]).

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APPENDIX A: First Survey Results

(1) What percentage of your work time is devoted to warranty related activities?	Percent
Less than 10%	22%
Between 10% and 20%	17%
Between 20% and 30%	15%
Between 30% and 40%	11%
Between 40% and 50%	17%
More than 50%	25%
No Response	1%

(2) Current resources (Manpower) in your department are adequate for warranty issues.	Percent
Strongly agree	6%
Agree	38%
Neither agree nor disagree	24%
Disagree	27%
Strongly disagree	4%
No Response	0%

(3) Current resources (Manpower) in your department are being effectively utilized.	Percent
Strongly agree	17%
Agree	36%
Neither agree nor disagree	22%
Disagree	21%
Strongly disagree	4%
No Response	1%

(4) More simulation and physical testing are needed to objectively determine the effectiveness of design-related	Percent

warranty corrective actions.	
Strongly agree	44%
Agree	45%
Neither agree nor disagree	16%
Disagree	3%
Strongly disagree	0%
No Response	1%

(5) For design related warranty issues, there is sufficient engineering knowledge and experience to resolve problems.	**Percent**
Strongly agree	10%
Agree	34%
Neither agree nor disagree	30%
Disagree	18%
Strongly disagree	7%
No Response	0%

(6) For manufacturing related warranty issues, current Six-Sigma and 8D problem solving tools are adequate to resolve problems	**Percent**
Strongly agree	18%
Agree	35%
Neither agree nor disagree	32%
Disagree	10%
Strongly disagree	3%
No Response	1%

(7) Current warranty administration system is effective and efficient in providing early warning of warranty issues.	**Percent**
Strongly agree	22%
Agree	43%
Neither agree nor disagree	29%

Disagree	3%
Strongly disagree	2%
No Response	1%

(8) Cross-functional warranty reduction teams are the best approach to promptly resolve warranty issues.	**Percent**
Strongly agree	23%
Agree	46%
Neither agree nor disagree	24%
Disagree	5%
Strongly disagree	1%
No Response	1%

(9) On Time Delivery is more critical than the rigid product design process, therefore, some product development stages may be skipped.	**Percent**
Strongly agree	3%
Agree	5%
Neither agree nor disagree	20%
Disagree	38%
Strongly disagree	33%
No Response	1%

(10) In addition to the reactive approach, warranty issues should be reduced proactively by applying Design For Six-Sigma and DFX (Design For Reliability, Manufacturability, Serviceability) in the new product development process.	**Percent**
Strongly agree	33%
Agree	48%
Neither agree nor disagree	16%
Disagree	0%
Strongly disagree	1%
No Response	2%

(11) Current warranty reduction activities include data collection, analysis, root cause identification and problem solving. With the addition of proactive warranty prevention in product development, which function is the most appropriate to lead the warranty process	Percent
Product engineering	35%
Advanced Engineering	2%
Operation	2%
Quality	25%
Reliability	22%
Procurement	0%
Sales	3%
Other - please specify	8%
No Response	2%

(12) For supplier related warranty issues, the company does not usually have internal testing capability on supplier components	Percent
Strongly agree	22%
Agree	37%
Neither agree nor disagree	28%
Disagree	8%
Strongly disagree	3%
No Response	2%

(13) For supplier related warranty issues, suppliers tend to disguise problems instead of proactively solving them with help from the company.	Percent
Strongly agree	23%
Agree	42%
Neither agree nor disagree	25%
Disagree	9%
Strongly disagree	1%
No Response	0%

(14) Lessons learned from warranty issues are documented and shared with other teams	Percent
Strongly agree	2%
Agree	14%
Neither agree nor disagree	32%
Disagree	41%
Strongly disagree	11%
No Response	0%

APPENDIX B: Follow-up Survey Results

(1) Company decisions are often made in such a way that treats the project's on-time-delivery as more important than rigid product development stages.	Percent
Strongly agree	0%
Agree	64%
Neither agree nor disagree	27%
Disagree	9%
Strongly disagree	0%
No Response	0%

(2) If decisions are made to prioritize time ahead of quality, what are the reasons that decisions are made in that way?	Percent
Incentives to complete on time are strong and immediate while quality results are slower (and uncertain) to show up	45%
Lack of project management skills	0%
Insufficient product engineering resources	45%
Lack of accountability when system later fails	27%
Pressure to fit customer schedule	91%
Some stages in PDP have no added value	9%
No warranty concerns from similar/prior products	18%
Lack of knowledge with some of the PDP stages	18%
Suppliers cannot meet their schedule	9%
Others - please specify	3%

(3) How do you grade your knowledge level of quality/reliability improvement methods such as statistics, robust design, Design for Six-Sigma, and reliability engineering?	Percent
Very Good	0%
Good	45%
Medium	55%
Poor	0%
Very Poor	0%
No Response	0%

(4) Relative to how often there could be benefit to using these quality/reliability improvement methods, how often do you actually use them?	Percent
Always	0%
Almost Always	27%
Sometimes	55%
Seldom	18%
Never	0%
No Response	0%

(5) What are the reasons that keep people from using these tools?	Percent
Not enough time	45%
Lack of experience and understanding of the tools	82%
Not required by customer	18%
Not required by PDP	0%
Others - please specify	6%

(6) Current test validation is not adequate due to which of the following reasons:	Percent
Not enough time	27%
Lack of belief in the importance of test	0%

validation	
Lack of correlation between field performance and lab testing	64%
Insufficient knowledge of potential failure mode	45%
Insufficient lab equipment/facility	45%
Lack of test samples	0%
No customer requirement on testing	9%
Others – please specify	7%

(7) What are the reasons why the company does not perform internal testing on supplier components?	Percent
Budget constraints	27%
Suppliers testing is trusted	64%
Lack of communication with suppliers	0%
Component is not part of company core competency	18%
System test already covers component failures	45%
No warranty concerns from similar/prior components	18%
Others – please specify	6%

(8) What actions can help to reduce the time to resolve warranty issues?	Percent
Improve communications between operation and engineering	55%
Improve accountability on warranty issues	64%
Improve reward system	9%
Others – please specify	2%

(9) How do you grade the current reward system to promote employee efforts to reduce warranty?	Percent
Very Good	0%
Good	9%
Medium	64%
Poor	27%
Very Poor	0%
No Response	0%

(10) How do you grade the current reward system in terms of increasing employees' relevant technical knowledge and capability?	Percent
Very Good	0%
Good	18%
Medium	55%
Poor	9%
Very Poor	18%
No Response	0%