Identifying and Analyzing Quality in Supply Chain

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Measuring and analyzing quality in supply chain processes is a largely unexplored topic. This research intends to identify and analyze quality performance measurements in supply chains and the impact of various supply chain steps on quality performance. We accomplish this research by collecting customer complaint data on household appliance supply chains. This data was analyzed and insights were derived using critical incident technique methodology. We find that highest frequency of quality problems is associated with the manufacturing step of the supply chain, and the next highest is with customer service. Further, we conclude that quality problems in the upstream of supply chain may not affect those in the downstream. Finally, we identify strong positive correlations between the number of quality problems in supply chain and products' age and price. Our research methodology and findings are helpful in aligning companies' supply chain process with customer expectations.

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I. INTRODUCTION

The past two decades have seen a sharp increase in the use of outsourcing and global network of companies to deliver products to achieve the dual objectives of differentiation and cost efficiency. Enterprises depend on the effectiveness of supply chain networks to offer better and cheaper products, shorter response times, and higher service levels. On the other hand, the global supply chains are posing challenges in ensuring the quality of products. Lately, a number of instances of product quality and product safety issues have been reported in industry and academic literature. Kukor (2010) indicates that the global supply chain created great savings but quality control suffered, resulting in major product recalls. Further, he states that that operational savings disappeared as organizations rushed to offset their quality risks in a complex supply chain process.

Kukor (2010) conducted interviews with two industry leaders to examine the current direction of quality management and sustainable quality improvements in supply chains. These interviews indicate that the overall goal of reducing cost through the extended supply chain has proved to be less effective than expected. Further, the organizations need to embrace the technologies presently available not only to control costs but also to control quality in the global supply chains. Hence, the quality management in the supply chain context has become a necessity in the industry today.

Our literature review presented in the following section, suggests that the quality management in the supply chain is gaining much attention in academia as well. For brevity, we have discussed key research papers in our literature review, and have organized the discussion along the following focus areas: (a) defining the Supply Chain Quality Management (SCQM), (b) Quality Management (QM) and supply chain (SC) practices that are utilized to manage quality in supply chain, and (c) identifying a linkage between QM and SC practices in conjunction with the supply chain performance.

We find that the empirical research have moved the SCQM concept beyond the definition stage. However, SCQM research area is relatively new and a number of gaps and issues need further work (Foster, 2008). In our exploratory research, we intended to answer several important questions in relation to quality in supply chain. First, how to define and measure quality in a supply chain process? Second, how this quality measures are linked to the customer satisfaction in the supply chain process? Finally, what are the relationships among these various measures of quality? Understanding into these questions will help companies in aligning SCQM practices towards final customer's expectations.

In this study, we investigate the research questions in the context of household appliances supply chain. We have chosen the appliances industry for this research because of the following reasons. The appliances fall into the specialty goods category and customers spend a significant amount of time and money in purchasing these products. This type of classification is used by researchers in operations management area. For example, Thirumalai and Sinha (2005) classify the products types as convenience goods, shopping goods and specialty goods, and then compare customer satisfaction with order fulfillment across the three groups. The appliances supply chain is complex and every entity from component manufacturers to after-sales support services impact the customer satisfaction (Slone, 2006; Arithes, 2005). Further, the customer dissatisfaction is more likely to be reported in the specialty goods area because of the dollar value of the merchandize. Finally, it has been reported that the quality of the appliances has taken a hit due to cost pressures and excessive outsourcing (Carter et al., 2009; Arithes, 2005)

The rest of the paper is organized as follows. In section II, we review the literature on Supply Chain Quality Management, identify the gap in the literature and pose research questions. In section III, we describe the research methodology and data collection in the context of appliances supply chain. In section IV, we present the results of the data analysis. This is followed by the conclusion section V, where we summarize contributions and of this research and future research directions.

II. LITERATURE REVIEW

Quality management (QM) research has evolved over the last 20 years. Research in quality management has often focused on internal versus external views of quality, with the internal view focusing on process and the external view focusing on the customer. The increasing emphasis on supply chain management is causing researchers to rethink models, constructs, and frameworks for quality management that have been developed for the field of operations management. As firms adopt the systems approach implicit in supply chain management, they must merge these views as they internalize upstream and downstream processes with their own.

As mentioned in the Introduction, we have discussed key research articles here, and have organized the discussion into three focus areas. The first area of focus has been the definition of supply chain quality management (SCQM). Flynn and Flynn (2005) discuss synergies between supply chain management and quality management. Sroufe and Curkovic (2008) used the case method to study the efficacy of ISO 9000:2000 within a supply chain management context. Kannan et al. (2005) discuss the linkages between just-in-time, total quality management, and supply chain management and their impact on business performance. Foster (2008) defines supply chain quality management (SCQM) as a system-based approach to performance improvement that leverages opportunities created by upstream and downstream linkages with suppliers and customers.

The second area of focus is the Quality Management (QM) and Supply Chain (SC) practices that are utilized to manage quality in supply chain. The empirical study of Sila et al.

(2006) was motivated by Chrysler's supply chain quality management initiatives. Chrysler forced its second and third tier suppliers to implement the same quality standards as its first tier suppliers. The company hoped that the implementation of the same quality procedures through the entire supply chain in a similar manner would improve the quality performance of the suppliers. Sila et al. (2006) investigated effect of Chrysler's SCQM activities on product quality. In this paper, SCQM is characterized along the following dimensions: (1) the level of supply chain integration, (2) attributes that characterize customer supplier relationships, (3) development of QS within the supply chain, (4) involving supply chain partners in quality initiatives. Survey data was collected from 107 US manufacturers and the hypotheses were tested. This study reports the following important findings: (1) companies mainly develop their QS internally, placing less weight on external input from customers, (2) companies included their major customers in their quality initiatives but major suppliers were not.

Kaynak and Hartley (2008) analyzed the relationship among the eight QM practices: management leadership, training, employee relations, customer focus, quality data and reporting, supplier quality management, product/service design, and process management. Survey data was collected from US based manufacturing and service firms that were using QM practices. The findings of this study are: (1) QM practices are interdependent, and QM practices should be implemented as an integrated system rather than as a subset of QM practices. (2) A prerequisite to supply chain quality is the implementation of QM internally within each supply chain member's organization. (3) Integration of processes both downstream and upstream impacts quality performance.

Lin et al. (2005) characterize the supply chain quality management using four multivariate scales that were derived from the prior research. The first variable QM practice is represented by the following nine constructs: top management leadership, training, product/service design, supplier quality management, process management, quality data reporting, employee relations, customer relations and benchmarking learning. The second variable Supply participation strategy consists of the following constructs: product design collaboration and joint kaizen projects with suppliers. The third variable Supplier selection strategy consists of quality and cost considerations. The final variable, Organizational performances, consists of intangible and tangible business results. The relationship among these four variables was analyzed using structural equation modeling and using the survey data from manufacturers in Hong Kong area. The important conclusions of this study are: (1) QM practices should be integrated with the suppliers, which in turn would result in improved organizational performance. In other words, The SCQM process incorporates not just the participation of suppliers but also, the relevant TQM practices in their environment. (2) Organizational performance can be optimized when the organization considers its suppliers as important trading partners and members of the value chain.

Gray et al. (2009) examines how cost and quality priorities influence a manufacturer's propensity to outsource in an empirical study where data was collected from 867 US manufacturing units. They found that the competitive priority placed on cost played an integral role in sourcing decisions, while conformance quality priorities did not. Authors indicate that this bias may partially explain why there is an emergence of so many nonconforming products associated with outsourcing. Yeung (2008) examined the effects of contextual factors such as size, process, ISO 9000 certification, and quality management (QM) on strategic supply management (SSM). In addition, he investigates the impact of SSM on organizational performance in the form of efficiency, customer satisfaction, and business outcomes. This study was based on the survey data obtained from manufacturers in Hong Kong and the Pearl River

Delta region of Guangdong. Das et al. (2008) study how differences in perceptions of plant safety influences quality outcomes, thus highlights the linkage between safety and quality performance.

The final focus area is the linkage between QM/SC practices that affects the quality performance in the supply chain. There is a considerable body of empirical research that has examined the impact of QM practices on quality performance. For example, Fynes and Voss (2001) developed a model that examines the impact of quality practices on various measures of quality performance such as design quality, conformance quality, and external quality-in-use. Fynes et al. (2005) state that a linkage between the QM and SC practices, and how they influence the supply chain quality performance, is largely unexplored. The authors developed a conceptual framework that links the supply chain relationship characteristics with quality performance. The supply chain relationship is characterized by Trust, Adaptation, Communication, Dependence and interdependence, Commitment and Co-operation. The quality performance is measured by the design and conformance quality. These two quality dimensions are linked to customer satisfaction as measured by frequency of customer complaints and adequacy of customer complaint tracking/feedback systems. This relationships stated in the framework was tested using the survey data from manufacturing firms at Ireland. Firstly, this study finds that supply chain relationship quality has a positive impact on design quality but not on conformance quality. This suggests that by developing and engaging in true partnership types of SC relationships, suppliers can become much more proactive in the new product development process and contribute much more than merely conforming to a manufacturing specification. Secondly, both design and conformance quality impacts customer satisfaction.

In summary, we find that the empirical research have moved the SCQM concept beyond the definition stage. However, the articles are more focused on the quality management (QM) and supply chain (SC) practices that are deployed to manage the quality in supply chains and exploring their impact on supply on quality/business performance. As stated above, quality management research has focused on internal versus external views of quality, with the internal view focusing on process and the external view focusing on the customer. The second aspect of connecting the external customer quality requirements back into supply chain quality management practices is largely unexplored. In particular, a lack of an input from the customer to develop QM/SC practices is evident from the findings of Sila et al. (2006).

III. RESEARCH METHODOLOGY AND DATA COLLECTION

The literature review and analysis of the appliances' supply chain process left unanswered a number of questions related to the industry's supply chain quality. Specifically, it is unclear which part(s) of supply chain "contribute" the most to quality issues in supply chain, and how big this "contribution" is. It is also unclear if there is a relationship between quality issues in different parts of supply chain, for example, between upstream and downstream portions. In addition, it is important to understand the influence of various factors on quality in supply chain. All these persuade use to conduct a research study to address the issues of in supply chain quality management. The main research objectives of this study were to (a) understand the influence of various supply chain parts on product and service quality, (b) evaluate the relationships between quality issues in different parts of supply chain, and (c) assess the impact of product characteristics (age, price, company, product group, etc.) on the overall supply chain quality.

In general, quality, as a multi-dimensional characteristic, can be measured by an extensive variety of variable and attribute indicators that

may be associated with different parts of supply chain process. The discussion of quality measurements in supply chain are presented in (Foster, 2008; Evans and Lindsay, 2008; Sila et al., 2006; Love et al., 2003; Forker et al., 1997). In this study, however, we decided to investigate quality from the standpoint of the final step of supply chain, the customer fulfillment. The fulfillment of customer needs and customer satisfaction are the ultimate goal of any supply chain, and, thus, measuring quality by customer responses in a form of customer complaints related to supply chain results is quite acceptable for this study. In fact, we identified several studies where a similar approach in relation to different industries and research subjects were used, for example, to investigate failures in retail industry (Lee and Park, 2010; Park et al., 2008).

To identify and measure customer responses related to quality issues in appliances' supply chain, we utilize publically available data from websites that accumulate information on customer complaints for in-home and commercial appliances. The balk portion of information came from the following websites: *www.consumeraffairs.com*, *www.bizrate.com*, *www.epinions.com*, and *www.buzzillions.com*. They are all well-known third-party consumer online resources that provide an abundance of records on customer issues with various products including those in appliance industry.

The in-home appliances contain a great mixture of items that vary in types, size, functionality, and usability. For this study, however, we chose the three well-represented and commonly employed groups of appliances: refrigerators, dishwashers, and washers/driers. Our choice for these three groups was also triggered by the fact that a sufficient number of customer responses for these product groups were readily available in the third-party consumer websites. In addition to a limited number of appliance product groups, we have considered in this study six major appliance product lines and companies: Whirlpool, KitchenAid, Maytag, GE, LG, and Samsung. The first three product lines – Whirlpool, KitchenAid and Maytag – are produced by Whirlpool, but in reality manufacture, market and sold as completely separate lines of products. The reason of choosing these six product lines and companies is primarily based on their popularity and overall market share in the United States (Carter et al., 2009).

For the three selected groups and six product lines (companies) we initially collected more than 900 records of customer complaint stories posted in the third-party websites in the period of 2008-2010. The goal was to collect 300 stories per each product group, and around 50 per each company/product line. The records of customer complaints included, besides the actual complaint, information on product type, company name, retailer name, product price, and product age. The preliminary analysis of these records showed that some of them were incomplete in terms of the clearly defined product type age, or price. Moreover, some complaint stories were rather vague, and not cohesive enough to include them into the analysis. Thus, we eliminated these incomplete records leaving the number of records as 856, or 4.9% lower than the initial collection. This number of records is certainly statistically significant to provide analysis of quality complaints in appliances' supply chain process.

To systemize and categorize customer complaints, we employed the critical incident technique (CIT), which is a popular approach of classifying in a systematic manner stories' contents (Lee and Park, 2010; Forbes et al., 2005; Holloway and Beatty, 2003). Each customer complaint that we collected from the third-party website involves a customer story of one or more failures of an appliance product, customer service, or recovery effort. Following the guidelines of the CIT approach (Gremler, 2004), each incident was carefully read and dissembled into separate product and service failure attributes by two researchers Based upon the CIT approach and its description in literature sources (Mattila and Cranage, 2005; Kelley et al., 1993), these attributes were categorized into 8 main

quality categories presented in Table 1. We then categorized the collected customer complaints (856 records) utilizing these 8 quality categories. Finally, the categories presented in Table 1 were summarized into 5 groups associated with a traditional supply chain, i.e., Customer Service, Retailer, Distribution, Manufacturer, and Supplier. These supply chain groups are reflective of typical supply chain parts, and thus, is a valuable categorization in this study for analyzing quality problems in different parts of supply chain.

TABLE 1: QAULITY CATEGORIES AND ASSOCIATED SUPPLY CHAIN GROUP

Quality Category	***Description of Typical Service Complaints***	***Supply Chain Group***
Service Competency	• Service technician cannot identify or solve the service problem. • Service technician does not have sufficient technical skills or equipment to solve the service problem. • Service technician made several unsuccessful attempts to solve the problem.	**Customer Service**
Service Availability	• Slow response time to customer complaint. • Insufficient service availability.	**Customer Service**
Customer Support	• Poor or inconsistent customer information • Poor or inconsistent customer service and support for product selection, installation, maintenance, upgrading, or return.	**Retailer**
Product Fulfillment	• The customer purchases from retailer a broken product or a product with missing parts (components). • Out of stock products.	**Retailer**
Delivery	• Delays in product delivery. • Delivery of a broken product or a product with missing parts. • Delivery of a wrong product.	**Distribution**
Customer Support	• Poor or inconsistent service and support provided by the manufacturer to assist customers with different issues such as product installation, maintenance, repairing, upgrading, product recall and returns, and disposal of the product with immediate or quick action.	**Manufacturer**
Product Quality	• Inconsistent product performance • Poor product reliability and durability • Quality defects in product design	**Manufacturer**
Component Quality	• Broken supplier part or component • Inconsistent performance of a supplier part or component	**Supplier**

The consistency of the customer complaints' classification was checked by comparing the categorization results of each researcher and calculating percent agreement (Lee and Park, 2010; Lombard et al., 2002; Neuendorf, 2002). The percent agreement between the two researchers was 92.5%. In addition, to gain further consistency of complaints allocation in the specified dimensions, two more researchers were asked to classify customer complaints according to the developed quality dimensions. The classification results of the third researcher were 90.5% consistent with the existing allocation, and the fourth researcher was 93.6% consistent. All these indicated a high level of reliability for the classification results of customer complaints.

Based on the research objective and preliminary analysis of the categorized customer complaints, we have formulated the following research hypotheses:

- H1. Patterns of quality problems in supply chain for different groups of appliances are similar.
- H2. Patterns of quality problems in supply chain for different appliance companies/product lines are similar.
- H3. The most frequent quality problems are with manufacturing and customer service steps of supply chain.
- H4. Quality problems in the upstream of supply chain (manufacturing and suppliers) affect quality problems in the downstream of supply chain (customer services).
- H5. The amount of quality problems in supply has a strong positive correlation with the product age.
- H6. The amount of quality problems in supply chain has a strong negative correlation with the product price.

IV. RESULTS OF DATA ANALYSIS

To answer the research questions and test hypothesis H1-H3, we analyzed first the distribution of quality problem and their frequencies for the five groups of appliances' supply chain introduced in the previous section and various product groups (see Table 2). The results in Table 2 show that the average for the total number of quality problems per complaint (record) is around 1.94, or about 2 problems per record. This number is pretty close to the averages in each product group ranging from 1.84 for refrigerators to 2.04 – for washers and driers. However, a distribution of quality problems between different parts of supply chain varies significantly. The highest proportion of quality problems, with the average of 50.9%, is associated with the manufacturer; the next highest – 24.8% on the average – with customer service; and the lowest – 2.2% on the average – with distribution (see Table 2). A similar pattern of quality problems' frequencies is observed for various companies and product lines (see Table 3).

The chart containing frequencies of quality problems in the parts of supply chain process versus product groups (Figure 1) clearly shows similar patterns of these frequencies for three different product groups. Very similar patterns can be also observed for frequencies of quality problems in the part of supply chain process versus companies/product lines (Figure 2).

As a result of this analysis, we have to accept (cannot reject) Hypotheses H1 and H2 stating the similarities of patterns of the quality problems' frequencies in various parts of supply chain process regardless of the group of product or specific company or product line. Moreover, as can be seen from Table 2 and 3 and associated Figures 1 and 2, we have also to accept (cannot reject) Hypothesis H3, i.e., the highest level of quality problems is observed in the manufacturing part of the supply chain process, and the next highest – in customer service. Overall, the acceptance of the first three

hypotheses is rather important outcomes of this study that essentially identify the important parts of the supply chain process that need to be approached first in order to reduce the number of quality problems in appliance supply chain.

TABLE 2: FREQUENCIES OF QUALITY PROBLEMS VS. PRODUCT GROUPS

Product group	*Customer Service*	*Retailer*	*Distribution*	*Manufacturer*	*Supplier*	*Total Number of problems*	*Average Number of Problems*
Dishwasher							
Number of problems	112	36	10	259	77	494	1.96
Frequency, %	22.7	7.3	2.0	52.4	15.6	100.0	
Washers and Driers							
Number of problems	122	57	14	249	67	509	2.04
Frequency, %	24.0	11.2	2.8	48.9	13.2	100.0	
Refrigerators							
Number of problems	152	23	10	284	84	553	1.84
Frequency, %	27.5	4.2	1.8	51.4	15.2	100.0	
Total for all groups							
Number of problems	386	116	34	792	228	1556	1.94
Frequency, %	24.8	7.5	2.2	50.9	14.7	100.0	

TABLE 3: QUALITY PROBLEMS VS. COMPANIES/PRODUCT LINES

Company	*Customer Service*	*Retailer*	*Distribution*	*Manufacturer*	*Supplier*	*Total Number of problems*	*Average Number of Problems*
Whirlpool							
Number of problems	56	13	9	143	49	270	1.89
Frequency, %	20.7	4.8	3.3	53.0	18.1	100.0	
KitchenAid							
Number of problems	30	14	7	99	23	173	2.01
Frequency, %	17.3	8.1	4.0	57.2	13.3	100.0	
Maytag							
Number of problems	67	30	3	125	33	258	2.31
Frequency, %	26.0	11.6	1.2	48.4	12.8	100.0	
GE							
Number of problems	89	23	1	171	39	323	1.79
Frequency, %	27.6	7.1	0.3	52.9	12.1	100.0	
LG							
Number of problems	89	21	8	145	41	304	1.82
Frequency, %	29.3	6.9	2.6	47.7	13.5	100.0	
Samsung							
Number of problems	55	15	6	109	43	228	1.74
Frequency, %	24.1	6.6	2.6	47.8	18.9	100.0	
Total							
Number of problems	386	116	34	792	228	1556	1.94
Frequency, %	24.8	7.5	2.2	50.9	14.7	100.0	

FIGURE 1: FREQUENCIES OF QUALITY PROBLEMS BY PRODUCT GROUPS

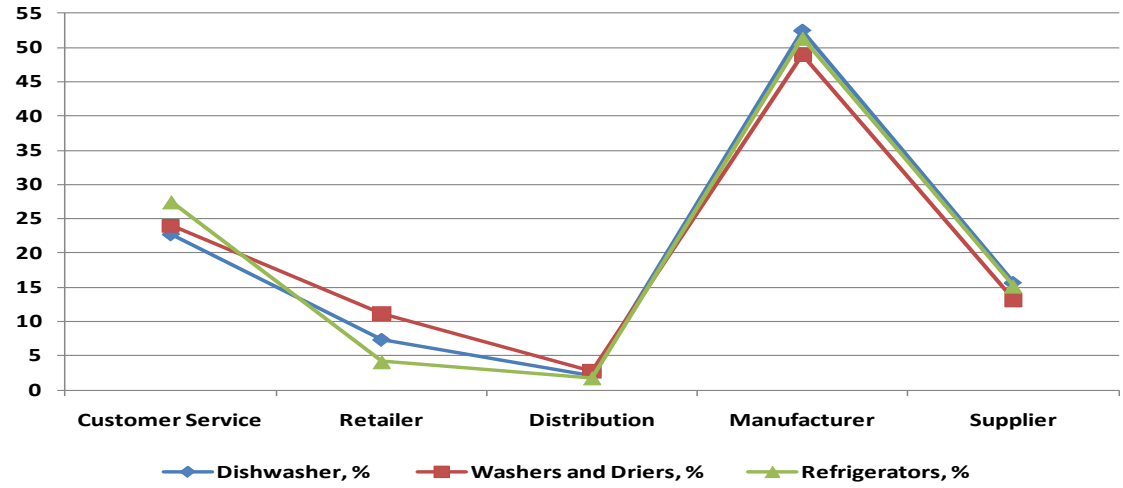
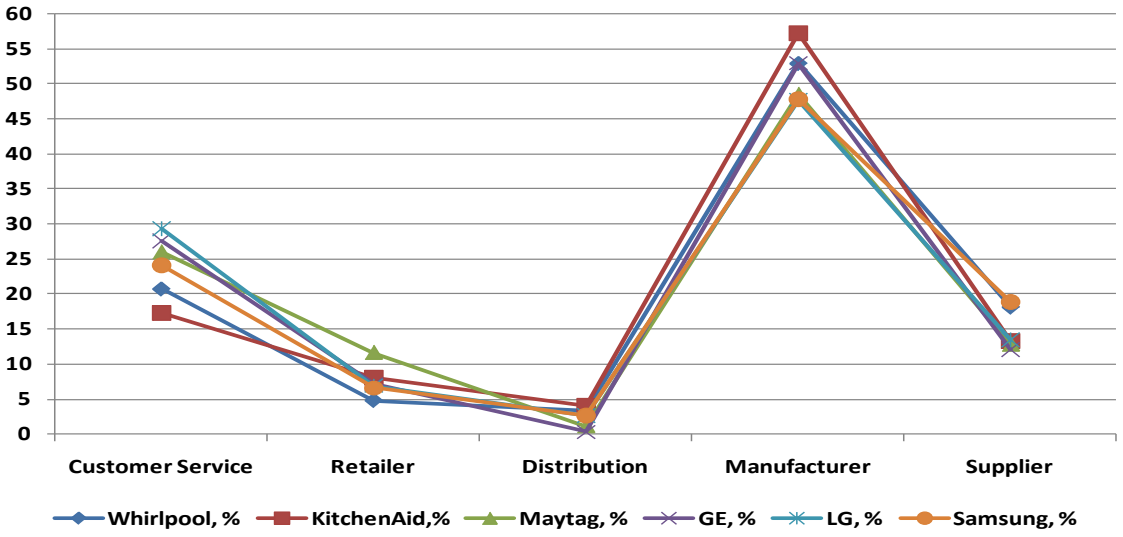


FIGURE 2: FREQUENCIES OF QUALITY PROBLEMS BY COMPANIES/PRODUCT LINES



To examine the relationships between quality problems of different parts of supply chain process, we analyze the correlation coefficients between the quality problems in the upstream of supply chain (Manufacturer and Supplier) and downstream of supply chain (Customer Service) for all records utilized in this study (Table 4). As can be seen from Table 4, the correlation coefficients of -0.1239 and -0.0385 indicate really weak opposite relationships between the number of quality problems in the upstream (Manufacture and Supplier, respectively) and downstream of supply chain (Customer Service). The T-test for these coefficients (with 298 degrees of freedom and one-tailed test with $\alpha/2 = 0.025$) cannot reject (need to accept) the null-hypothesis that the population correlation coefficients are equal to 0. All this means that the analysis of the complaints data does not show any significant relationships

between the number of upstream and downstream quality problems in supply chain, and thus, we need to reject Hypothesis H3 that the level of quality problems in the Manufacturer and Supplier parts may affect the number of quality problem in the Customer Service part of the supply chain process.

TABLE 4: CORRELATION MATRIX

	Price	*Age*	*Customer Service*	*Retailer*	*Distribution*	*Manufacturer*	*Supplier*	*Total number of problems*
Price	1							
Age	0.1554	1						
Customer Service	0.3499	0.0718	1					
Retailer	0.1557	0.0604	0.0812	1				
Distribution	0.0909	-0.0347	0.0156	0.1146	1			
Manufacturer	0.1569	0.0134	-0.1239	-0.0289	-0.0550	1		
Supplier	0.1936	0.0026	-0.0385	0.0673	0.0170	-0.1561	1	
Total number of problems	0.5628	0.3724	0.5247	0.4730	0.2293	0.3845	0.3921	1

The correlation coefficient between the total number of quality problems and age of the product, 0.3724, is statistically significant (for the previously specified 298 degrees of freedom and one-tailed test), and it does shows some relatively strong correlation between the age of the product and the number of quality problems. Therefore, we cannot reject (need to accept) Hypothesis 5 that the higher product age may increase the overall number of quality problems in supply chain.

The correlation coefficient between the price and total number of quality problems, 0.5628, shows even stronger positive relationships between the two variables. However, this positive relationship is counterintuitive, because in practice the lower price may be conducive of lower level of product quality, and thus, increased number of quality complaints. Therefore, we need to reject Hypothesis H6 that there is a negative correlation (opposite relationships) between the product price and number of quality problems. However, we should not disregard the fact that the strong positive correlation between price and number of quality problems does exist. The interpretation of this phenomenon may be derived from the point that customers acquiring expensive (pricy) appliances tend to become more conscientious about the item performance issues, and, thus, may complaint more frequently.

V. CONCLUSIONS

The idea of this research stems from the importance of identifying quality performance measurements and analyzing them in the context of supply chain management. As described in this paper's literature review, this imperative issue of measuring and analyzing quality in supply chain processes is not well represented in the literature sources, and, thus, requires full research considerations. Our study intends to understand the influence of various supply chain parts on product and service quality and evaluate the relationships between quality issues in different parts of supply chain. In addition, we aim to assess the impact of product characteristics (age, price, company, product group, etc.) on the overall supply chain quality. The important point of this study is that we investigate quality from the perspective of the final step in supply chain, the customer fulfillment. The fulfillment of customer needs

and customer satisfaction in this study is measured by the adversary characteristic – customer complaints, which are derived from supply chain results.

Identifying and then analyzing data records on customer complaints in the appliance industry, we tested several important hypotheses related to patterns of quality complaints/problems in supply chain, relationships between quality problems in different steps of supply chain, and influence of product characteristics like age and price on product quality. The results of hypothesis testing are presented in Table 5.

TABLE 5: RESULTS OF HYPOTHESES TESTING

Hypothesis	***Results***
H1. Patterns of quality problems in supply chain for different groups of appliances are similar.	Accept (Cannot reject)
H2. Patterns of quality problems in supply chain for different appliance companies/product lines are similar.	Accept (Cannot reject)
H3. The most frequent quality problems are with manufacturing and customer service steps of supply chain.	Accept (Cannot reject)
H4. Quality problems in the upstream of supply chain (manufacturing and suppliers) affect quality problems in the downstream of supply chain (customer services).	Reject
H5. The amount of quality problems in supply has a strong positive correlation with the product age.	Accept (Cannot reject)
H6. The amount of quality problems in supply chain has a strong negative correlation with the product price.	Reject* *However, the amount of quality problems has a strong positive correlation with the product price

The important conclusion of this study is that the patterns of quality problems in appliances' supply chain are very similar for various product groups and companies/product lines. In particular, the highest frequency of quality problems is associated with the manufacturing step in the supply chain process, and the next highest – with customer service. The results of this study also show that quality problems in the upstream portion of supply chain may not affect those in the downstream of supply chain. We also identified a strong positive correlation between the number of quality problems in supply chain and product age and price.

A future expansion of this research needs to address the patterns of quality problems between different industries. In addition, it will be important to investigate if, besides product price and age, there are other internal and external factors in supply chain that can affect quality problems.

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