Application of Six Sigma in Retail Supply Chain to Improve Profitability

by

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ABSTRACT

Quality of merchandise offered, is an important element that affects customer satisfaction in any supply chain network. The purpose of this study was to measure, analyze and improve the quality of furniture supplied by a Distribution Center; by studying the source and magnitude of issues driving unacceptable furniture. Six Sigma methodologies were used to conclude that, manufacturing defect was the main cause of unacceptable furniture that eventually disappointed the consumer. From a general perspective, this study demonstrated application of Six Sigma philosophy to improve quality in a retail supply chain.

INDEX WORDS: quality, six sigma, supply chain, customer satisfaction

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CHAPTER 1

INTRODUCTION

Customers are the main focus of any retail organization. All operations performed and product / services offered are aimed at meeting expectations of the customer. The ability to meet those expectations directly affects the bottom line of the organization. Thus customer satisfaction affects the performance and sustainability of any retail organization (Hennig-Thurau & Klee, 1997). There is definitely a connection between customer satisfaction and customer retention (Rust & Zahorik, 1993). A long term relationship with existing customers is more beneficial than less loyal customers. This long term relationship can be achieved if an expected level of service is consistently provided. A group of faithful customers is thus achieved, and the strength of this group increases as the quality of service or product provided improves (Holmlund & Kock, 1996).

Quality of product or service offered is one important requirement to achieve customer satisfaction (Millen, Sohal, & Moss, 1999). The emergence and the acceptance of Total Quality Management (TQM) as a management philosophy have given firms a competitive edge. In fact, to a substantial extent, there is a positive relationship between TQM and innovation. TQM can be considered as an important input for possible innovative management, which is a requirement to maintain a competitive advantage, thereby meeting customer expectation (Prajogo & Sohal, 2003). One important feature of the retail industry is the supply chain network. A supply chain typically is made up of manufacturers, suppliers and customers. The supply chain provides an important link between the production and distribution channels to meet customer requirements. It is important for the supply chain to respond quickly, accurately and profitably with respect to market demands (Kuei, Madu, & Lin, 2001). There is positive association between quality of product or service provided by the supply chain and overall performance of the company, in turn improving customer relations (Kuei et al., 2001).

This particular study is about measuring, analyzing and improving the quality of product (furniture) offered by a currently operating distribution center of a retail chain in the southern United States. A flowchart summarizing the operation of the distribution center is shown below (See Figure 1).

Figure 1. Flow Chart of the Supply Chain.

The purpose of the study was to analyze existing data of returns provided by the company's database to decrease the return rate of furniture or controlling the passage of defective furniture pieces through process steps before the furniture is actually delivered to the customer. A comprehensive quality data package was obtained through this analysis that provided actionable information in a clear format that showed where resources need to be focused in order to ensure that the distribution center is providing quality merchandise that is acceptable to customers the first time.

The objective of the study was to firstly identify product quality, i.e., the quality of furniture as an important factor driving returns compared to other relevant factors discussed later, then to further use the data to recognize vendors which are major drivers of returns. Further, the data was drilled down to identify styles of furniture having the highest return rate and also the type of defect for each of the worst vendors identified. Thus, the study attempts to find sources and magnitude of issues driving unacceptable products as identified by the customer (which is returned, exchanged or needed to be inspected for repair, if possible). Further, the study investigates the reasons, sources and causes for the returns in a detailed format, and consequently a probable solution.

This study was imperative for the distribution center due to the increasing return rate of furniture (more than 12%) over an extended period of time. Customers become disappointed with poor quality, high retail price furniture. To address the issue of defective furniture the distribution center had to either replace the furniture, send technicians to try and repair the defect, if possible or in worst case, the customer would just give up on the furniture and the distribution center had to accept it as scrap. Every time a customer would return defective furniture, the tractor-trailer which is sent out of the distribution center would need to pick up the defective piece and deliver a non defective piece; thus increasing the transportation cost. Consequently, the multiple trips of the tracker-trailer to accommodate the defective furniture decreased the space for possible non defective furniture to be delivered to a different customer on any given trip of a tractor-trailer. The transportation cost was important since the distance travelled by the tractor-trailer was significant, over 300 miles, in many trips, and with the recent high gas prices, the problem was compounded. Due to the recent economic crises as with every industry, this particular retail chain also suffered low sales. Hence, it is even more necessary than before to improve quality and reduce additional cost of transportation, consequently improving customer retention to gain a competitive advantage. More importantly, the customer was dissatisfied which adversely affected the financial bottom line of the distribution center, since the situation directly affected the profit margin. Apart from receiving defective furniture, sometimes the customer was delivered furniture of a different SKU (stock keeping unit) / style than ordered, or the delivery of furniture would be missed by the customer more than once due to improper / unconfirmed scheduling of delivery by the store, which disappointed the customers even further. Hence the analysis to reduce returns was needed urgently.

A pilot study was conducted which revealed interesting results because it showed that decreasing the return rates by small percentages would have huge impacts on the whole organization. If the study helps the organization to take necessary steps to decrease the return rate, then it is possible to have timely and effective improvements that will lessen return and exchange rates, and ultimately, improve the Product Delivery Rate (PDR), the rate at which the product is delivered to a customer as acceptable the first attempt of delivery. The potential value of improving the PDR by 10% alone is approximately **$1.6 Million** annually for the company's total network. Customer Satisfaction will also improve with increase in quality.

The study can be generalized to other retail industries by applying management tools to improve the quality of products offered to gain high customer satisfaction. It would be a useful contribution to the field of logistics, supply chain management or any industry operations dealing with providing products or services to customers as it explains the quantitative problem solving technique used to address the issue of unacceptable products identified by the customer. These management tools are described and explained in current literature, but still the study would be unique in the sense that it involves data of an actual ongoing distribution center of a major retail chain in the United States. Hence the study can be considered a case study toward development of solutions affecting the decision making of senior management and if positive, could possibly be used throughout the entire company distribution center network.

The study, however, has its limitations too. The findings of the study would not be applicable in the distribution center immediately since it would need additional cost of labor and cooperation of senior management over an extended period of time. Hence, it is not possible to compare the performance of the distribution center after the recommended necessary change. Also the study's initial approach of problem solving is not ideal, as it would need to be improved and modified as the change is implemented over extended period of time; however the idea would be the foundation of future improvements in the distribution center.

CHAPTER 2

LITERATURE REVIEW

As discussed in the previous section, the present study deals with analyzing risks for distributing furniture with defects to consumers and making efforts to control these defects. Specific to the operation of furniture distribution there are factors that increase the risk of defects in furniture, and there are factors that minimize these risks and improve customer satisfaction. Therefore the risk and protective factors theory (Hawkins, 1992) is relevant in this context as it deals with analyzing factors that encourage, and factors that discourage, the occurrence of an unwanted event.

Risk and protective factors theory, is popular in social sciences application. Hawkins (1992) examined the risk and protective factors at the community level, school level, and family level and also at individual / peer level. Hawkins, Catalano, Kosterman, Abbott, & Hill (1999) identified the long term effect of intervention efforts in terms of parenting classes offered to parents of kids through grades one to six. They examined risk and protective factors with respect to behaviors like violence, drinking, and underage sex and such social issues. By identifying corresponding risk and protective factors, Hawkins et al., (1999) examined the long term effects of intervention in preventing risk taking behavior in adolescence.

Michael, Hawkins, John, Richard, & Baglioni (2002) measured risk and protective factors for adolescent risk taking behavior like substance use, delinquency and other behaviors. The study defines risk as a behavior or characteristic peculiar to a person who is more likely to develop a disorder compared to a randomly selected person. Protective factors reduce the likelihood of occurrence of such disorder directly or by reducing exposure to risks. By analyzing such risk and protective factors, specific adolescent groups can be identified; having the highest possibility of disorders and preventive programs can be directed toward that specific group. Similarly, Howell & Hawkins (1998) attempted to use risk and protective factors theory to implement violence prevention programs in youth. While this theory's application is based in social sciences, there was no evidence that this theory has not previously been used in business.

The current study, however, deals with risk of defects in furniture supplied to customers, and the risk factors seem to parallel those in the social sciences. The furniture procured through vendors is originally produced by different manufacturers. The furniture is shipped to the distribution center from the vendor and is subsequently delivered to a customer after an order has been placed at the store by the customer. There are factors at each stage of the chain which either risk defects on the furniture or protect the furniture from getting defective and are acceptable to the customer first time. Table 1 indicates Risk and Protective Factors related to furniture delivery (See Table 1).

Table 1

Risk and Protective Factors

Risk Factors	**Protective Factors**
Manufacturer 1. Manufacturing resources 2. Infrastructure of the manufacturing unit 3. Quality of labor 4. Packaging process 5. Transportation system to get furniture from manufacturer to vendor	**Manufacturer** 1. Established relations between manufacturer and supplier of resources e.g. wood, finish, etc 2. Sophisticated machinery 3. Worker training programs 4. Long term relationship between

	manufacturer and vendor
Vendor 1. Inspection of furniture from vendor 2. Quality of labor inspecting furniture 3. Transportation to distribution center 4. Relations with buyers	**Vendor** 1. Inbound inspection at vendor 2. Outbound inspection before furniture is sent to distribution center 3. Long term relations with distribution center 4. Tracking styles having high return rates and manufacturer notification
Store 1. Understanding of furniture specification by sales associate in the store 2. Pre call to inform customer about arrival of furniture 3. Communication with the distribution center about the right SKU to be delivered	**Store** 1. Details of room size, door size for entry of furniture, elevator size, room background and exact specification of furniture 2. Personal call to customer before departure of furniture, rather than automated reminder
Distribution Center 1. Inspection at outbound before delivering furniture to customer 2. Handling and stocking of furniture in the distribution center 3. Workers unwrapping, inspecting and	**Distribution Center** 1. Inbound and outbound inspections at the distribution center 2. Tracking of vendor with high return rates, worst styles returned and type of defect identified

wrapping furniture 4. Loading of furniture on tractor-trailer to be sent to customer 5. Transportation system	3. Coordination with sales associates in the store

The above table lists some risk and protective factors associated with the process of procuring furniture from the vendor and ultimately delivering it to the customer. This study deals with improving quality of merchandise offered to customers to improve customer satisfaction, as well as cutting cost by decreasing return rates.

Deming's management philosophy (Deming, 2000) is also relevant to form the theoretical basis for the study. This management idea is based on decreasing costs by improving quality, which may be understood as opposed to the traditional belief of cutting cost by decreasing quality of merchandise to maintain profit margin, especially when sales are low. According to Deming, if efforts are focused toward quality, costs decrease over time and quality improves; conversely, if efforts are focused towards costs, quality declines over time and costs increase. Deming's philosophy can be summarized in fourteen points as mentioned in (Anderson & Rungtusanatham, 1994). According to Deming's theory, quality is achievable when the following principles are practiced in an organization:

1. Consistency of efforts to improve products and services offered to have an edge over competitors and provide stable employment to workers.
2. New philosophy leadership in management intended towards better handling, reducing waste and better work standards.

3. Focusing on building quality in the product in initial stages like manufacturing, to avoid the need for mass inspection where the possible defects are already present.
4. Develop long term relationship with supplier and work in coordination to get better quality supplies rather than constant change of vendors / suppliers in search of lowest price offerings.
5. Keep track of deficiencies in process and constantly improve production and services to decrease cost overtime.
6. Train personel to handle operations better and create leaders.
7. Role of supervision of employees should be to inculcate leadership qualities. Supervision should help workers and machinery used to perform better jobs.
8. Overcome fear throughout the hierarchy to improve accessibility and transfer of information.
9. Different departments of operation like research, design, production, and sales should work as a team rather than operate as mutually exclusive departments to predict defects in operation or work to solve existing defects.
10. Avoid pressurizing workers for zero defects, since the root cause of low quality and productivity is mostly the system and factors beyond control of workers. Doing so would only create adversaries between workers and management.
11. Management should not be driven by numbers or by objective goals. Numerical goals cannot be set for an unstable system, since they cannot identify crucial information like system capabilities. The quality obtained is a result of system capability which is better for stable systems, hence numerical goals cannot be set for unstable system (Rienzo, 1993).

12. Supervisors focus should be quality and not numerical goals. Quality is pride of workmanship and factors decreasing this pride for a worker should be removed.
13. Educate existing workers for self improvement over a long run.
14. Change in operation to improve quality requires involvement of all.

Deming describes links between quality, productivity, cost reduction and market capture, as a chain reaction initiated by improved quality. With improved quality, cost decreases as there are fewer defects, returns, reworks, time loss and delays. This in turn improves the productivity of the process. Hence the operation produces better quality merchandise or services at a competitive price over the long term. This also benefits the employers or workers as it provides sustainable and reliable source of income (Deming, 2000).

Deming also listed factors that would make it difficult for an organization to follow the fourteen principles. They include: no constancy of efforts to reduce variation in process, appraisal of individual based on merit, short term projects, focus on numerical goals, moving management and excess medical and liability cost as explained by Stamatis (2003). Deming's philosophy is also related to Six Sigma philosophy since the factors listed by Deming that stop organizations from adopting the fourteen principles intended to improve operation, are the same for the Six Sigma philosophy (Stamatis, 2003).

The Six Sigma philosophy was an important management philosophy popularized by Motorola in early 1980's. Motorola introduced the concept of Six Sigma with the intention of reducing defects in manufacturing electronic goods to offer the best commodity to the consumer (Hahn, Doganaksoy, & Hoerl, 2000). Six Sigma techniques can be described in many ways. It is a philosophy, a methodology or a measurement method to pinpoint causes of quality inadequacy in a given operation and to implement controls to improve quality (Markarian, 2004). Initially, Six Sigma was used only in manufacturing applications, but its applicability can be seen in other sectors such as the service industry, human resource, product design, research and development and logistics (Dasgupta, 2003). Companies of different production capacities, have reported significant saving and efficiency in operation using this method (Klefsjo, Wiklund, & Edgeman, 2001). It is a top-down, rather than a bottom-up approach. Specially trained managers are used to implement this method in a company at the ground level to initiate change in operation. The responsibility to bring about this difficult change primarily belongs to experts known as Master Black Belt and Black Belt managers. They decide on quantitative goals, train subordinates and select Six Sigma projects to be initiated and monitored in the long run (Hahn et al., 2000). The implementation of Six Sigma projects is the responsibility of project team members like scientists, engineers, finance managers and other important employees who receive green belt training from Black Belt and Master Black Belt managers (Hahn et al., 2000). It is a disciplined strategy that makes heavy use of real time company data which is analyzed by statistical tools (Klefsjo et al., 2001). The process of implementing Six Sigma projects can be summarized in five basic steps as mentioned by (Hahn et al., 1999). A schematic diagram of the D-M-A-I-C model is as shown below. (See Figure 2)

Figure 2. D-M-A-I-C Model

From Hahn, G. J., Hill, W. J., Hoerl, R. W., & Zinkgraf, S. A. (1999). The Impact of Six Sigma Improvement-A Glimpse into the Future of Statistics. *The American Statistician, 53*(3), 208-215.

The first step is Defining the Six Sigma project. At this stage, issues adversely affecting the bottom line of the company are defined from the view point of the customer (Hahn et al., 1999). The next step is the Measurement step which is unique to Six Sigma as compared to other management philosophies (Dasgupta, 2003). In this step a defect in the product / service offered is defined and quantified appropriately as viewed by the customer. Definition of the defect should be carefully decided upon, keeping the customer as the focus, since less stringent process specification would mislead one to believing that the process is efficient. These variables identified to be improved should be quantifiable and recorded in current operating situations of the company (Hahn et al., 1999). The third step is Analyzing the collected data. This stage should present the data collected in analyzable form, i.e., Pareto charts, to indicate current process capability and identify independent variables that are beyond specification limits and affect the operation adversely. The independent variables which are beyond specification limit are primarily responsible for defects in the product or service offered, and hence, resources of the management should be focused on these specific issues first. The fourth step is to Improve. The previous three steps lead to an action plan for making changes in the process. Several attempts are made to bring about this change and decrease defects. Thus the goal of this step is to decrease process variability which is the root cause of the problem. In other words, attempts are made so that the values of the identified independent variables causing the variability are within specification limits as viewed by the customer (Hahn et al., 1999). The fifth and final step, Control, is crucial for sustainability of the improvements achieved. A proper system should be in place to ensure long term running of selected Six Sigma projects (Hahn et al., 1999). Bringing about any change in an established operation involving people of different ideas and responsibilities is always a daunting task (Klefsjo et al., 2001). Hence Six Sigma projects should be initiated and supported by the top management of the company (e.g. CEO). If urgency is displayed at such a high level to bring about change in operations then elements of Six Sigma like aggressive projects, definition of performance metrics, and training of project managers could be done quickly (Klefsjo et al., 2001). Therefore Six Sigma is defined as a top down approach.

Specific to Logistics in the retail sector, Six Sigma can be effectively used to decrease defects in the products offered (Dasgupta, 2003). Six Sigma is used as a system, to measure the performance of a given supply chain and its individual entities. It is comprehensive, flexible and adaptable. The advantage of Six Sigma is that the performances of different processes like manufacturing, service, human resource, research and development, and retail can be measured on a common scale and is benchmarked against world class standards (Dasgupta, 2003). Quality of the product offered is influenced by the operation involved in the whole process of procurement and distribution to the final customer in the case of supply chain of any retail industry. Hence the performance of the process needs to be measured to know about existing process capabilities. Performance evaluation is crucial in any process, and a framework is needed to evaluate the performance of a given supply chain and individual entities which have to be comprehensive, flexible & adaptable (Dasgupta, 2003). Six Sigma metrics is a structured methodology with which the performance of the entire supply chain can be measured, monitored and improved (Dasgupta, 2003). Traditional accounting performance measures based on accounting figures such as sales turnover, profit, debt and ROI (Return on Investment) are insufficient to evaluate performance of companies in today's competitive world. Supply chain operations reference model (SCOR) uses strategic criteria like delivery performance, order fulfillment performance, cycle time, order fulfillment, lead time, total supply chain management cost, and inventory levels. These measures, however, cannot compare processes of different nature on a common scale. The Six Sigma method allows reduction to a common denominator, e.g., defect per opportunity (dpo), defects per unit (dpu), z-value or sigma value, throughput yield, rolled throughput yield (RTY). The system is based on principle of Define – Measure – Analyze – Improve – Control (D-M-A-I-C) as explained earlier, and its uniqueness is attributed to its measure stage. Primary advantage of Six Sigma is the ability to compare processes of fundamentally different natures on a common scale. Six sigma (which necessarily measures how well a given process is performing) and Supply Chain Management (SCM) are both process oriented. Every function within a supply chain is a key process, and therefore Six Sigma can be used as an effective performance measuring tool of given supply chain. Six Sigma has advantages over Total Quality Management (TQM) as a performance measuring tool since goals which are expressed in terms of Six Sigma metrics (yield, dpmo or sigma level) are better perceived by people, as people can equate the goals to dollar impact.

The statistical background of this measurement technique is based on the popular concept of normal distribution of data. For example, if the length of manufactured parts should ideally be 4 inches, then some parts that are manufactured would be more than 4 inches, some less than 4 inches and the remaining would be exactly 4 inches. If most of the manufactured parts are 4 inches long, then the frequency distribution of the length value of the manufactured parts, would peak around 4 inches. All processes have variability which gives us range of values around the mean and decrease the efficiency of the process, leading to customer dissatisfaction. Expecting the process to run at this ideal mean is unrealistic. Therefore the organization has to set a specification limit or tolerance level beyond which the operation cannot be continued successfully, e.g., if the ideal length of a part of automobile is 4 inches (mean), then acceptable variation could be set as + or – 0.001 inches from the mean. This would give the upper and lower specification limit.

If the operation is of different nature, e.g., inspection of furniture for defects, then the possible outcome of the operation would be "defective furniture" or "non-defective furniture". Thus the variable measured in this case is a binomial variable, as only two outcomes are possible for any furniture that is inspected. The process ideal mean of this operation would be 0% defective furniture, and a specification limit could be set as 5% defective furniture. The specification limit should be set by taking into consideration the cost associated with a defective piece of furniture. The selection of the specification limit is very important. Relaxed specification limits would mislead the organization to believe that the process is efficient, and conversely, a stringent specification limit is difficult to meet. More important is the definition of the defect. A defect and an opportunity for a defect must be defined keeping the customer in focus. Automobiles, for example, may have hundreds of manufacturing parts that need to be within specification limit, and each part could be considered as a possibility for the occurrence of a defect. Therefore, a defect in any of these possibilities / opportunities would lead to a defective piece from the point of view of the customer.

In case of furniture inspections, the entire piece of furniture e.g. a sofa, chair, and table, etc, is a defect opportunity leading to a defective furniture piece. Therefore, in this case, the defect per opportunity (DPO) is the same as the defect per unit (DPU) of furniture. There may be more than one defect on the same piece of furniture, but still it is a defective piece in view of the customer. DPU or DPO is an important variable to evaluate in the measure phase of the D-M-A-I-C model.

Once the specification limit is determined, the ideal mean and the data points, i.e., measurements of critical to quality variables are known, a frequency distribution can be drawn. The corresponding standard deviation of the process can be calculated. If the variability of the process is less, then more standard deviations would fit between the mean and the nearest specification limit. As the variability decreases, additional data points fall in the tolerance limit, and the operation becomes efficient as viewed by the customer. According to normal distribution, and taking in account the 1.5 sigma shift for the long term running of a process (Dasgupta, 2003), if the process operates at such a level where six standard deviations fit between the mean and nearest specification limit, then the process is said to have a short term sigma value of six or is said to have sigma value as six. Therefore at Six Sigma level there would be only 3.4 defects per million opportunity of per million units, and the corresponding yield of the process would be 99.9997%. Thus, the system would be free of almost all defects. The relation between Sigma levels, DPMO (Defect per Million Opportunity) and corresponding efficiency is explained by (*Six Sigma*, 2008) as follows :

One Sigma = 690,000 DPMO = 31% efficiency

Two Sigma = 308,000 DPMO = 69.2% efficiency

Three Sigma = 66,800 DPMO = 93.32% efficiency

Four Sigma = 6,210 DPMO = 99.379% efficiency

Five Sigma = 230 DPMO = 99.977% efficiency

Six Sigma = 3.4 DPMO = 99.9997% efficiency

Thus Six Sigma metrics is one method to measure the process capability in a common term (DPU) which is applicable to every sub process irrespective of its nature. Antony (2004) summarizes the pros and cons of Six Sigma philosophy as follows.

The advantages are clear, Six Sigma strategy focuses on gaining quantifiable financial success, developing a passionate and aggressive leadership, integrates human elements (culture change, customer focus, etc.) with process elements (data collection and measurement, statistical tools, etc.) of improvement, creates aggressive and specialized leaders like Green Belt managers, Black Belts managers and Master Black Belt managers. Six Sigma gives importance to data collection and measurement, to ensure the decisions made are driven by pure logic driven out of data analysis, not by personal judgment or gut feeling. It is based on statistical methods and encourages statistical thinking and usage of statistical tools for reducing process variability. Six Sigma, however, has limitations too. Data collection processes to track defects could be challenging and in some cases impossible, as the nature of the process is such that it has no data to start with. Application of the suggested changes could be expensive and therefore partially applied. Prioritization of various Six Sigma projects to increase overall process efficiency may be difficult to decide upon, and the prioritization is often done based on personal judgment. Defects in a process may vary in their importance; therefore they do not affect the process to the same extent. Not all processes follow normal distribution; the Critical to Quality variables may change over time for the same process, the link between the sigma level and the cost of poor quality may be unclear, and the training given to develop Six Sigma managers may be inconsistent across the organization leading to differential capabilities of Six Sigma managers. In spite of these disadvantages, Six Sigma is an established management practice in organizations. This study attempts to use Six Sigma as the theoretical base for making efforts to reduce return rates of furniture in a warehouse.

CHAPTER 3

METHODOLOGY

This study is focused on decreasing the return rate of defective furniture of one Distribution Center in the southeastern part of the United States. The retailer offers apparel, furniture, bedding, home goods, jewelry, and other merchandise in the “brick and mortar” store.

The company was recently facing a problem with big ticket merchandise (Furniture) being returned, asked for exchange or needed to be inspected and fixed by technicians, as requested by the customers. This merchandise which needs to be returned, exchanged or inspected is collectively termed as unacceptable for the customer. If the amount of such unacceptable merchandise increased, then the cost of transportation and technician work hours would also increase. Further it would reduce space for new merchandise on a given customer delivery tractor-trailer (opportunity cost), thereby causing an overall reduction in profit margin. The retuned merchandise is repaired, marked down or crushed. With the economy going down, so are large / big ticket sales, therefore efforts need to be made to save money on returns. The goal of this project is to firstly find the source and magnitude of the issues which are driving unacceptable merchandise. Further, the study aims at investigating these issues to eventually drill down to a specific cause where resources of the company could be directed to improve the Productive Delivery Rate (rate at which product is accepted without being retuned, exchanged or inspected after its first time successful delivery to the customer) and to reduce exchange and return rates. The following figure shows a flowchart of the project (See Figure 3).

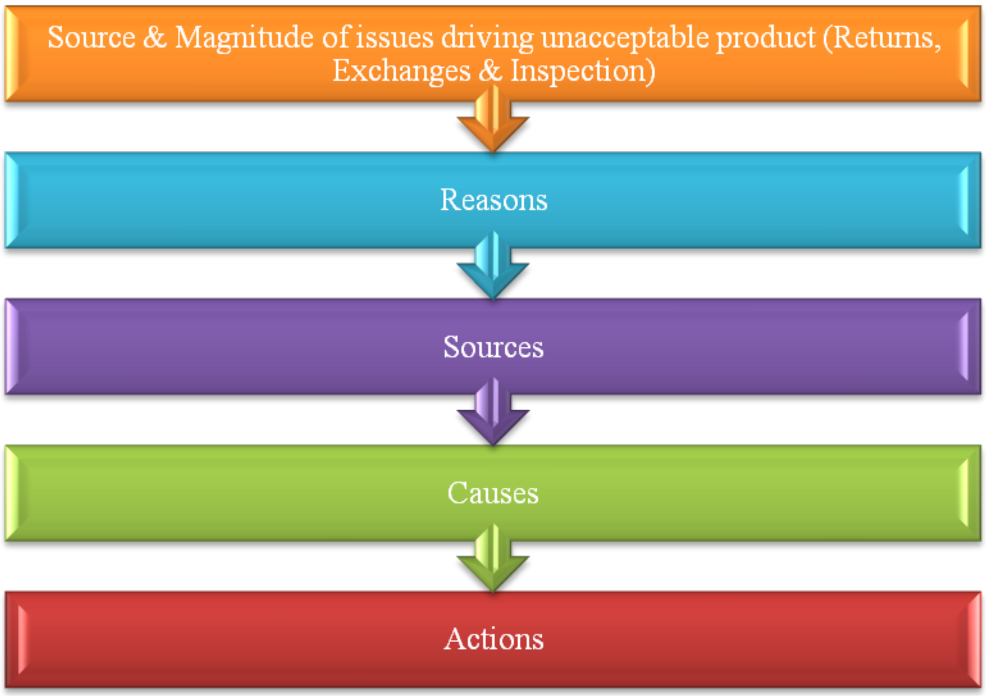


Figure 3. Project Flowchart.

The furniture available in the warehouse was purchased by the company from vendors who are typically located in the northern part of the United States. These vendors procure the furniture from manufacturers located mainly in China. When the merchandise is brought into the warehouse through the vendor tractor-trailer, no inbound inspection is done by the warehouse. The inventory is just stocked in shelves in the warehouse. A customer selects a furniture piece by looking at the sample pieces displayed in the store and then places an order. On receipt of the order the store informs the warehouse about the venue and time of delivery of particular merchandise and subsequently a tractor-trailer is sent out from the warehouse to the customer to deliver the furniture. Before loading the furniture on the tractor-trailer, an outbound inspection is done to scan for defects in the furniture and recorded according to predetermined codes. Not every piece is scanned. Those pieces which have been returned by previous customers or any particular style of specific vendor having a history of being returned and others which are randomly sampled are chosen for inspection. If a defect is found at outbound inspection, the piece is refurbished in the warehouse, but only 30 minutes are spent on a given piece. If the repair job requires additional time, the furniture was marked down and sold as clearance. Once the furniture is delivered, the customer would either accept it or launch a complaint, if dissatisfied. In case of a complaint, the furniture would be either repaired by a technician (In-home inspections) at the customer's home or will be accepted back (Return) by the company or would be exchanged with equivalent merchandise.

Four major sources of unacceptable merchandise include Vendor Defects, Store Controllable, Logistics and Operations Controllable and Credit Customer Service (CCS) Accommodation. When defective furniture is returned by the customer, the reason for it is placed in one of four categories. The various return codes that make up these four sources are tabulated below. (See Table 2)

Table 2.

Return Codes.

Reason	**Code**	**Explanation**
Vendor Defect	M – Vendor (Manufacturing) Defect	Defect based on in-home technician (technicians sent to customers place for inspection) findings, and/or is determined as the ROOT CAUSE for the return.
Store Controllable	P – Preference / Policy	Merchandise did not meet the expectation of the customer. Customer called within 3-day Preference period for furniture or between days 30 and 37 (preference period) for mattresses. Customer did not like merchandise, uncomfortable, changed mind, did not fit with décor (i.e. size, color, and or style is wrong for room).
	C – Cancel	Merchandise was loaded on the truck, and the driver has left the building. While at the customer's home, or in route to the customer's

Reason	Code	Explanation
		home, he is informed that the customer cancels order.
	S – Store Error	Sales Associate wrote wrong SKU on the sales check, or the floor sample was tagged incorrectly. Incomplete or incorrect items.
	A – Store Accommodation	Merchandise is returned due to decision made by Store Management, regardless of age or condition.
	F – No Fit	Merchandise that due to physical limitations will not fit in the home, or due to size, will not fit into a room in the house. Item would not fit in door, elevator, stairs, etc.
Logistics and Operations Controllable	H – Hold / Reschedule	Merchandise was loaded on the truck, and the driver has left the building. While at the customer's home or in route to the customer's home, he is informed that the customer cannot accept delivery today & will reschedule for another date.
	N – Not at Home	Driver arrives at the customer's home, and no one is there to accept the delivery. Once the driver has been to a home, and it is deemed a NAH, it cannot become a reschedule. Even if the customer calls during the day to reschedule, it should still be classified as a NAH because this is the reason why the merchandise is being returned to the warehouse.
	W – Warehouse damage/error	Merchandise returned due to a warehouse error. Used if the wrong merchandise is picked or the piece is tagged incorrectly.
	D – Damage	Customer returns damaged merchandise that was called in within 3-day preference period for furniture or 30-37 day preference period for mattresses, and source of damage cannot be determined. Driver damage and manufacturer's defect have been ruled out, but source could be freight handling or customer related.
	R – Driver Damage	Merchandise was returned damaged. It is determined by visual observation and / or sales check notes that the driver damaged the piece.

Reason	Code	Explanation
	I – Inconclusive damage	The returned merchandise has an unknown source of damage.
CCS Accommodation	Y - CCS Accommodations (CCS – Credit and Customer Service, located in north US, provides credit services, telemarketing and mail/phone order processing services for company's Operating Divisions. Each day CCS collects, organizes and analyzes millions of customer transactions. This provides a tool for company to market more efficiently to their core customer lifestyles.	Customer called outside of 3-day preference policy for furniture or 30-37 day preference period for mattresses. Please see definition of P code for preference period clarification. Merchandise is returned due to a CCS management/customer service decision made regardless of condition, age, or damage (unrelated to manufacturer's defect or out of warranty defect).

According to the "DEFINE - MEASURE - ANALYZE - IMPROVE - CONTROL" model, the first step is defining defects in the process. Therefore, for the distribution center, if we consider Vendor defects, the definition of defect is a scan for manufacturing defect at outbound, scan for manufacturing defect at in-home by In-home technicians and every furniture piece returned by the customer due to manufacturing defect. Manufacturing defects originate in the factory where the furniture is manufactured. The vendors do not inspect the furniture for manufacturing defects when they procure the furniture from the manufacturers or when they deliver it to the warehouse through tractor – trailer. The manufacturing defects, therefore, would be passed on the warehouse. As a result, if manufacturing defects are identified in the warehouse at outbound inspection (when the furniture is ready to be sent to the customer), the vendors are held accountable, even though the furniture was not manufactured by the vendor. Therefore, in this study terms like, vendor defects and manufacturing defects are used interchangeably. For other sources like Store Controllable, Logistics and Operations Controllable and CCS Accommodation, the definition of defect is as mentioned in the return codes (Refer Table 2).

The second stage of the "DEFINE - MEASURE - ANALYZE - IMPROVE - CONTROL" model is "Measure". In this step the defects defined in the first step were measured. The measurement of defect was done at three points of inspection. First point of inspection was outbound inspection. The outbound technician scans for defects on the pieces that are randomly selected for inspection. If a defect is noticed then it is scanned and recorded under a quality code. Quality code is nothing but a number given to a type of defect. The company has defined several types of defects for each type of furniture, and a quality code is assigned to every type of defect. These quality codes are tabulated below (See Table 3).

Table 3
Quality code based on type of defect

Case Goods		Upholstery		Leather furniture	
Code	Defect	Code	Defect	Code	Defect
300	Pickup / Redelivery	350	Insert missing	370	Fabric/leather rubbed
303	Season splits	357	Mismatched pattern	371	Unacceptable scars / marks
306	Part Missing	359	Fabric cut too short	372	Leather cracking / peeling
307	Misaligned table tops	360	Fabric torn by tack strip	373	Dye lot problem
309	Chipped edges	361	Tack strip loose	375	Frame split
310	Dents finished over	362	Staples protruded	376	Poor fitted joints
311	Veneer sanded through	363	Crooked seams	377	Finish missing / light edges
312	Chipped veneer	364	Uneven welting	378	Debris in finish
315	Poor drawer fit	365	Skirt uneven / too long	380	Packing marks
318	Glue blocks not seated	366	Buttons missing	381	Warped / loose frames
319	Drawer guide split	367	Defective zipper	382	Insufficient fill / batting
320	Machining marks	368	Pattern markings	383	Sloppy tailoring
322	Poor finish application	351	Scratched / dented exposed legs	388	Debris under fabric

The quality codes in Table 3 are all for manufacturing defects. There are, however, some quality codes which are not for manufacturing defects. These are 391 (Warehouse damage), 392 (Delivery Damage) and 396 (Customer Abuse or Returned).

The second point of inspection is In-Home. When a customer complains about performance or quality of the furniture, technicians are sent to the customer's house to inspect the defect. The defect could be a manufacturing defect as all pieces are not inspected at outbound inspection, in which case the defect is recorded under quality code for manufacturing defect (Table 3). The In-home technicians may decide that the furniture needs to be exchanged if the defect cannot be corrected. The exchanges are also counted under In-home defects. Third point of inspection is “Returns”. When the furniture comes back to the warehouse from the customers house it is recorded as a “Return”. There may be several reasons for returns. They are discussed in Return codes under Table 2.

The third step of the “DEFINE - MEASURE - ANALYZE - IMPROVE - CONTROL” model is “Analyze”. The company maintains a record of all defects found at Outbound, In-Home and Returns in a common database. The data is available in the form of data sheets which show all the defects for any month. The company’s fiscal year begins with February of that year and ends with January of the next year. Data for the Fiscal year 2008 (Feb 08 – Jan 09) was extracted from the defect database of the company, and analysis was done in following steps.

Step1 – Merchandise quality or vendor defect, Store Controllable, Logistics and Operations Controllable and Credit customer services controllable were four main factors causing defects. Based on all the defects found at outbound, in-home and returns for the entire Fiscal year 2008, the factor making up most of the defect was calculated.

Step2 – The most important factor was found to be “Vendor Defects” (Refer to results and conclusion section). In step 2 the research question was to find if there is a difference between the vendors with respect to pieces returned or percentage returned. In the first step, defects from all the sources i.e. outbound, in-home and returns was taken into consideration to find the most important factor which was driving total defects from all three sources, not just the pieces that were returned. We found Vendor defects to be the most important cause from Step 1. But the defective pieces that were found at outbound never reached the customer, as they were repaired in the distribution center or marked down and sold in clearance. Similarly, the defective pieces that were found during in-home inspection were corrected by the technicians or were exchanged with equivalent furniture. Therefore, the last case in which the furniture is rejected by the customer and returned will have the most financial impact on the company. The pieces that are found to be defective and corrected / marked down / exchanged during outbound or in-home inspection impacted the company financially, but the most significant impact would be returns, as the furniture is never sold and the customer is disappointed. Therefore percentage returned was considered to be base for ranking the vendors. The company purchased furniture from 14 vendors in total. The names of these vendors are kept confidential as per the company's policy. The company's management set certain specifications for analyzing most influential vendors to initiate improvement. The specification was set such that among these 14 vendors, those which scheduled more than 2000 furniture pieces for delivery and with more than 5% returned due to vendor defects, would be worked on first for improvements. Five out of fourteen vendors met these specifications and were subject to further statistical analysis. These vendors were named as Vendor B, C, D, N and R. Details about these five vendors is given in following table (See Table 4).

Table 4

Top five worst vendors

Vendor Name	Pieces scheduled	Pieces returned due to vendor defects	Percentage Vendor defect returned
B	3440	189	5.49%
C	9007	507	5.63%
D	2257	178	7.89%
N	9509	663	6.97%
R	2602	198	7.61%

The five vendors listed in Table 4, have scheduled more than 2000 pieces and their percent returned values due to vendor defects is above 5%. Therefore they meet the specification set by the company. For statistical analysis, pieces returned due to vendor defects was selected as the dependent variable as it relates to financial impact on the company better than percentage vendor defect returned.

The first hypothesis to be tested was:

H1 – There is a significant difference between pieces returned due to vendor defects among Vendor B, C, D, N and R for Fiscal year 2008.

One way ANOVA and Tukey's multiple comparison method was used to test H1. Also a pairwise t-test was done to compare performance of each vendor for Fiscal year 2007 and Fiscal year 2008.

Step3 – The Company has 5 different departments / types of furniture. They are Recliners, Leather Upholstery, Occasional Furniture, Entertainment / Wall and Dining Room. Step 2 gives analysis by vendor performance. Step 3 analyzes pieces returned due to vendor defect by these 5 departments. The second hypothesis to be tested was:

H2 – There is a significant difference between pieces returned due to vendor defect among the 5 departments for fiscal year 2008.

One way ANOVA and Tukey's multiple comparison method was used to test H2. Also a pairwise t-test was done to compare performance of each department for Fiscal year 2007 and Fiscal year 2008.

Step4 – Quality codes as given in Table 3 define different types of vendor defects / manufacturing defect. When an outbound or in-home inspection is done, the quality code for every vendor defect is recorded. Also when furniture is returned by a customer and the reason for the return is a vendor / manufacturing defect, the defect is given a quality code, so that the exact type of defect which caused the furniture to be rejected is known. This information was available in the company's database. Also, from step 2, the vendor (Vendor N) with highest manufacturing defects was identified. Therefore the most important types of defect were identified for Vendor N. The third hypothesis to be tested was:

H3 – There is a difference between types of defects for Vendor N for fiscal year 2008.

One way ANOVA and Tukey's multiple comparison method was used to test H3. Also a pairwise t-test was done to compare each type of defect for Fiscal year 2007 and Fiscal year 2008 for Vendor N.

The company was primarily interested in analyzing Fiscal 2008 data and intended to decide future action plan based on analyzing Fiscal 2008 data only. Hence one way ANOVA and Tukey's comparison was done only on Fiscal 2008 data. The Fiscal 2007 data is included only for comparison with Fiscal 2008 data, which is possible by pair-wise t-test. One way ANOVA and multiple comparison is not done on Fiscal 2007 data separately as no specific action plan was undertaken to improve quality after Fiscal 2007. Action plan for quality improvement through Six Sigma method would be implemented only after Fiscal 2008. Therefore, as a part of analysis in the future, the company can use one way ANOVA and multiple comparisons on Fiscal 2009 data to compare the results with Fiscal 2008. This would tell if the action plan suggested by Six Sigma method and implemented by the company in Fiscal 2008, improved the quality in Fiscal 2009 or not.

The fourth step of “DEFINE - MEASURE - ANALYZE - IMPROVE - CONTROL” model is “Improve”. Based on the Analysis step, the most influential factor driving defects was estimated. This factor was found to be “Vendor”. Also by statistical analysis the worst vendors were found (Step 2 of Analysis). Further the data were drilled to find the most important type of defects for the worst vendor (Vendor N) using step 4 of Analysis. Also performance of different departments of furniture was analyzed for vendor defect returns (Step 3 of Analysis). Therefore, an action plan for the company was set to reduce unacceptable furniture and thus improve customer satisfaction. A discussion about the action plan for process improvement is done in the results section. The company intends to initiate quality improvement projects based on the results of this study.

The final step of the “DEFINE - MEASURE - ANALYZE - IMPROVE - CONTROL” model is “Control”. As discussed in the Six Sigma part of the literature, a sigma value for the company’s performance for Fiscal year 2008 was calculated. Whether the action plan recommended by the study would actually reduce unacceptable product in the future is not known since the company has just initiated efforts to work on process improvement. The sigma value, however, can be calculated for every year or 6 months after implementing the solutions suggested by the study. These sigma values would reveal the improvements in process and can be used as a measure to check defects in the process. Thus, the process can be tracked every year to see if the company is achieving its goal of reducing unacceptable products and improvements / changes in action plan can be made accordingly. The control step is important for the long term sustainability of this Six Sigma project for process improvement. With each year’s performance of the company, necessary changes could be made in data measurement or definition / specification of defect. The Six Sigma project for process improvement evolves in the long run. Suggestions are provided in the Results section for improvements on the current study. These suggestions / guidelines can be used for future projects to further reduce defects in the merchandise.

CHAPTER 4

RESULTS AND DISCUSSION

During fiscal year 2008 (Feb 08 – Jan 09), the company scheduled 88,164 pieces of furniture for delivery. Defects were recorded during outbound inspections, in-home inspection and returns. A summary of defects by its source is shown in following figure (See Figure 4).

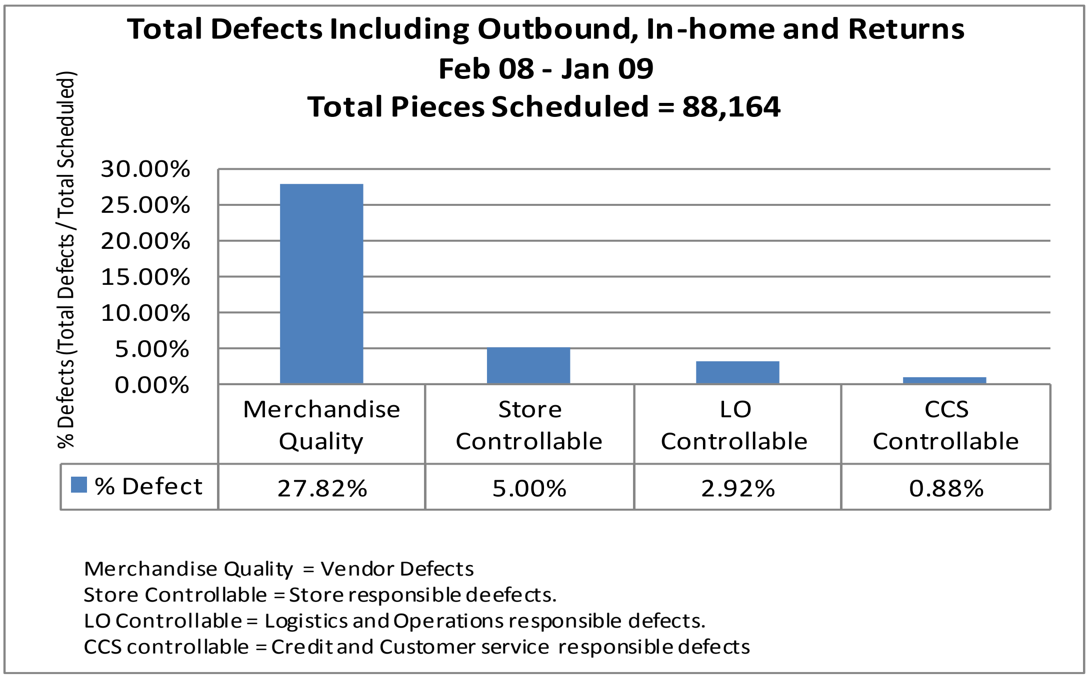
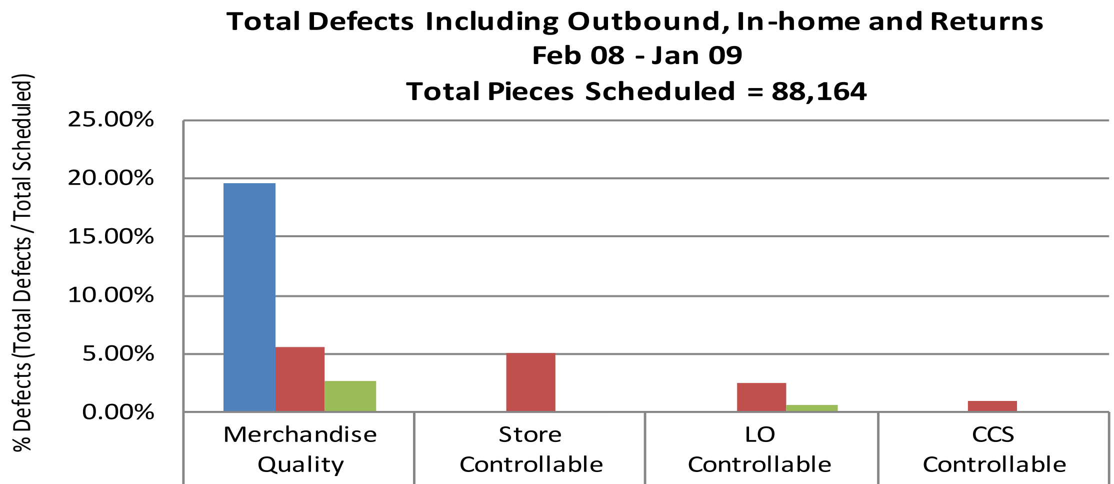


Figure 4. Summary of Defects by Factors Responsible.

It is clear from the data shown in Figure 4 that Merchandise Quality or Vendor Defects make up the majority of process defects. The summary of defects was further broken down by points of inspections, i.e., outbound, in-home or returns. Figure 5 shows breakdown of Figure 4 (See Figure 5).



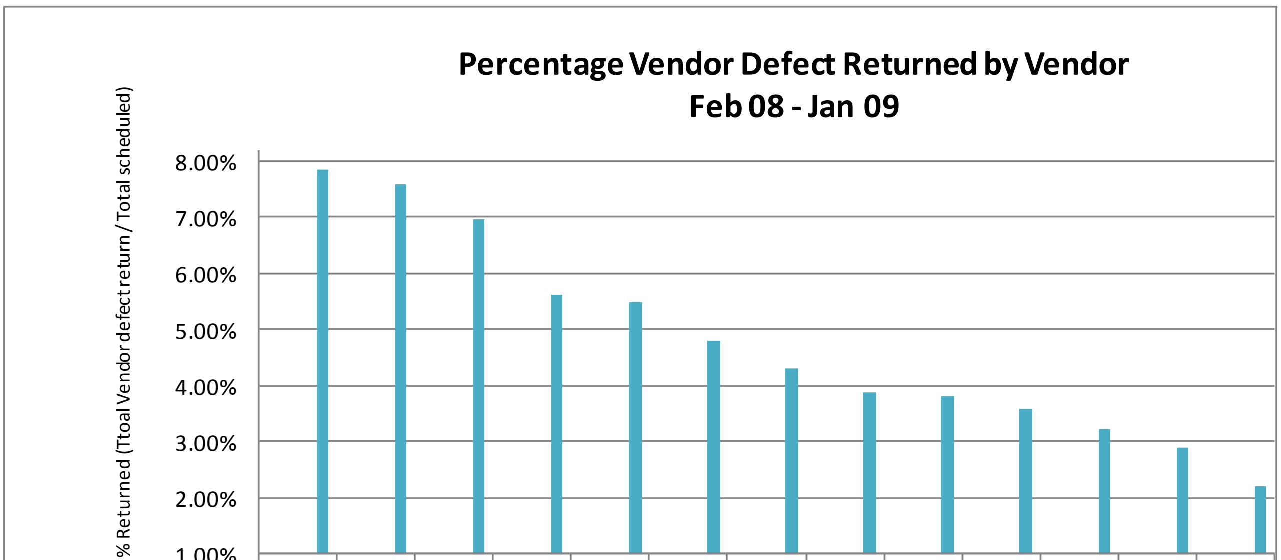
	Merchandise Quality	Store Controllable	LO Controllable	CCS Controllable
Outbound	19.59%	0.00%	0.00%	0.00%
Returns	5.52%	4.94%	2.36%	0.88%
In - Home	2.70%	0.06%	0.55%	0.00%

Merchandise Quality = Vendor Defects
Store Controllable = Store responsible defects.
LO Controllable = Logistics and Operations responsible defects.
CCS controllable = Credit and Customer service responsible defects.

Figure 5. Summary of Defects by Source of Inspection.

Data shown in Figure 5 is simply a breakdown of that shown in Figure 4 by source of inspection. All the defects inspected during outbound inspection by random sampling are vendor defects (19.59%). Thus the majority of vendor defects are caught before they reach the customer. But, these defective pieces are rectified in the workroom or are marked down; thus they still affect the company financially. The defects that reach the customers are found at in-home inspection and returns. Returns due to vendor defects are the highest among all four factors (5.52%). Thus, in spite of outbound inspections done by random sampling, 5.52% of the scheduled merchandise is returned due to vendor defect. Thus the most important factor driving unacceptable furniture is Merchandise Quality / Vendor Defect.

The next step was to find which vendors have the highest percentage return due to vendor defect. The company purchased furniture from thirty four different vendors. It scheduled a total of 88,164 furniture pieces for Fiscal 2008. Out of thirty four vendors, the furniture pieces of fourteen vendors accounted for approximately 89% (78,586 pieces) of the total pieces scheduled. The company decided to analyze vendors with more than 2000 pieces scheduled, as the financial impact of any vendor with more than 2000 pieces scheduled would be substantial. Fourteen out of thirty four vendors had pieces scheduled values of at least 2000, as shown by the data in Figure 6. A summary of the performance of these fourteen important vendors for Fiscal year 2008 is shown in following figure (See Figure 6).



	D	R	N	C	B	1	2	3	4	5	6	7	8
Total Pieces Scheduled	2257	2602	9509	9007	3440	5087	2961	17472	7713	2393	4444	9506	2195
Total Pieces Returns	457	554	1732	1425	430	654	404	1754	1145	314	502	1055	237
Vendor Defect Return	178	198	663	507	189	245	128	678	294	86	144	275	49
Total % Returned	20.25%	21.29%	18.21%	15.82%	12.50%	12.86%	13.64%	10.04%	14.85%	13.12%	11.30%	11.10%	10.80%
% Vendor Defect Returned	7.89%	7.61%	6.97%	5.63%	5.49%	4.82%	4.32%	3.88%	3.81%	3.59%	3.24%	2.89%	2.23%

Figure 6. Percentage of Vendor Defect Returned by Vendor.

The data in Figure 6 shows total pieces scheduled, total pieces returned, pieces returned due to vendor defect only and percentage of Vendor defects returned. Since vendor defects are the most important cause for unacceptable products, the vendors are ranked according to percent vendor defects returned in Figure 6. The company's management team decided to improve on those vendors which scheduled more than 2000 pieces and which had more than 5% of vendor defect returns. The vendors that met this specification were the top five vendors as shown in Figure 6. The next step was to decide which vendor was the most critical among these five using statistical analysis. Hence the first hypothesis to be tested was:

H1 – There is a significant difference between pieces returned due to vendor defects among Vendor B, C, D, N and R for Fiscal year 2008.

For statistical analysis, pieces returned due to vendor defects was selected as the dependent variable as it relates to financial impact on the company better than percent vendor defect returned. If the percent vendor defect returned values are considered, then vendor D and R have higher percent values than vendor N and C. The pieces scheduled and pieces returned values of vendor C and N, however, are much higher than that of Vendor D and R. Thus because of Vendor N and C, more customers would be disappointed and they also affect the company financially more than vendor D and R. Hence to relate the statistical analysis to the financial impact on the company, Pieces Returned was selected as the dependent variable. Pieces Returned is a continuous variable and the five different vendors are independent variables. The independent variables are nominal variables. For analysis, Pieces Returned values were collected for all five vendors by month for the fiscal year 2008 (Feb 08 – Jan 09) and fiscal year 2007 (Feb 07 – Jan 08). Thus for each vendor we have 12 data points (pieces returned values) for fiscal year 2008 and 2007. Therefore, for each vendor, two frequency distributions are possible. Each frequency distribution can be checked for normal distribution by One Sample Kolmogorov – Smirnov test. The SPSS output for the test is shown in the following table (See Table 5).

Table 5

One – Sample Kolmogorov – Smirnov Test for H1

Vendor			Returned 07	Returned 08
B		N	12	12
	Normal Parameters[a,,b]	Mean	13.2500	13.0000
		Std. Deviation	9.06667	8.75941
	Most Extreme Differences	Absolute	.221	.134
		Positive	.221	.134
		Negative	-.129	-.105
		Kolmogorov-Smirnov Z	.767	.464
		Asymp. Sig. (2-tailed)	.598	.982
C		N	12	12
	Normal Parameters[a,,b]	Mean	59.7500	37.4167
		Std. Deviation	17.68988	10.48339
	Most Extreme Differences	Absolute	.098	.122
		Positive	.096	.112
		Negative	-.098	-.122
		Kolmogorov-Smirnov Z	.339	.423
		Asymp. Sig. (2-tailed)	1.000	.994
D		N	12	12
	Normal Parameters[a,,b]	Mean	5.1667	13.2500
		Std. Deviation	4.98786	11.51383
	Most Extreme Differences	Absolute	.176	.244
		Positive	.176	.244
		Negative	-.150	-.164
		Kolmogorov-Smirnov Z	.609	.846
		Asymp. Sig. (2-tailed)	.852	.472
N		N	12	12
	Normal Parameters[a,,b]	Mean	48.2500	47.1667
		Std. Deviation	12.90613	18.65882
	Most Extreme Differences	Absolute	.196	.192
		Positive	.196	.192
		Negative	-.108	-.118
		Kolmogorov-Smirnov Z	.679	.664
		Asymp. Sig. (2-tailed)	.746	.770
R		N	12	12
	Normal Parameters[a,,b]	Mean	22.2500	14.1667
		Std. Deviation	9.90064	7.10740
	Most Extreme Differences	Absolute	.171	.203
		Positive	.099	.203
		Negative	-.171	-.143
		Kolmogorov-Smirnov Z	.592	.704
		Asymp. Sig. (2-tailed)	.874	.705

a. Test distribution is Normal.

b. Calculated from data.

If the distribution of pieces returned (Fiscal 2007 and Fiscal 2008) for each vendor is normal (at 95 % confidence level), then the Asymp. Sig. (2-tailed) values would be more than 0.05. As we see from the data in Table 5 the Asymp. Sig. (2-tailed) values for pieces returned 2008 and 2007 for each vendor is more than 0.05. Therefore, for every vendor the distribution of pieces returned for both Fiscal year 2008 and 2007 is a normal distribution. Parametric tests can therefore be done. A pairwise t-test was done to compare each vendor for fiscal year 2008 and 2007. The SPSS output for the test is as shown below (See Table 6, 7, 8).

Table 6

Vendor: Descriptive Statistics

Paired Samples Statistics

Vendor			Mean	N	Std. Deviation	Std. Error Mean
B	Pair 1	Returned 07	13.2500	12	9.06667	2.61732
		Returned 08	13.0000	12	8.75941	2.52862
C	Pair 1	Returned 07	59.7500	12	17.68988	5.10663
		Returned 08	37.4167	12	10.48339	3.02629
D	Pair 1	Returned 07	5.1667	12	4.98786	1.43987
		Returned 08	13.2500	12	11.51383	3.32376
N	Pair 1	Returned 07	48.2500	12	12.90613	3.72568
		Returned 08	47.1667	12	18.65882	5.38634
R	Pair 1	Returned 07	22.2500	12	9.90064	2.85807
		Returned 08	14.1667	12	7.10740	2.05173

Table 7

Vendor: Confidence Intervals

Paired Samples Test

Vendor			Paired Differences: 95% Confidence Interval of the Difference Lower	Upper
B	Pair 1	Returned 07 - Returned 08	-9.16675	9.66675
C	Pair 1	Returned 07 - Returned 08	8.31500	36.35167
D	Pair 1	Returned 07 - Returned 08	-15.75316	-.41351
N	Pair 1	Returned 07 - Returned 08	-11.65135	13.81801
R	Pair 1	Returned 07 - Returned 08	3.21834	12.94832

Table 8

Vendor: Sigma 2-tailed values

Paired Samples Test

Vendor			t	df	Sig. (2-tailed)
B	Pair 1	Returned 07 - Returned 08	.058	11	.954
C	Pair 1	Returned 07 - Returned 08	3.507	11	.005
D	Pair 1	Returned 07 - Returned 08	-2.320	11	.041
N	Pair 1	Returned 07 - Returned 08	.187	11	.855
R	Pair 1	Returned 07 - Returned 08	3.657	11	.004

As per the t-test, for vendor B and N, there is no significant difference between the pieces returned values for Fiscal year 2008 and 2007 at 95% confidence level, since the p values are more than 0.05. For vendor C, D and R, there is a significant difference between the pieces returned values for Fiscal year 2008 and 2007 at 95% confidence level, since the p values are less than 0.05. A means plot can show the direction of these significant differences (See Figure 7).

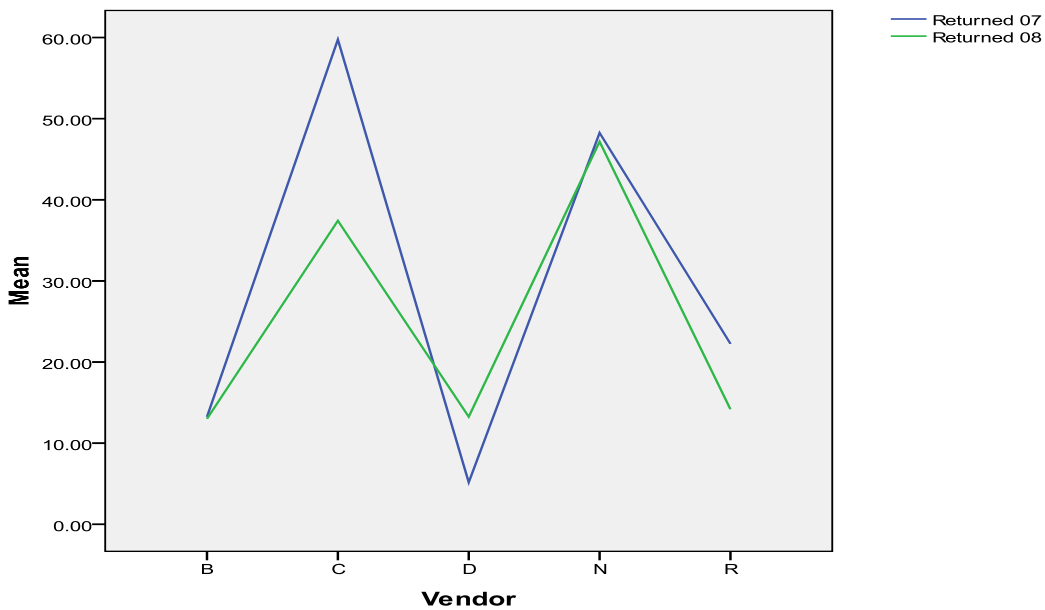


Figure 7. Vendor: Pieces Returned Means Plot

As per the means plot, vendor C and R have shown improvements from year 2007 to 2008 as the number of pieces returned have decreased. Vendor D has shown increases in pieces returned from 2007 to 2008. Vendor B and N have shown no significant differences in their performance between the two years.

To test H1, One way ANOVA was used. The experimental design is independent measures and before using a parametric test like ANOVA, the assumptions for the test were tested. Since the data is normally distributed it satisfies normality assumption for ANOVA. To satisfy homogeneity of variance assumption, however, log transformation of the pieces returned values was done to make variances among different groups more homogeneous. Levene's test of

Homogeneity of Variances table shows that after log transformation, the homogeneity assumption was met (See Table 9).

Table 9

Vendor: Test of Homogeneity of Variances

Ln '08

Levene Statistic	df1	df2	Sig.
2.484	4	55	.054

If the Levene's test result is not significant ($p>0.05$), the variances are approximately equal. Since the Sig. value is 0.054, which is just above 0.05, we can assume that the variances are approximately equal. One –way ANOVA was used to test H1 to see if there is any statistically significant difference between the pieces returned values of the 5 vendors. The SPSS output of this test are as follows (See table 10, 11).

Table 10

Vendor: ANOVA Descriptive Statistics

Ln '08

	N	Mean	Std. Deviation
B	12	2.293646	.8437885
C	12	3.582407	.3025754
D	12	2.251727	.8826176
N	12	3.781239	.4005610
R	12	2.484686	.6909556
Total	60	2.878741	.9281792

Table 11

Vendor: ANOVA

ANOVA (Ln '08)

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	26.405	4	6.601	14.865	.000
Within Groups	24.425	55	.444		
Total	50.829	59			

Since the p = 0.001 which is less than 0.05, there is a highly significant difference between the vendor defect returns values among the five vendor groups. Hence H1 cannot be rejected. To see where the differences do lie, multiple comparisons were done (See Table 12).

Table 12

Vendor: Multiple Comparisons

Ln '08

(I) Vendor	(J) Vendor	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
B	C	-1.2887612*	.2720547	.000	-2.056045	-.521478
	D	.0419192	.2720547	1.000	-.725364	.809203
	N	-1.4875925*	.2720547	.000	-2.254876	-.720309
	R	-.1910396	.2720547	.955	-.958323	.576244
C	B	1.2887612*	.2720547	.000	.521478	2.056045
	D	1.3306804*	.2720547	.000	.563397	2.097964
	N	-.1988314	.2720547	.948	-.966115	.568452
	R	1.0977215*	.2720547	.002	.330438	1.865005
D	B	-.0419192	.2720547	1.000	-.809203	.725364
	C	-1.3306804*	.2720547	.000	-2.097964	-.563397
	N	-1.5295118*	.2720547	.000	-2.296795	-.762228
	R	-.2329589	.2720547	.911	-1.000242	.534325
N	B	1.4875925*	.2720547	.000	.720309	2.254876
	C	.1988314	.2720547	.948	-.568452	.966115
	D	1.5295118*	.2720547	.000	.762228	2.296795
	R	1.2965529*	.2720547	.000	.529269	2.063836
R	B	.1910396	.2720547	.955	-.576244	.958323
	C	-1.0977215*	.2720547	.002	-1.865005	-.330438
	D	.2329589	.2720547	.911	-.534325	1.000242
	N	-1.2965529*	.2720547	.000	-2.063836	-.529269

*. The mean difference is significant at the 0.05 level.

The Sig. column tells if the mean differences between the different combinations of vendors are significant or not. For the combinations with p value less than 0.05, significant difference exists at 95% confidence level. To summarize the multiple comparisons, we look at Homogenous subsets (See Table 13).

Table 13

Vendor: Homogeneous Subsets

Ln ‘08

Tukey HSD[a]

Vendor		Subset for alpha = 0.05	
	N	1	2
D	12	2.251727	
B	12	2.293646	
R	12	2.484686	
C	12		3.582407
N	12		3.781239
Sig.		.911	.948

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 12.000.

The homogeneous subsets table combines together those pair wise comparisons that were found not to be significantly different from each other. We have two groups which are thus significantly different from each other. One reason for no significant difference between vendor N and C may be because both offer similar type and material of furniture. They offer leather furniture, e.g., sofas, chairs, recliners and love seats. The factors causing manufacturing defects in leather furniture, offered by vendor N and C, in their respective parent manufacturing companies, could be same. Another reason for similarity between vendor N and C could be because vendor N and C have almost same number of pieces scheduled. In general as the number of pieces scheduled increases, the pieces returned would also increase (assuming a constant rate of return) and since the pieces scheduled by Vendor N and C are in the same range, their pieces returned (due to vendor defect) values would more likely be in the same range. This is confirmed by the data in Table 13, there is no significant difference between pieces returned values of vendor N and C, due to vendor / manufacturing defects. Similarly, the reason for no significant difference between vendor D, B and R could be due to the same type of furniture they offer. Vendor B, D and R offer case goods. Wooden furniture and mirrors are common type of case goods that they offer. The manufacturing conditions leading to defects in the factory for vendor B, D and R could be the same, leading to similarity in defects. The exact cause of manufacturing defects in the case good manufacturing company needs to be investigated to improve quality of case goods. As in case of Vendor N and C, the pieces scheduled values for vendor B, D and R are in close range. This could be another reason that their pieces returned values due to manufacturing defect are in same range; this is confirmed by the data shown in table 13. As a result, there is no significant difference between vendor B, D and R. Hence, Group 2 (Vendor C and N) have higher mean values of pieces returned than group 1 (vendor D, B and R) as shown by means plot in the following figure. Thus vendor N and C have higher returns than vendor D, B and R (See Figure 8).

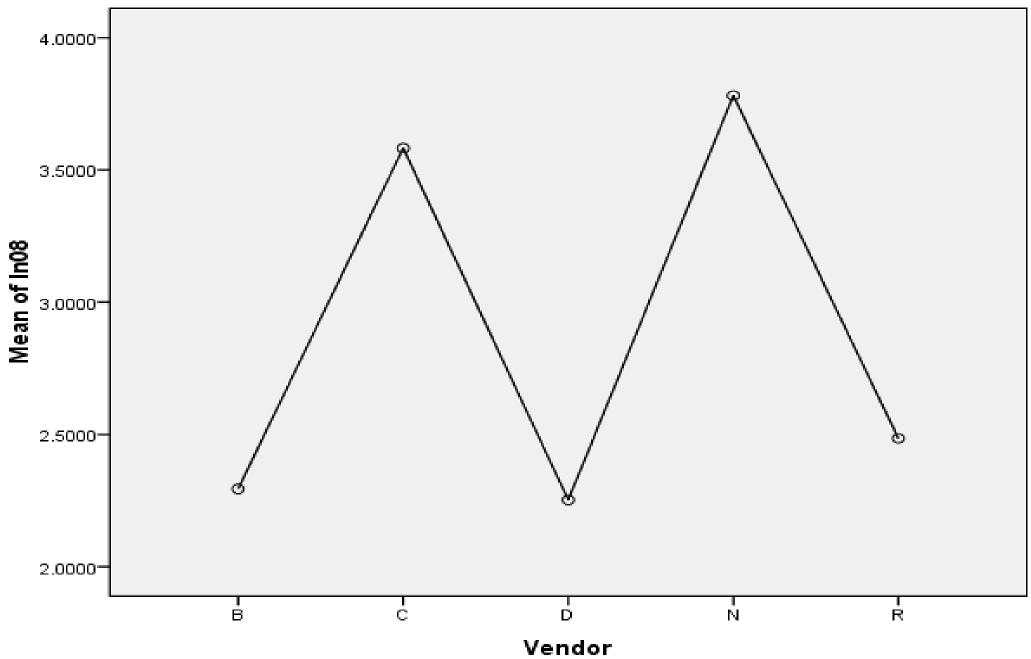


Figure 8. Vendor: Mean Plots of Log (Pieces Returned 2008).

The means plot shows that the company needs to focus on Vendor N and C first to initiate process improvement.

The next hypothesis to be tested was:

H2 – There is a significant difference between pieces returned due to vendor defect among the five departments for fiscal year 2008.

The company has five departments of furniture namely Leather Upholstery, Recliners, Entertainment / Wall, Dining Room and Occasional Furniture. Figure 7 shows performance of the departments for fiscal year 2008 (See Figure 9).

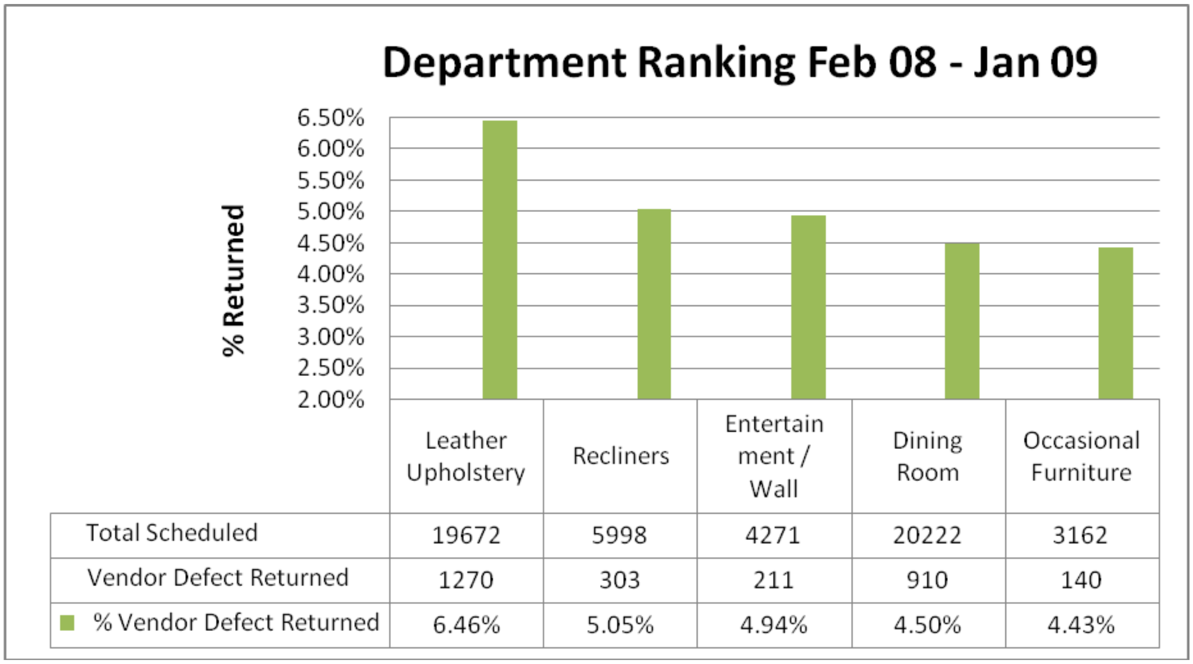


Figure 9. Department ranking Fiscal year 2008.

Percentage Vendor Defect Returned is caluclated as Vendor defect returns / Total Scheduled. The indepent varibale is the deparmtent and the dependent variable is Vendor Defect Returned. Vendor returns data were collected by department for each month for fiscal year 2008 and fiscal year 2007. As in case of analysis for H1, Vendor Defect Returned is selected as the dependent variable. The design for H2 is independent measures. The independent variable “department” is a nominal variable and the dependent variable, Vendor Defect Returned, is continuous varible. The data was first tested to check for normal distribution for each deparment and for every year by One Sample Kolmogorov – Smirnov Test (See Table 14).

Table 14

One – Sample Kolmogorov – Smirnov Test for H2

Dept			Returned08	Returned07
Recliners	N		12	12
	Normal Parameters[a,b]	Mean	25.25	24.1667
		Std. Deviation	8.915	8.26640
	Most Extreme Differences	Absolute	.142	.189
		Positive	.142	.189
		Negative	-.094	-.095
	Kolmogorov-Smirnov Z		.493	.654
	Asymp. Sig. (2-tailed)		.968	.786
Leather Upholstery	N		12	12
	Normal Parameters[a,b]	Mean	105.83	127.7500
		Std. Deviation	38.844	28.03934
	Most Extreme Differences	Absolute	.222	.213
		Positive	.222	.213
		Negative	-.119	-.158
	Kolmogorov-Smirnov Z		.771	.737
	Asymp. Sig. (2-tailed)		.593	.649
Occasional Furniture	N		12	12
	Normal Parameters[a,b]	Mean	11.67	14.1667
		Std. Deviation	3.798	5.92120
	Most Extreme Differences	Absolute	.170	.184
		Positive	.153	.120
		Negative	-.170	-.184
	Kolmogorov-Smirnov Z		.588	.637
	Asymp. Sig. (2-tailed)		.879	.812
Entertainment / Wall	N		12	12
	Normal Parameters[a,b]	Mean	17.58	18.8333
		Std. Deviation	8.836	11.33645
	Most Extreme Differences	Absolute	.186	.209
		Positive	.186	.209
		Negative	-.140	-.170
	Kolmogorov-Smirnov Z		.645	.724
	Asymp. Sig. (2-tailed)		.799	.671
Dining Room	N		12	12
	Normal Parameters[a,b]	Mean	75.83	96.1667
		Std. Deviation	27.693	42.28654
	Most Extreme Differences	Absolute	.145	.131
		Positive	.145	.131
		Negative	-.095	-.118
	Kolmogorov-Smirnov Z		.502	.452
	Asymp. Sig. (2-tailed)		.962	.987

a. Test distribution is Normal.

b. Calculated from data.

If the distribution of pieces returned (Fiscal 2007 and Fiscal 2008) for each department is normal (at 95 % confidence level), then the Asymp. Sig. (2-tailed) values would be more than 0.05. As we see from the data in Table 5 the Asymp. Sig. (2-tailed) values for pieces returned 2008 and 2007 for each department is more than 0.05. Therefore, for every department the distribution of pieces returned for both Fiscal year 2008 and 2007 is a normal distribution. Parametric tests can therefore be done. A pairwise t-test was done to compare each department for fiscal year 2008 and 2007. The SPSS output for the test is as shown below (See Table 15, 16, 17).

Table 15

Department: Descriptive Statistics

Paired Samples Statistics

Dept			Mean	N	Std. Deviation	Std. Error Mean
Recliners	Pair 1	Returned08	25.25	12	8.915	2.574
		Returned07	24.1667	12	8.26640	2.38630
Leather Upholstery	Pair 1	Returned08	105.83	12	38.844	11.213
		Returned07	127.7500	12	28.03934	8.09426
Occasional Furniture	Pair 1	Returned08	11.67	12	3.798	1.096
		Returned07	14.1667	12	5.92120	1.70930
Entertainment / Wall	Pair 1	Returned08	17.58	12	8.836	2.551
		Returned07	18.8333	12	11.33645	3.27255
Dining Room	Pair 1	Returned08	75.83	12	27.693	7.994
		Returned07	96.1667	12	42.28654	12.20707

Table 16

Department: Confidence Intervals

Paired Samples Test

Dept			Paired Differences 95% Confidence Interval of the Difference Lower	 Upper
Recliners	Pair 1	Returned08 - Returned07	-6.43182	8.59848
Leather Upholstery	Pair 1	Returned08 - Returned07	-43.18272	-.65061
Occasional Furniture	Pair 1	Returned08 - Returned07	-6.83053	1.83053
Entertainment / Wall	Pair 1	Returned08 - Returned07	-4.93619	2.43619
Dining Room	Pair 1	Returned08 - Returned07	-36.07795	-4.58872

Table 17

Department: Sigma 2-tailed values

Paired Samples Test

Dept			t	df	Sig. (2-tailed)
Recliners	Pair 1	Returned08 - Returned07	.317	11	.757
Leather Upholstery	Pair 1	Returned08 - Returned07	-2.268	11	.044
Occasional Furniture	Pair 1	Returned08 - Returned07	-1.271	11	.230
Entertainment / Wall	Pair 1	Returned08 - Returned07	-.746	11	.471
Dining Room	Pair 1	Returned08 - Returned07	-2.842	11	.016

As per the t-test, for department of Recliners, Occasional Furniture and Entertainment / Wall, there is no significant difference between the pieces returned values for Fiscal year 2008 and 2007 at 95% confidence level, since the p values are more than 0.05. For department of Leather Upholstery and Dining Room, there is a significant difference between the pieces returned values for Fiscal year 2008 and 2007 at 95% confidence level, since the p values are less than 0.05. A means plot can show the direction of these significant differences (See Figure 10).

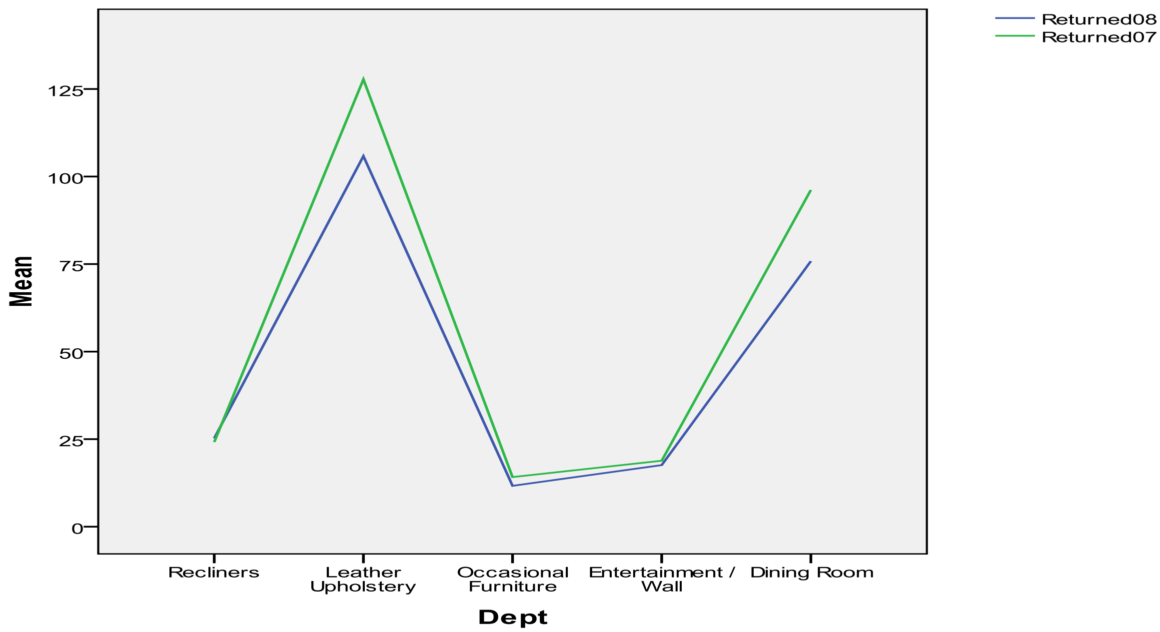


Figure 10. Department: Pieces Returned Means Plot

As per the means plot, department of Leather Upholstery and Dining Room have shown improvements from year 2007 to 2008 as pieces returned have decreased. Department of Recliners, Occasional Furniture and Entertainment / Wall have shown no significant difference in their performance between the two years.

To test H2, One way ANOVA was used. The experimental design is independent measures and before using a parametric test like ANOVA, the assumptions for the test were tested. Since the data is normally distributed it satisfies normality assumption for ANOVA. To satisfy homogeneity of variance assumption, however, log transformation of the pieces returned values was done to make variances among different groups more homogeneous. Levene's test of Homogeneity of Variances table shows that after log transformation, the homogeneity assumption was met (See Table 18).

Table 18

Department: Test of Homogeneity of Variance

Lnreturned '08

Levene Statistic	df1	df2	Sig.
.566	4	55	.688

If the Levene's test result is not significant (p>0.05), the variances are approximately equal. Since the Sig. value is 0.688, which is more than 0.05, we can assume that the variances are approximately equal. One –way ANOVA was used to test H2 to see if there is any statistically significant difference between the pieces returned values of the five departments. The SPSS output of this test are as follows (See table 19, 20).

Table 19

Department: ANOVA Descriptive Statistics

lnreturned08

	N	Mean	Std. Deviation	Std. Error
Recliners	12	3.1701	.36293	.10477
Leather Upholstery	12	4.6064	.34047	.09829
Occasional Furniture	12	2.4030	.35486	.10244
Entertainment / Wall	12	2.7596	.48217	.13919
Dining Room	12	4.2659	.37412	.10800
Total	60	3.4410	.93927	.12126

Table 20

Department: ANOVA

ANOVA (Ln '08)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	43.846	4	10.961	73.466	.000
Within Groups	8.206	55	.149		
Total	52.052	59			

Since the p = 0.001 which is less than 0.05, there is a highly significant difference between the vendor defect returns values among the five vendor groups. Hence H2 cannot be rejected. To see where the differences do lie, multiple comparisons were done (See table 21, 22).

Table 21

Department: Multiple Comparisons 1

Ln returned '08

(I) Dept	(J) Dept	Mean Difference (I-J)	Std. Error	Sig.
Recliners	Leather Upholstery	-1.43635*	.15769	.000
	Occasional Furniture	.76701*	.15769	.000
	Entertainment / Wall	.41049	.15769	.084
	Dining Room	-1.09587*	.15769	.000
Leather Upholstery	Recliners	1.43635*	.15769	.000
	Occasional Furniture	2.20337*	.15769	.000
	Entertainment / Wall	1.84684*	.15769	.000
	Dining Room	.34048	.15769	.211
Occasional Furniture	Recliners	-.76701*	.15769	.000
	Leather Upholstery	-2.20337*	.15769	.000
	Entertainment / Wall	-.35652	.15769	.173
	Dining Room	-1.86288*	.15769	.000
Entertainment / Wall	Recliners	-.41049	.15769	.084
	Leather Upholstery	-1.84684*	.15769	.000
	Occasional Furniture	.35652	.15769	.173
	Dining Room	-1.50636*	.15769	.000
Dining Room	Recliners	1.09587*	.15769	.000
	Leather Upholstery	-.34048	.15769	.211
	Occasional Furniture	1.86288*	.15769	.000
	Entertainment / Wall	1.50636*	.15769	.000

*. The mean difference is significant at the 0.05 level.

Table 22

Department: Multiple Comparisons 2

Ln Returned ‘08 (Tukey HSD)

(I) Dept	(J) Dept	95% Confidence Interval Lower Bound	Upper Bound
Recliners	Leather Upholstery	-1.8811	-.9916
	Occasional Furniture	.3223	1.2118
	Entertainment / Wall	-.0343	.8552
	Dining Room	-1.5406	-.6511
Leather Upholstery	Recliners	.9916	1.8811
	Occasional Furniture	1.7586	2.6481
	Entertainment / Wall	1.4021	2.2916
	Dining Room	-.1043	.7852
Occasional Furniture	Recliners	-1.2118	-.3223
	Leather Upholstery	-2.6481	-1.7586
	Entertainment / Wall	-.8013	.0882
	Dining Room	-2.3076	-1.4181
Entertainment / Wall	Recliners	-.8552	.0343
	Leather Upholstery	-2.2916	-1.4021
	Occasional Furniture	-.0882	.8013
	Dining Room	-1.9511	-1.0616
Dining Room	Recliners	.6511	1.5406
	Leather Upholstery	-.7852	.1043
	Occasional Furniture	1.4181	2.3076
	Entertainment / Wall	1.0616	1.9511

The data in the Sig. column shows if the mean differences between the different combinations of department are significant or not. For the combinations with p value less than 0.05, significant difference exists at 95% confidence level. To summarize the multiple comparisons, we look at Homogenous subsets (See Table 23).

Table 23

Department: Homogeneous Subsets

Ln '08

Tukey HSD[a]

Dept	N	Subset for alpha = 0.05		
		1	2	3
Occasional Furniture	12	2.4030		
Entertainment / Wall	12	2.7596	2.7596	
Recliners	12		3.1701	
Dining Room	12			4.2659
Leather Upholstery	12			4.6064
Sig.		.173	.084	.211

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 12.000.

The homogeneous subsets table combines together those pair wise comparisons that were found not to be significantly different from each other. We have three groups which are thus significantly different from each other. In general as the number of pieces scheduled by a department increases the pieces returned due to vendor defects would also increase, assuming a constant rate of return. Each group has two vendors whose pieces returned values (due to vendor defects) are not significantly different from each other as shown by the data in Table 23. As per the data in Figure 9, the pieces scheduled by vendors in same group are approximately close to each other. The pieces returned (due to vendor defects) of vendors in the same group could therefore more likely be close to each other. As a result this could be a reason for no significant difference between the vendors in the same group. The group 3 (Leather Upholstery and Dining

Room) have higher mean values of pieces returned than group 1 (Occasional Furniture and Entertainment / Wall) and group 2 (Entertainment / Wall and Recliners) as shown by means plot. (See Figure 11).

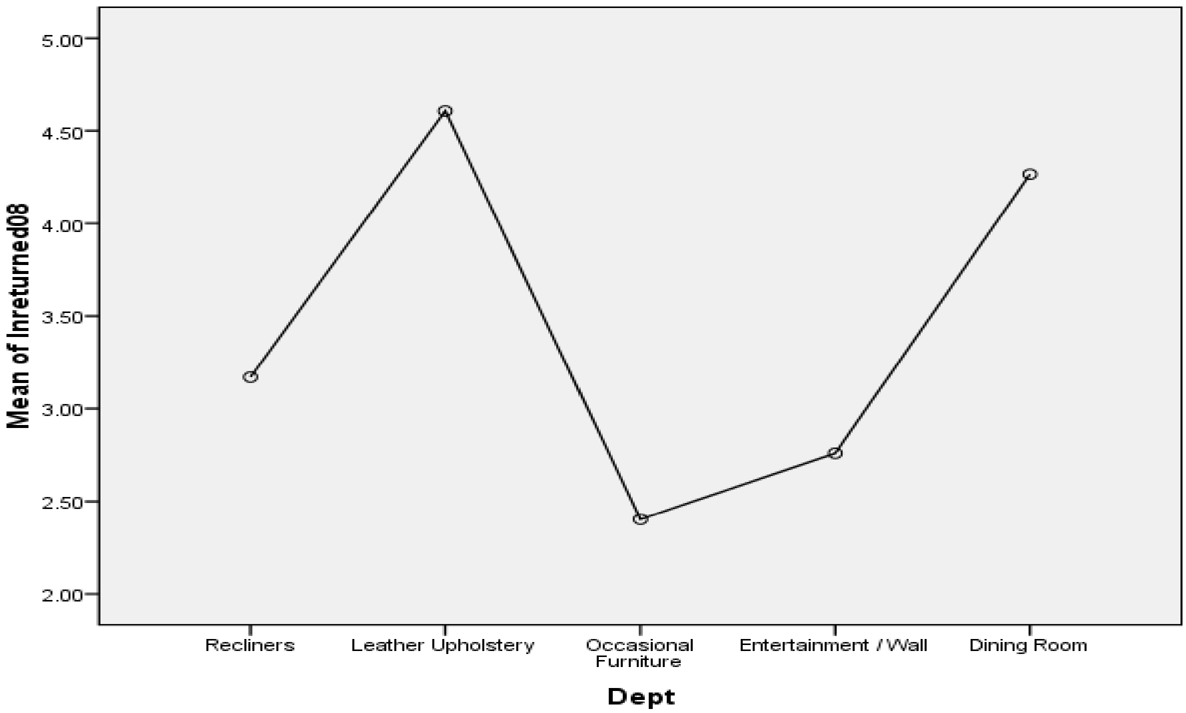


Figure 11. Department: Mean Plots of Log (Pieces Returned) 2008.

Thus Leather Upholstery and Dining Rooms are the departments which have higher returns due to vendor defects than other departments. Even though there is not a statistical significance difference between Leather Upholstery and Dining Rooms, Leather Upholstery department has higher mean vendor defect returns than Dining room for fiscal year 2008. Hence the company can start processing improvement projects focused toward Leather Upholstery to see possible reduction in defects for the next year.

The next hypothesis to be tested was:

H3 – There is a significant difference between types of defects for Vendor N for fiscal year 2008.

H1 tested for vendors which have the most financial impact on the company. Vendor N and C were found to have highest pieces returned due to vendor defects, during fiscal year 2008. The next step was to find the most prominent type of defects that are causing the furniture of these vendors to be defective. The quality codes listed in Table 3 summarized all the vendor defects defined. The company's next question was to know the type of defects that a vendor is vulnerable to. For analysis purpose vendor N was selected, as it showed the highest value of pieces returned during fiscal 2008. A summary of type of defects for Vendor N for fiscal year 2008 is shown below (See Figure 12).

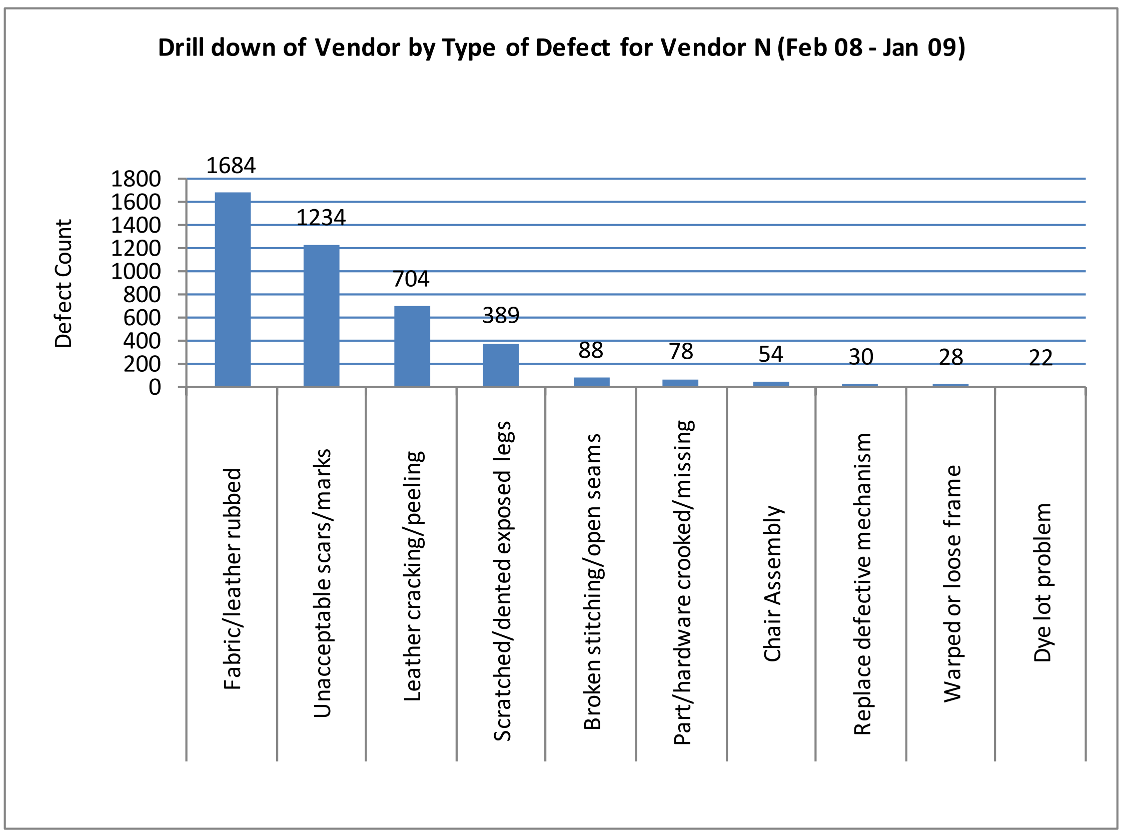


Figure 12. Drill Down of Vendor by Type of Defect for Vendor N (Feb 08 – Jan 09)

For analysis, the top four types of defects were analyzed to see if there was a significant difference between them. Monthly data for these types of defects for vendor N was collected for fiscal 2008 and 2007. The indepent varibale is type of defect and the dependent variable is Vendor Defect Count. The design for H3 is independent measures. The independent variable “Type of Defect” is a nominal variable and the dependent variable, Vendor Defect Count, is continuous varible. The data was first tested to check for normal distribution for each deparment and for every year by One Sample Kolmogorov – Smirnov Test (See Table 24).

Table 24

One-Sample Kolmogorov-Smirnov Test for H3.

DefectType			Defects07	Defects08
Fabric / Leather Rubbed	N		12	12
	Normal Parameters[a,b]	Mean	111.33	140.33
		Std. Deviation	46.998	38.981
	Most Extreme Differences	Absolute	.219	.181
		Positive	.219	.181
		Negative	-.162	-.118
	Kolmogorov-Smirnov Z		.758	.627
	Asymp. Sig. (2-tailed)		.613	.827
Leather Cracking / Peeling	N		12	12
	Normal Parameters[a,b]	Mean	53.25	58.67
		Std. Deviation	15.475	14.889
	Most Extreme Differences	Absolute	.122	.187
		Positive	.122	.187
		Negative	-.109	-.148
	Kolmogorov-Smirnov Z		.421	.648
	Asymp. Sig. (2-tailed)		.994	.796
Scratched / Dented Exposed Legs	N		12	12
	Normal Parameters[a,b]	Mean	28.67	32.42
		Std. Deviation	5.516	8.447
	Most Extreme Differences	Absolute	.143	.176
		Positive	.143	.176
		Negative	-.125	-.100
	Kolmogorov-Smirnov Z		.494	.608
	Asymp. Sig. (2-tailed)		.968	.853
Unacceptable Scars / Marks	N		12	12
	Normal Parameters[a,b]	Mean	53.25	102.83
		Std. Deviation	46.697	34.319
	Most Extreme Differences	Absolute	.220	.151
		Positive	.220	.151
		Negative	-.172	-.093
	Kolmogorov-Smirnov Z		.763	.522
	Asymp. Sig. (2-tailed)		.605	.948

a. Test distribution is Normal.

b. Calculated from data.

If the distribution of vendor defect count (Fiscal 2007 and Fiscal 2008) for vendor N follows normal distribution (at 95 % confidence level), then the Asymp. Sig. (2-tailed) values would be more than 0.05. As we see from the data in Table 5 the Asymp. Sig. (2-tailed) values for Vendor defect count for 2008 and 2007 for vendor N is more than 0.05. Therefore, for vendor N, the distribution of vendor defect count for both Fiscal year 2008 and 2007 is a normal distribution. Parametric tests can therefore be done. A pairwise t-test was done to compare each department for fiscal year 2008 and 2007. The SPSS output for the test is as shown below (See Table 25, 26, 27).

Table 25

Type of Defect: Descriptive Statistics

Paired Samples Statistics

DefectType			Mean	N	Std. Deviation	Std. Error Mean
Fabric / Leather Rubbed	Pair 1	Defects07	111.33	12	46.998	13.567
		Defects08	140.33	12	38.981	11.253
Leather Cracking / Peeling	Pair 1	Defects07	53.25	12	15.475	4.467
		Defects08	58.67	12	14.889	4.298
Scratched / Dented Exposed Legs	Pair 1	Defects07	28.67	12	5.516	1.592
		Defects08	32.42	12	8.447	2.439
Unacceptable Scars / Marks	Pair 1	Defects07	53.25	12	46.697	13.480
		Defects08	102.83	12	34.319	9.907

Table 26

Type of Defect: Confidence Intervals

Paired Samples Test

			Paired Differences	
			95% Confidence Interval of the Difference	
DefectType			Lower	Upper
Fabric / Leather Rubbed	Pair 1	Defects07 - Defects08	-75.521	17.521
Leather Cracking / Peeling	Pair 1	Defects07 - Defects08	-14.811	3.978
Scratched / Dented Exposed Legs	Pair 1	Defects07 - Defects08	-9.881	2.381
Unacceptable Scars / Marks	Pair 1	Defects07 - Defects08	-96.766	-2.400

Table 27

Type of Defect: Sigma 2-tailed values

Paired Samples Test

DefectType			t	df	Sig. (2-tailed)
Fabric / Leather Rubbed	Pair 1	Defects07 - Defects08	-1.372	11	.197
Leather Cracking / Peeling	Pair 1	Defects07 - Defects08	-1.269	11	.231
Scratched / Dented Exposed Legs	Pair 1	Defects07 - Defects08	-1.346	11	.205
Unacceptable Scars / Marks	Pair 1	Defects07 - Defects08	-2.313	11	.041

As per the t-test, for Fabric / Leather rubbed, Leather Cracking / Peeling, Scratched /dented exposed legs, there is no significant difference between the defect count values for Fiscal year 2008 and 2007 at 95% confidence level, since the p values are more than 0.05. For Unacceptable scare / marks, there is a significant difference between the vendor defect count values for Fiscal year 2008 and 2007 at 95% confidence level, since the p value is less than 0.05. A means plot can show the direction of these significant differences as shown below (See Figure 13).

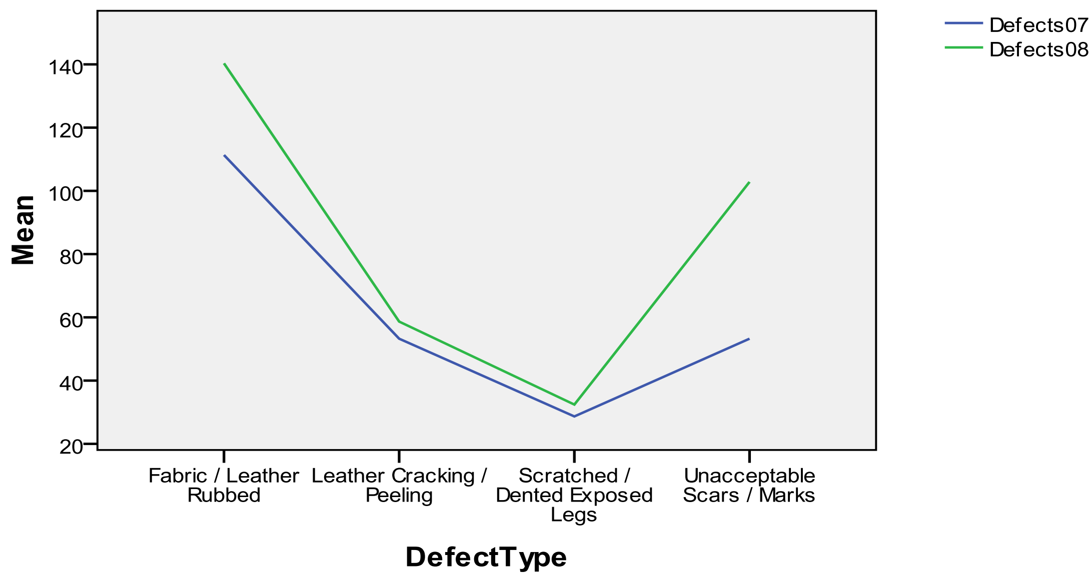


Figure 13. Type of Defect: Vendor Defect Count Means Plot

As per the means plot, unacceptable scars / marks for vendor N have shown an increase in count from year 2007 to 2008. Fabric / Leather Rubbed, Leather Cracking / Peeling, Scratched /dented exposed legs, however, have shown no significant difference in their performance between the two years.

To test H3, One way ANOVA was used. The experimental design is independent measures and before using a parametric test like ANOVA, the assumptions for the test were tested. Since the data is normally distributed it satisfies normality assumption for ANOVA. To satisfy homogeneity of variance assumption, however, log transformation of the vendor defect count values was done to make variances among different groups more homogeneous. Levene's test of Homogeneity of Variances table shows that after log transformation, the homogeneity assumption was met (See Table 28).

Table 28

Type of Defect: Test of Homogeneity of Variances.

LnDefect '08

Levene Statistic	df1	df2	Sig.
.367	3	44	.777

If the Levene's test result is not significant (p>0.05), the variances are approximately equal. Since the Sig. value is 0.777, which is more than 0.05, we can assume that the variances are approximately equal. One –way ANOVA was used to test H3 to see if there is any statistically significant difference between the vendor defect count values of the 4 type of defect. The SPSS output of this test are as follows (See Table 29, 30).

Table 29

Type of Defect: ANOVA Descriptive Statistics

Ln '08

	N	Mean	Std. Deviation
Fabric / Leather Rubbed	12	4.9089	.27748
Leather Cracking / Peeling	12	4.0398	.26981
Scratched / Dented Exposed Legs	12	3.4449	.27887
Unacceptable Scars / Marks	12	4.5806	.34326
Total	48	4.2436	.62953

Table 30

Type of Defect: ANOVA

ANOVA (Ln '08)

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	14.827	3	4.942	57.239	.000
Within Groups	3.799	44	.086		
Total	18.627	47			

Since the p = 0.001 which is less than 0.05, there is a highly significant difference between the vendor defect count values among the four defect types. Hence H3 cannot be rejected. To see where the differences do lie, multiple comparisons were done (See Table 31, 32).

Table 31

Type of Defect: Multiple Comparisons 1

Ln Defects '08

Tukey HSD

(I) DefectType	(J) DefectType	Mean Difference (I-J)	Std. Error	Sig.
Fabric / Leather Rubbed	Leather Cracking / Peeling	.86909*	.11996	.000
	Scratched / Dented Exposed Legs	1.46399*	.11996	.000
	Unacceptable Scars / Marks	.32834*	.11996	.043
Leather Cracking / Peeling	Fabric / Leather Rubbed	-.86909*	.11996	.000
	Scratched / Dented Exposed Legs	.59490*	.11996	.000
	Unacceptable Scars / Marks	-.54075*	.11996	.000
Scratched / Dented Exposed Legs	Fabric / Leather Rubbed	-1.46399*	.11996	.000
	Leather Cracking / Peeling	-.59490*	.11996	.000
	Unacceptable Scars / Marks	-1.13565*	.11996	.000
Unacceptable Scars / Marks	Fabric / Leather Rubbed	-.32834*	.11996	.043
	Leather Cracking / Peeling	.54075*	.11996	.000
	Scratched / Dented Exposed Legs	1.13565*	.11996	.000

*. The mean difference is significant at the 0.05 level.

Table 32

Type of Defect: Multiple Comparisons 2

Ln Defects '08

Tukey HSD

(I) DefectType	(J) DefectType	95% Confidence Interval Lower Bound	Upper Bound
Fabric / Leather Rubbed	Leather Cracking / Peeling	.5488	1.1894
	Scratched / Dented Exposed Legs	1.1437	1.7843
	Unacceptable Scars / Marks	.0080	.6486
Leather Cracking / Peeling	Fabric / Leather Rubbed	-1.1894	-.5488
	Scratched / Dented Exposed Legs	.2746	.9152
	Unacceptable Scars / Marks	-.8611	-.2205
Scratched / Dented Exposed Legs	Fabric / Leather Rubbed	-1.7843	-1.1437
	Leather Cracking / Peeling	-.9152	-.2746
	Unacceptable Scars / Marks	-1.4560	-.8154
Unacceptable Scars / Marks	Fabric / Leather Rubbed	-.6486	-.0080
	Leather Cracking / Peeling	.2205	.8611
	Scratched / Dented Exposed Legs	.8154	1.4560

The Sig. column tells if the mean differences between the different combinations of type of defects are significant or not. For the combinations with p value less than 0.05, significant difference exists at 95% confidence level. To summarize the multiple comparisons, we look at Homogenous subsets (See Table 33).

Table 33

Type of Defect: Homogeneous Subsets

LnDefect '08

Tukey HSD[a]

DefectType	N	Subset for alpha = 0.05			
		1	2	3	4
Scratched / Dented Exposed Legs	12	3.4449			
Leather Cracking / Peeling	12		4.0398		
Unacceptable Scars / Marks	12			4.5806	
Fabric / Leather Rubbed	12				4.9089
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 12.000.

The homogeneous subsets table combines together those pair wise comparisons that were found not to be significantly different from each other. We have four groups which are thus significantly different from each other. Since four types of defects were compared and four subsets were obtained, each type of defect is significantly different than other types at 95% confidence level. Vendor N offers leather furniture. The leather furniture offered by Vendor N consists of sofas, chairs, recliners and love seats. The manufacturing conditions causing defects like scratched / dented exposed legs, leather cracking / peeling, unacceptable scars / marks and leather rubbed in the leather furniture offered Vendor N would primarily be different in nature. This could be one possible reason for the four defect types to be significantly different than each other. To make a judgment of which type of defect is most prominent for Vendor N, a means plot was constructed (See Figure 14).

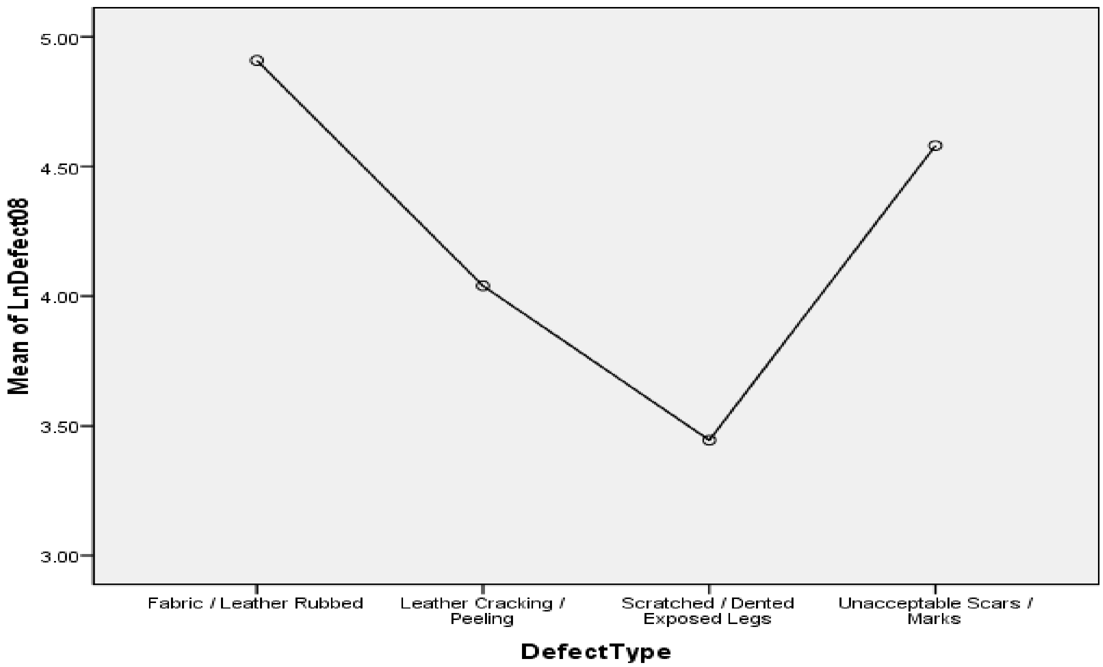


Figure 14. Type of Defect: Mean Plot of Ln (Vendor Defect Count) 2008.

As per the means plot Fabric / Leather Rubbed is the most prominent type of defect found for vendor N. The company, therefore, can start processing improvement projects focused toward monitoring and checking for Fabric / Leather Rubbed defects for Vendor N to see possible reduction in overall defects for the next year. The best solution for preventing rubbing of leather for the furniture of vendor N could be investigating the factory condition of manufacturing that causes them originally. The warehouse / company does not communicate with the manufacturer overseas, but it can put pressure on Vendor N to encourage the manufacturers to find process conditions / reasons that leads to rubbing of leather furniture. Similar analysis of type of defect for every vendor can be done. Vendor N is used as an example as it most financial impact on the company as per the data shown in Figure 8.

Data analysis revealed that Vendor defects are the most important factor driving defects in furniture. Then the different vendors were analyzed and tested to see if H1 can be rejected. Differences between Vendor Defect Returns among the vendors did exist and Vendor N and C stood out as the worst vendors. Also Vendor Defect Returns were analyzed by department to test which departments need process improvement first. Leather Upholstery and Dining room were the departments with most vendor defect returns, thus needing process improvement. Also for Vendor N, different types of defect were analyzed and Fabric / Leather Rubbed were found to be most common cause of defective furniture for Vendor N. The overall sigma value at which the process was operating for fiscal year 2008 can be calculated (See Table 34).

Table 34

Process Six Sigma '08

Fiscal Year	Total pieces scheduled	Total pieces returned	Pieces returned proportion	Process Yield	Sigma value
2008	88164	12734	0.1444	0.8556	1.06

The sigma value is calculated using standard normal distribution table. The sigma value is for long term. For short term sigma value i.e. for fiscal year 2008, 1.5 is added to the sigma value. Thus process sigma value of fiscal year 2008 for the company is 2.56.

The sigma value can be used to track overall performance of the company by year. The higher the sigma value, the more defect free is the process. The results of the study give guidelines for action plan to improve process. The company now knows it must focus on Vendor N and C to reduce overall defects. For every vendor, analysis of the type of defect can be done to look for the most prominent defect during inspections. As an example, the company should inspect for Fabric / Leather rubbed defects in furniture by vendor N. All the pieces by every vendor cannot be inspected by the company before delivering it to the customer. Inspections require unwrapping and rewrapping of the furniture, which is a risky and lengthy process. Also it requires time and labor, which has a financial impact on the company. Thus the goal of the study was to focus the limited resources that the company has on those issues which are most important. As an action plan the company can inspect furniture offered by vendor N and C more frequently than other vendors. The company cannot change its vendors overnight as it has established relations with them. So with this study the company intends to work with the quality team of vendor N and C, to avoid defective furniture in the first place. For example, vendor N can install outbound inspections to check for Fabric / leather rubbed defects before they send the furniture to the company. This would help the company immensely as defective products would be prevented from entering in the workroom. Alternatively, vendor N can work with the manufacturers from which it buys the furniture to pass the information about source and type of defects in furniture. The company intends to train the quality management team to conduct such studies to find which manufacturers offer most defective furniture and what the type of defect is. If the vendors would initiate such studies then the manufacturers would know about the furniture that are inspected as defective or returned by the customer as defective. Thus preventive measures can be taken in the manufacturing factory itself to avoid defective furniture to be passed to vendor, to company and ultimately to the end consumer. The manufacturers can inspect for damage during overseas transportation to ensure furniture is not damaged. The vendors can also ensure transportation from their unit to the company is safe.

Since vendor defects are the most important cause of defect, the root cause is inefficiency of the manufacturing process in the factory overseas. If the information obtained by this study is passed from the retailer to vendors to manufacturers, then production quality can be improved at the factory level and entire supply chain would be more efficient with fewer defects, thus benefiting the end consumer. Manufacturing defects are caused at factory level but are caught by the company and some passed on the consumer. Hence it is imperative that the production quality is improved at factory so that defects are prevented in its initial stage. Manufacturers, vendors and the distribution center would have to work as a team to improve the supply chain; and information about quality has to be passed efficiently between these crucial elements. It is indeed a daunting task to make the entire supply chain efficient, but improving quality is the only key to remain sustainable in the market for manufacturers, vendors and retailers. Hence the findings of this study would give direction to make the supply chain more efficient and satisfy customers. The company can also improve quality of different departments. The quality control team in leather upholstery and dining room could use this study to ensure inspection is increased for these two departments. Thus quality can be improved both by department and vendor.

The sigma value calculated is just a mathematical measuring scale for the performance of the company. More important is the findings of analysis, which provides solutions to the defect problem. Nevertheless, the sigma value can track if the process improvement projects are benefiting the company or not. Hence the sigma value is a quality check. It may not be possible to operate the company at Six Sigma level, since the company is dependent on manufacturers and vendors to improve quality, but it can aim for an increase in sigma value each year. The sheer motivation of achieving Six Sigma can help increase customer satisfaction.

CHAPTER 5

CONCLUSION

This study is a suitable example of Six Sigma application, to improve quality in a supply chain network. The study was done using "DEFINE - MEASURE - ANALYZE - IMPROVE - CONTROL" model which is an improvement over previous management theories like Risk and Protective Factors theory, Total Quality Management and Deming's Management philosophy. The potential value of improving the Product Delivery Rate (PDR) by 10% alone is approximately **$1.6 Million** annually for the company's total network. In other words, the company was losing $1.6 Million annually because of poor quality of furniture. With tough economic conditions and sales going down, accurate solutions were required to improve the quality and therefore customer satisfaction. Since the quality of final furniture was dependent on complex factors, a concrete method of analysis was needed to pin point the process defects and find the root cause of defects in furniture. Six Sigma methodologies provided the crucial direction for the company, which could minimize defects in future operations.

Vendor defects are the most important cause of defective furniture. Vendor N and C are most influential vendors which contribute to most of the defects. Most common defects found in furniture offered by vendor N is Fabric / leather rubbed. From the departmental point of view, Leather upholstery and dining room are the contributors of the majority of defective furniture. The company is currently operating at an overall sigma level of 2.56 for fiscal year 2008. These conclusions can provide direction for the company to improve quality and thereby increase customer satisfaction. Suggestions for improving quality for the company are as follows:

- Increase outbound inspections on furniture supplied by vendor N and C.

- Install inbound inspection to prevent defective furniture from entering the company. Alternatively, outbound inspections at vendor N and C can prevent incoming defective furniture in the first place.
- Increase inspections on Leather Upholstery and Dining room furniture.
- Work with the quality team of vendors to help them conduct such quality studies and find manufacturers which provide most of defective furniture.
- Coordinate with vendors to install outbound inspections at vendor side.
- Conduct such quality measurement study each month in the company to track for vendor performances by month.

Suggestions for Future Research

The company can conduct similar quality studies to find the root causes of returns due to Store controllable factors. The data in Figure 5 shows that the store controllable factor is responsible for 4.94% of the merchandise returned by the customer. The percentage of pieces returned due to poor merchandise quality (manufacturing defect) is 5.52%, which is almost close to the percentage of pieces returned due to store controllable factor. The customer selects the furniture from the samples displayed in the store. The store is primarily responsible for accepting all furniture orders from the customers and passing the information to the warehouse for delivery. The store is responsible for knowing crucial information about the order like customers residence, residence type (e.g., apartment or row house, elevator, size of door entry), details of the merchandise ordered (SKU, color specifications, material specifications, physical dimensions of the merchandise, etc.) and time of delivery as per availability of the customer. If the store fails to know any of the crucial information or does not communicate the exact information with the warehouse, then the merchandise is returned back to the warehouse. Hence in such cases, the company has to make multiple trips of the tracker-trailer to get the right merchandise to the customer at the right time. Each piece of furniture retuned from the customer's house due to store controllable factor is counted as a defect in the store operation. A single piece retuned by the customer more than once is counted as multiple defects.

Future studies can be done to find what factors of store operation are responsible for the defects. The information about the merchandise order is passed from the store representative to the central store system and then to the warehouse. The central store system organizes details about all the merchandise order and sends it electronically to the representative at the warehouse. If the cause of all defects due to store operation is known then it is possible to track the most important store controllable factor causing defects (store representative, central store system and warehouse representative). When a furniture piece is returned back to the warehouse due to store controllable factors, then the information supplied by each of the three main store controllable factors (store representative, central store system and warehouse representative) can be cross verified to detect for any deviation from the actual customer order and specification. Thus the store controllable defects can be recorded and classified according to the factors causing these defects. The company, therefore, can pin-point the exact factor causing majority of the store controllable defects and subsequently monitor those factors to reduce future defects. Since the defects due to store operation directly affect the customer, it could have negative impact on customer satisfaction.

The defects arising at the manufacturing site are major contributors to poor quality. Future study should aim at investigating the manufacturing conditions in factory, machinery used and quality of fabric / leather used. If major source of manufacturing defects in factory is known then the defects can be stopped at initial stage of the supply chain. Dollar values associated with each piece returned, exchange or fixed in the workroom or at customers residence can be recorded, so that financial impact of defective furniture is better understood.

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Appendix A – Pieces returned due to vendor defect by vendor

Vendor	Pieces Returned due to Vendor Defect		
	Fiscal 2007	Fiscal 2008	Ln (Fiscal 2008)
B	26	16	2.77
B	35	2	0.69
B	11	19	2.94
B	16	10	2.30
B	3	19	2.94
B	9	5	1.61
B	6	3	1.10
B	11	10	2.30
B	15	6	1.79
B	12	12	2.48
B	9	30	3.40
B	6	24	3.18
C	33	52	3.95
C	86	51	3.93
C	49	35	3.56
C	68	23	3.14
C	91	36	3.58
C	63	26	3.26
C	71	38	3.64
C	55	40	3.69
C	40	44	3.78
C	62	21	3.04
C	57	49	3.89
C	42	34	3.53
D	3	20	3.00
D	7	42	3.74
D	0	9	2.20
D	0	14	2.64
D	12	27	3.30
D	1	8	2.08
D	1	9	2.20
D	2	11	2.40
D	9	4	1.39
D	4	2	0.69
D	15	3	1.10

Vendor	Pieces Returned due to Vendor Defect		
	Fiscal 2007	Fiscal 2008	Ln (Fiscal 2008)
D	8	10	2.30
N	48	71	4.26
N	67	81	4.39
N	42	43	3.76
N	49	59	4.08
N	37	68	4.22
N	28	29	3.37
N	39	31	3.43
N	53	46	3.83
N	50	22	3.09
N	46	34	3.53
N	76	36	3.58
N	44	46	3.83
R	32	25	3.22
R	35	23	3.14
R	22	16	2.77
R	19	8	2.08
R	33	19	2.94
R	13	12	2.48
R	8	12	2.48
R	21	23	3.14
R	19	10	2.30
R	26	8	2.08
R	33	12	2.48
R	6	2	0.69

Appendix B - Pieces returned due to vendor defect by department

Department	Pieces Returned due to Vendor Defect		
	Fiscal 2007	Fiscal 2008	Ln (Fiscal 2008)
Recliners	24	36	3.58
Recliners	35	42	3.74
Recliners	17	19	2.94
Recliners	18	29	3.37
Recliners	18	34	3.53
Recliners	16	25	3.22
Recliners	12	22	3.09
Recliners	29	17	2.83
Recliners	28	12	2.48
Recliners	30	29	3.37
Recliners	39	20	3.00
Recliners	24	18	2.89
Leather Upholstery	103	154	5.04
Leather Upholstery	179	193	5.26
Leather Upholstery	111	92	4.52
Leather Upholstery	130	103	4.63
Leather Upholstery	165	142	4.96
Leather Upholstery	101	69	4.23
Leather Upholstery	112	87	4.47
Leather Upholstery	129	111	4.71
Leather Upholstery	109	75	4.32
Leather Upholstery	131	60	4.09
Leather Upholstery	166	92	4.52
Leather Upholstery	97	92	4.52
Occasional Furniture	19	17	2.83
Occasional Furniture	20	10	2.30
Occasional Furniture	9	8	2.08
Occasional Furniture	7	17	2.83
Occasional Furniture	10	13	2.56
Occasional Furniture	17	5	1.61
Occasional Furniture	13	11	2.40
Occasional Furniture	11	12	2.48
Occasional Furniture	22	17	2.83
Occasional Furniture	18	9	2.20

Department	Pieces Returned due to Vendor Defect		
	Fiscal 2007	Fiscal 2008	Ln (Fiscal 2008)
Occasional Furniture	20	11	2.40
Occasional Furniture	4	10	2.30
Entertainment / Wall	32	21	3.04
Entertainment / Wall	44	39	3.66
Entertainment / Wall	8	17	2.83
Entertainment / Wall	31	27	3.30
Entertainment / Wall	20	17	2.83
Entertainment / Wall	8	10	2.30
Entertainment / Wall	8	9	2.20
Entertainment / Wall	18	9	2.20
Entertainment / Wall	17	18	2.89
Entertainment / Wall	12	17	2.83
Entertainment / Wall	16	19	2.94
Entertainment / Wall	12	8	2.08
Dining Room	150	104	4.64
Dining Room	186	130	4.87
Dining Room	61	81	4.39
Dining Room	91	69	4.23
Dining Room	103	76	4.33
Dining Room	53	37	3.61
Dining Room	46	45	3.81
Dining Room	92	93	4.53
Dining Room	88	59	4.08
Dining Room	111	53	3.97
Dining Room	122	104	4.64
Dining Room	51	59	4.08

Appendix C – Vendor defect count by type of defect for vendor N

Type of Defect	Vendor Defect Count		
	Fiscal 2007	Fiscal 2008	Ln (Fiscal 2008)
Fabric/leather rubbed	90	171	5.14
Fabric/leather rubbed	109	220	5.39
Fabric/leather rubbed	82	175	5.16
Fabric/leather rubbed	40	171	5.14
Fabric/leather rubbed	85	157	5.06
Fabric/leather rubbed	79	122	4.80
Fabric/leather rubbed	109	105	4.65
Fabric/leather rubbed	82	107	4.67
Fabric/leather rubbed	115	117	4.76
Fabric/leather rubbed	184	82	4.41
Fabric/leather rubbed	166	135	4.91
Fabric/leather rubbed	195	122	4.80
Leather cracking/peeling	69	75	4.32
Leather cracking/peeling	74	78	4.36
Leather cracking/peeling	51	55	4.01
Leather cracking/peeling	23	64	4.16
Leather cracking/peeling	73	59	4.08
Leather cracking/peeling	55	67	4.20
Leather cracking/peeling	45	41	3.71
Leather cracking/peeling	39	43	3.76
Leather cracking/peeling	38	39	3.66
Leather cracking/peeling	54	39	3.66
Leather cracking/peeling	65	72	4.28
Leather cracking/peeling	53	72	4.28
Scratched/dented exposed legs	26	34	3.53
Scratched/dented exposed legs	31	43	3.76
Scratched/dented exposed legs	23	41	3.71
Scratched/dented exposed legs	24	27	3.30
Scratched/dented exposed legs	28	34	3.53
Scratched/dented exposed legs	24	33	3.50
Scratched/dented exposed legs	35	26	3.26
Scratched/dented exposed legs	29	31	3.43
Scratched/dented exposed legs	21	32	3.47
Scratched/dented exposed legs	29	17	2.83
Scratched/dented exposed legs	35	24	3.18

Type of Defect	Vendor Defect Count		
	Fiscal 2007	Fiscal 2008	Ln (Fiscal 2008)
Scratched/dented exposed legs	39	47	3.85
Unacceptable scars/marks	16	116	4.75
Unacceptable scars/marks	17	171	5.14
Unacceptable scars/marks	9	134	4.90
Unacceptable scars/marks	9	127	4.84
Unacceptable scars/marks	14	134	4.90
Unacceptable scars/marks	26	77	4.34
Unacceptable scars/marks	57	70	4.25
Unacceptable scars/marks	54	89	4.49
Unacceptable scars/marks	68	95	4.55
Unacceptable scars/marks	118	51	3.93
Unacceptable scars/marks	115	73	4.29
Unacceptable scars/marks	136	97	4.57