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QUALITY IN THE GLOBAL PICTURE TUBE INDUSTRY

Working Paper #9409-39

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Preface

The report that comprises this working paper is the first effort to document the results of our two-year study of quality and productivity practices in the global picture tube industry. Customized confidential versions of this report were sent to each participating manager comparing their plant's responses to summary statistics for the entire industry on the several hundred questions answered in the surveys. In order to protect confidentiality, the enclosed working paper version contains realistic, but fictitious, data for a hypothetical plant, which we call "A Picture Tube Company - Plant Number 1". Although data for this specific plant are fictitious, all industry-wide summary data in the working paper are real.

We have just scratched the surface in analyzing the rich data base we have assembled on this industry, and would welcome suggestions from managers or academic colleagues on fruitful paths to explore.

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Quality in the Global Picture Tube Industry

Customized and Confidential Project Report for:

A Picture Tube Company - Plant Number 1

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Executive Summary

This study of the global color picture tube industry was undertaken to assess current approaches to quality and manufacturing practices in this industry. The study was originally conducted in three phases, the last of which was a mail survey sent to 50 of 53 color picture tube factories in the world. This includes all factories in the world except those in Eastern Europe, the ex-Soviet Republics, and China. Forty-eight of these 50 plants responded to the survey, the results of which are summarized in this report. Subsequently, in 1994, color picture tube plants in China, Eastern Europe and the former Soviet Union agreed to participate. However, these data have not yet been received and analyzed, and are not included in this report.

The basic findings pertain to nearly a dozen factory practices and policies that are associated with superior quality and productivity performance at the plant level. The findings are rich in their detail, and are stated in the context of this industry. **Furthermore, this report is customized for each factory. That is, along with findings for the whole industry, we describe where your factory stands with respect to the rest of the industry on key quality and manufacturing practices. No one outside of your company will receive a copy of this confidential customized report for your factory from us. Hence, to maintain confidentiality it is important that you do not copy or distribute the copies we have sent to you.** Based on this report, your factory can identify strengths and weaknesses, and take steps to rectify your weaknesses, and reinforce your strengths. We expect that managers at all color picture tube factories, will be able to use the findings presented in this report to improve factory practices, and hence improve quality and productivity performance.

In addition to our emphasis on current factory quality and manufacturing practices, we also attempt to look into the future. What kinds of factory practices will yield the maximum benefits in the future? Will color picture tube factories see a major shift in their product mix as a result of radical changes in technology, e.g., the advent of flat-panel displays? Our report throws some light on these interesting and challenging issues.

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Preface and Acknowledgments

This study was made possible through the active participation of many managers in the industry. For reasons of confidentiality, we will not name any of them, but we offer our sincere thanks to them, for making this study possible, and even more importantly, for teaching us so much about the industry. A few people from outside the industry also helped us in our endeavors, and we are grateful to them, in particular, to Mr. Peter Keller (Tektronix), Mr. Duane Welch (Corning), and Mr. S. Baidyaroy (consultant).

Prof. Roger Johnson at The Michigan Business School was a member of Anil Khurana's Ph.D. dissertation committee and provided both encouragement and intellectual support for this research for which we are very grateful.

We also acknowledge the financial and research support of the Michigan Business School, the Center for International Business Education at the University of Michigan, the Executive Education Center at the University of Michigan, and the Office of the Vice President of Research at the University of Michigan. We would also like to thank one of the companies in the industry for providing a generous grant to support Mr. Khurana's doctoral thesis.

Finally, we acknowledge the super research support provided by Mr. Masaaki Yasukawa (MBA '93), Mr. Robert Rodriguez (MBA '95), Mr. Ishwari Prasad Singh (MBA '94), and Mr. Leland Smith (MBA '96) at The University of Michigan Business School. Ms. Edna Corby and Ms. Jackie Bolgos, both at The Michigan Business School were unflinching and efficient in providing secretarial support during the duration of this research project for which we thank them. We also thank the members of the Document Processing group at The Michigan Business School, in particular Ms. Melinda Stuber, for helping with the production of this document.

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How to Use This Report

This report has been prepared specifically for your factory. In addition to understanding what the rest of the industry is doing, you will probably be interested in knowing where your facility ranks relative to the other factories based on our data. To accomplish this, please turn to the section on manufacturing performance and factory rankings (Section IV, pg. 6) to see where you stand on the two dimensions of internal quality and overall labor factory productivity. **(Please note that if one or more of the managers at your factory did not respond fully to some of the key questions, it was impossible for us to calculate a score for your factory. If this was the case, we list your factory's score as "UNKNOWN".)** After you have looked at these data, and confirmed the validity of the numbers provided there, you would probably like to know what improvements your factory can make. The section on best practices for quality and productivity (Section VI, pg. 14) outlines the various practices and policies that we identified as being associated with superior performance, and should help you understand where you can improve. This is probably the key section, since it provides a basis for continuous improvement activities.

Among the other sections, Section III presents an industry overview (this description is supplemented by the Appendix I). Section V describes which quality and manufacturing approaches were used by color picture tube factories in the past 3 years, and how much emphasis is likely to be placed on these in the next few years. We hope these provide you with some ideas on practices your factory can adopt to improve your operations. Selected references are given in Section VIII.

I. Introduction

This study of the global color picture tube industry assesses current approaches to quality and manufacturing practices in this industry. Most managers in the industry agree that the industry is in a state of flux. Some of the influencing factors include changing product standards, increasing pressures from environmental regulation agencies, new competition in the form of recent entrants into the industry, and new technologies such as flat-panel displays emerging as a feasible technological alternative.

Given this, it becomes clear that manufacturing strategies for companies in this industry should focus on achieving better quality and productivity through the use of efficient automation, continuous improvement of product designs, a better understanding of the production processes and technologies, and more effective use of labor. We believe that we have some suggestions that may apply to your company. Though managers in various color picture tube companies are likely to be aware of the strengths and weaknesses of their companies, the results from our study are presented in such a form as to assist you and other managers to become aware of the keys to success, and identify opportunities for improvement for your factory.

II. Methodology

This study was conducted in three phases. In ***Phase one***, a detailed study of quality improvements at one picture tube factory was carried out. Both quantitative data from factory archives, and qualitative data (based on interviews with more than 30 managers, engineers, and supervisors) were gathered. Engineering documentation on product and process was studied to gain a better understanding of the manufacturing process, and key manufacturing issues. Engineers and managers, including those who had worked in other industries, were interviewed about differences in the nature of the manufacturing process, and their perceptions about the complexity of the process. A study of the past few years' issues of the Electronics Industries Association (EIA) newsletter provided further industry background. In ***Phase two*** we visited 10 color picture tube factories in N. America, Europe, and Japan. A structured questionnaire was used to compare practices, identify trends, and develop a framework (and survey items) that would help explain quality and manufacturing performance differences across plants. In ***Phase three***, a detailed study of quality and manufacturing practices in the color picture tube industry was carried out using four detailed mail questionnaires that were designed on the basis of prior research and the field interviews. Four key managers - plant manager, production manager, quality manager, and engineering manager - in all of the plants in the non-communist world were requested to complete these questionnaires. In March 1993, these four questionnaires were mailed to 50 of the 53 factories in the non-communist countries. Forty eight of these 50 responded to the questionnaires, giving a 91% response rate, and making it a near-census of the industry. The data from these factories were supplemented by performance data obtained from Consumer Reports for 1986 to 1993 (Consumer Reports 1987, 1988, 1992, 1993). Partial validation of the data, especially performance data, was done via interviews with two industry experts.

Subsequently, in January 1994, we obtained access to a few of the plants in Eastern Europe and China, and survey data are being collected from those plants. During June and July 1994, the authors visited some of these factories in Eastern Europe, China and India to interview managers and collect data.

III. Industry Overview

The following paragraphs give a brief overview of the color picture tube industry, as interpreted by our research team. This description is intended to narrate to you an outsider's view of the industry, and is based on our interviews with managers, and an industry analysis based on publicly available data. For further details, please see Appendix I at the end of this report.

Market Demand and Production Capacity

The global color picture tube industry is in its mature phase, marked by cut-throat competition. The main players are European (4), Japanese (7), and Korean (3). In all, there are approximately 20 companies in the world that manufacture TV color picture tubes (excluding the old communist bloc - China, ex-Soviet Union, and E. Europe), though at one time the U.S. alone had more than 75 color picture tube manufacturers. China, E. Europe, and some of the ex-Soviet republics have another 15 companies, most of these being joint ventures.

The lion's share of the worldwide demand for televisions originates in N. America and W. Europe. Together, they consume half the world's production of TVs *(but manufacture only 33%).* Over the past few years, TV production capacity first moved overseas - to Japan and Korea - and then, as a result of increasing tariffs and trade disputes, is moving back into N. America and Europe. Due to relatively inexpensive dedicated automation, and low wages, Korea still produces 15 million TV sets (about 13% of worldwide production). Also, much of the production capacity even in N. America and Europe is Japanese and Korean owned. A similar situation exists for TV color tubes. Again, Korea produces a major share of TV color picture tubes; in fact, at 24 million tubes *(29 million if computer monitor tubes are also included)*, it has the largest TV tube production capacity (21% of world production). N. America produces enough tubes to supply domestic TV assembly plants, but W. Europe imports approximately 6 million tubes for TV sets that are assembled in W. Europe. Production capacity for both TV sets and TV color tubes in N. America is expected to increase: to satisfy increased demand, in response to the North American Free Trade Agreement (NAFTA), and also to prepare for the emerging HDTV markets.

Competitiveness

In today's market, conformance quality, manufacturing costs, and tube design performance are all important priorities. Given that conformance and price are both key competitive dimensions, it immediately becomes evident that a quality-driven approach is the preferred one. A factory can try to follow an approach of cutting costs on materials and process refinement, and inspect all outgoing tubes, but it is likely to end up spending much more money.

Industry Projections

Today, the total market for electronic displays is $15 billion; by 1997, it is expected to reach $24 billion. Flat panel displays are expected to grow from about 25% ($3.75 billion) today to 35% by 1997 ($9 billion). Brightness, contrast, display size, pixel count and resolution are expected to remain the primary measurements of quality, but will increasingly be redefined for flat-panel displays.

Clearly, the share of flat-panel displays will increase at the expense of CRTs. Even though the absolute market will increase from $11 billion in 1993 to $16 billion by 1997, the CRT market share will drop from 75% to 65% of the total display market. The cost-effectiveness of CRTs will not be enough of an asset to enable CRTs to maintain their current hold on the market (though if picture tube manufacturers are unable to maintain or improve cost and conformance performance, the demise of the CRT may be hastened). The bulk and weight of CRTs is heavy baggage in many current and potential applications, and CRTs are being gradually replaced by flat-panel displays, or are not even being considered for new display applications.

Neither is the CRT environmentally friendly; leaded glass is used to minimize the effect of harmful X-ray radiation. If environmental concerns pertaining to its disposal increase, and CRT manufacturers are required to set up disposal and recycling systems, tube costs are likely to go up. The same will be the case if pollution prevention requirements for the picture tube manufacturing process become stricter.

On the other hand, the benefits of the mature CRT are its simplicity, broad utility, high luminance, excellent image quality, and cost-effectiveness. Some of the large market segments -

business systems, industrial products, medical equipment, computer products, and TV receivers - are expected to continue to use CRTs into the foreseeable future, and thus support CRT sales.

Production Process Complexity

Picture tubes have often been described as "*the most complex and difficult consumer product ever made by mankind*", primarily because the production process is complex. Color picture tubes have only about 2 dozen primary components, none of them complex by themselves, except for the electron gun which is generally manufactured by suppliers or in a separate factory. However, these components do have somewhat complex and multiple interactions, as also mentioned by managers during our interviews (see the Appendix 1 for a detailed discussion).

Such complex processes require a higher knowledge at different stages of the process. Consequently, they benefit from multiskilling, place a premium on complex engineering knowledge, and highlight the need to share knowledge and data.

IV. Manufacturing Performance and Factory Rankings

Dimensions of Manufacturing Performance

We collected data on multiple dimensions of factory manufacturing performance, but due to limited responses, we focus our discussion on three key dimensions. The **first** is internal quality at the factory, as measured by consumption of four critical picture tube components - glass panels, masks, electron guns, and glass funnels. The measure of internal quality we report here is a simple average of the material consumption for these four components. During our interviews with managers, we identified component material consumption as a much more reliable measure of internal quality than factory-reported measures of yields. The **second** performance measure we report is customer quality, or line rejects, expressed in parts per million (ppm).

We derived our **third** measure, productivity, using data on factory production volumes, factory employment, product mix (e.g., tube sizes), degree of outsourcing of components, and differences in process design. The measurement unit for our productivity measure, as used in this report, is tubes produced per employee-hour. Overall labor productivity is the measure we use for this report (though we have data on direct and indirect productivity also). Formulas for our measures of productivity and quality are given in Appendix II.

We also sought data on other measures of performance, such as tube emission, and field failures. However, we received limited responses from engineers and managers on these questions; thus, we decided not to use these measures for the current analysis. We hope to obtain these data through follow-up letters to factory managers.

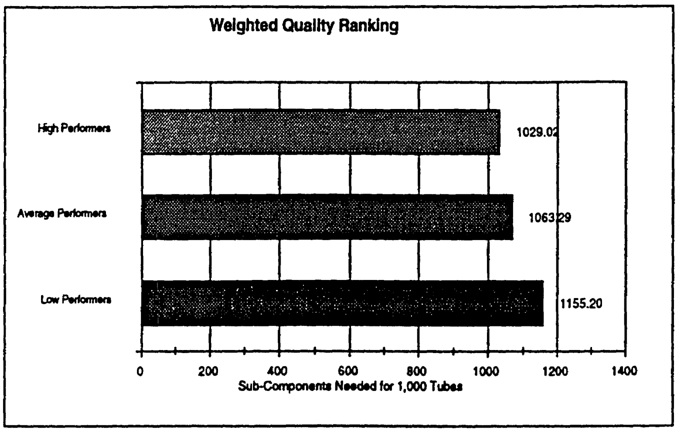
Factory Rankings

The factory rankings in this report were done on the basis of two sets of information. **First**, we used the data provided by managers on the consumption of the four key components used in picture tube manufacturing - glass panels, masks, funnels, and electron guns - to compute a score for internal, or factory quality. However, we did not correct for tube size while computing the different internal quality scores. A separate analysis of internal quality and tube size did indicate that larger tube sizes are likely to have poorer internal quality. More specifically, every inch increase in size causes an increase of approximately 2 units in material consumption. Thus, if your factory produces tubes larger than 21 inches, subtract 2 units from your factory's current score for every inch greater than 21 inches to make it comparable to the numbers used in this report; if your factory's typical tube size is smaller than 21 inches, for every inch smaller than 21 inches add 2 units to your factory's current score. Once this measure was calculated, we ranked all factories on this dimension and split them into three groups; lowest 1/3 middle, middle 1/3, and highest 1/3, labeling them respectively, Low, Average, and High performers. This internal quality-based ranking and grouping is what we use for most of the subsequent analysis in this report.

Second, we computed a score for factory productivity based on data on annual production volume, product mix (tube sizes), and factory employment. As for internal quality, we ranked all factories on factory productivity and split them into three groups: lowest 1/3, middle 1/3 and highest 1/3; labeling them respectively, "Low," "Average," and "High" performers.

Factory Internal Quality: Material Consumption

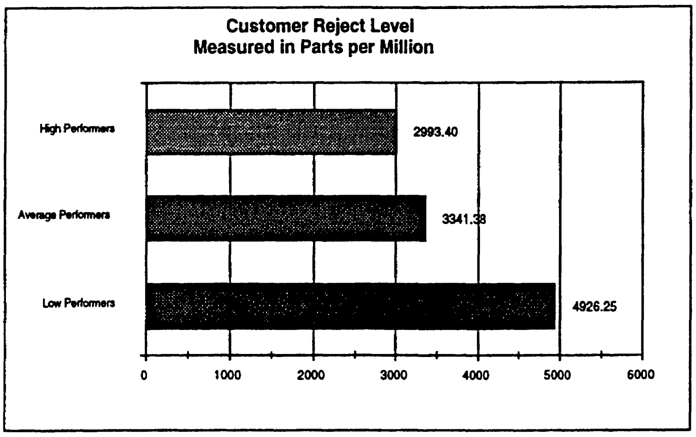
The factory internal quality scores are based on the material consumption for each factory, i.e., the number of tube components (glass panels, masks, funnels, and guns) that were used for every 1000 good picture tubes manufactured. However, when evaluating your own factory's performance, please remember that if your factory typically manufactures large picture tubes (greater than 25"), the material consumption is likely to be higher. Thus, your factory's internal quality score and rank, when corrected for the larger size, are likely to be better than what we indicate here. In general, compared to an average size of 21", the material consumption is 2 units higher for every inch beyond this size.



Compared to the scores shown above, your factory's score is 1,072.05 which is a "Average Performer" on the quality ranking above. Your facility ranked 19 out of 47 factories on this quality score. However, please do keep in mind that the tube size typically manufactured by your factory is different from the average tube size of 21 inches that we have used to indicate the rankings and scores.

Customer Quality: Line Rejects

Customer line rejects for tubes is a key measure that managers at picture tube plants use to evaluate factory effectiveness. Clearly, this measure represents customer requirements, and is the end result of activities contributing to the design of product (the tube itself) and process, choice and implementation of factory production technology, extent of technical knowledge of engineers at the factory and in the picture tube business unit, and the extent to which production workers are knowledgeable and motivated. Also, though there are some differences in customer quality standards, our interviews and survey responses indicate that these differences across the four key economic regions of the world - Europe, Japan, N. America, and the Newly Industrialized Countries (NICs), are not very significant.



Note: One part per million (ppm) = 0.0001%.
I.e., 1% = 10,000 (ppm)

The figure above indicates the range of scores that the low, average, and high performers obtained. Unlike the case for internal quality measures, customer rejects are not higher for larger tube sizes; rather, larger tubes typically have lower customer rejects, possibly because tube manufacturers pay more attention to bigger tubes. For every inch increase in tube size beyond 21", the customer reject level goes down by 50 ppm. You can use this rule of thumb to compute your factory's score for comparison purposes; **the absolute score for your factory is 2,450 (in ppm rejects).**

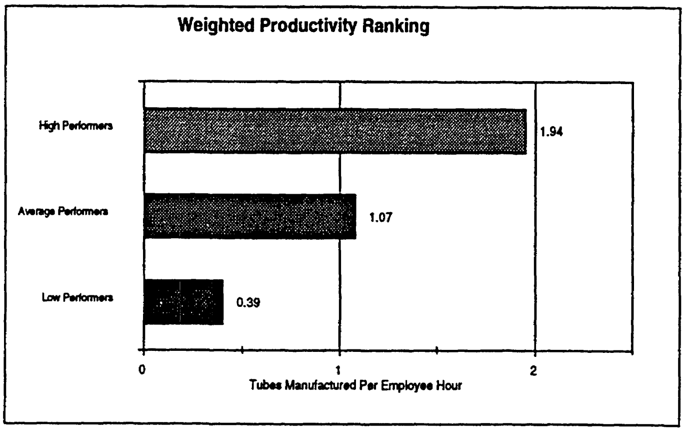
Due to continuous improvements being made by the factories, as well as enhancements in production technology, performance measurements are a moving target. Hence, it is important to note that all plants reported 1992 data.

At the end of 1992, average customer line rejects for the high performers (top one-third factories) were approximately 2900 ppm, for the average performers this number was 3400 ppm, while the bottom one-third factories had an average customer reject level of 5000 ppm. In general, we found that factories that also manufacture computer monitor tubes have a higher customer reject level than those that do not. So, if your factory manufactures computer monitors, your customer reject level if you manufactured TV (entertainment) color picture tubes only would be somewhat lower (about 150 ppm lower for every 10% of capacity that is devoted to computer monitor tubes).

Factory Productivity: Overall Employee Productivity

Labor productivity is a figure that production managers typically use to evaluate factory performance. We report the results on this measure (we use overall employee productivity, i.e., both direct and indirect), though we would like to emphasize that direct labor costs are only about 12% of total tube production costs, and indirect labor is 7% of tube production costs.. Further, automation influences labor productivity; we do not report productivity measures after correcting for automation, because there is no systematic way of doing so. However, factory scores on automation **are** reported in **Section VI.**

During discussions with managers, we realized that even though the generic picture tube is quite similar across the world, there are differences in factory activities that account for different productivity levels. For example, some factories do not have the "black matrix" process, others do not do yoke-matching, and a few factories also assemble electron guns, manufacture masks and steel bands in the picture tube factory itself. For the purpose of our calculations here, we have taken only the common set of activities while computing factory employment levels (i.e., we excluded employees working in black matrix, yoke-matching, gun manufacture, etc.) .



The measurement unit in the above figure is **tubes/employee-hour. Thus, the high performers, with an average productivity of 1.94, are four times as productive as the low performers**, keeping in mind, however, that these are **labor productivity** scores.

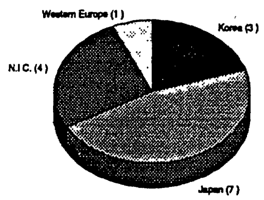
Compared to the scores for the whole industry, your factory's productivity score is 1.55, and that places your factory as a "High Performer" on the productivity rating chart above. Further, your factory's score was ranked 9 out of 45 possible factories.

Regional Ownership and Location, and Factory Performance

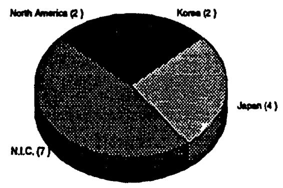
The figures on the next page give a regional breakout of factories that are high, average, and low performers, **on internal quality**. The breakout is given both by ownership and by location. As one can see from these figures, not all of the "best-performing" factories are Japanese factories; some of the Taiwanese-owned factories are among the best performers. Also, some of the Japanese-owned factories do not perform well. Further, contrary to popular belief, factory location does not correlate with performance, e.g., factories in Singapore, Malaysia, and Taiwan are among the high-performing factories.

Factory Performance in Different World Regions: Quality

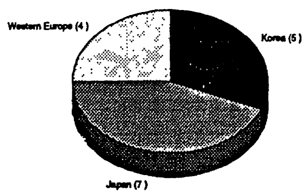
Regional Ownership of High Performance Factories



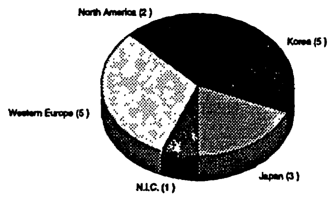
Location of High Performance Factories



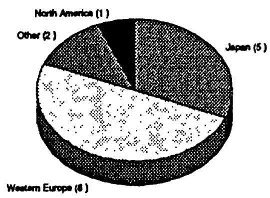
Regional Ownership of Average Performance Factories



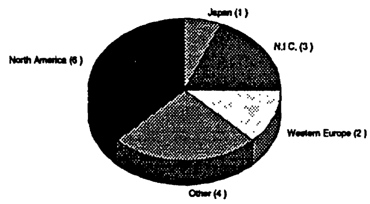
Location of Average Performance Factories



Regional Ownership of Low Performance Factories



Location of Low Performance Factories



Note: NIC = Newly Industrialized Countries
= Singapore, Thailand, Taiwan, Malaysia, etc.
Other = South America, India, Eastern Europe

V. Company and Factory Manufacturing Strategies

One of the issues that emerged from our interviews with managers was the future of the factory for the next generation of display technologies. In particular, color picture factories may start manufacturing color monitors, or as some managers suggested, may even start production of flat displays. Though we did not focus on this issue for our research, we did ask managers as to the nature of their company's and factory's future strategies. The responses are indeed interesting. Eight of the 48 responding plant managers expected that their factory would start manufacturing liquid crystal displays (LCDs) of one kind or another. Thirty-five of the 48 managers said that they expected their factories to start producing color computer monitors or tubes. It appears that most managers believe that the CRT will ultimately (but not very soon) be replaced by flat-panel displays, and expect their factories to take steps to respond to the change gradually.

We also asked managers to respond to questions about the utility and effectiveness of a variety of factory quality practices. Naturally, there was a lot of variation in what managers perceived to be useful. However, some of the trends are interesting. The table below highlights the trends by presenting the average measures for each category. The scale used for this table is **1=Little Benefit/Emphasis, 3=Some Benefit/Emphasis, 5=Great Benefit/Emphasis.**

Factory Quality Practice	Benefits in last 2 years	Emphasis in next 2 years
Using Statistical Process Control charts	3.38	4.13
Use of experimentation (e.g. Taguchi)	2.37	3.56
Use of cross-functional teams	3.67	4.26
Use of customer quality teams	3.32	4.16
Use of work teams, quality circles, etc.	3.33	4.04
Use of job rotation	2.85	3.38
Systematic preventive maintenance	3.72	4.57
Use of information systems for quality	3.63	4.44
Use of bar coding systems	2.13	3.72

The preceding table indicates that managers expect to emphasize most of the tools and practices listed there. For example, the use of Statistical Process Control (SPC) charts is expected to be even more greatly emphasized, even though some of the benefits from using SPC charts have been realized in the past 2 years. The list also indicates that the greatest relative emphasis is expected to be on increasing experimentation, improving preventive maintenance, enhancing quality information systems, and using bar code systems.

VI. Managerial Best Practices: Quality and Productivity

Based on the study, several key management practices were identified as influencing quality and productivity at color picture tube plants world wide. We grouped these practices into two sets. The **first** is a set of activities that appears to influence both quality and productivity, while the **second** set of activities influences productivity, but does not appear to be strongly associated with quality.

Factory Practices that Influence Quality and Productivity

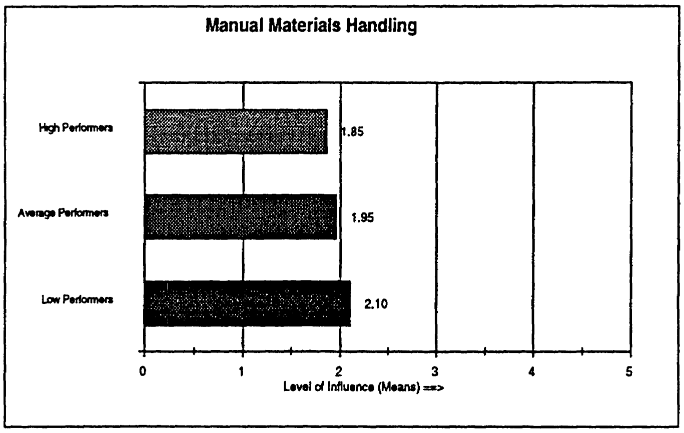
There are seven practices that correspond to production sites having both high quality and high productivity ratings. These seven practices pertain to:

1. Use of automated materials handling processes
2. Use of process automation
3. Implementation of process automation
4. Strategic planning for quality
5. Quality policies
6. Organization of engineers at factories
7. Use of quality information systems

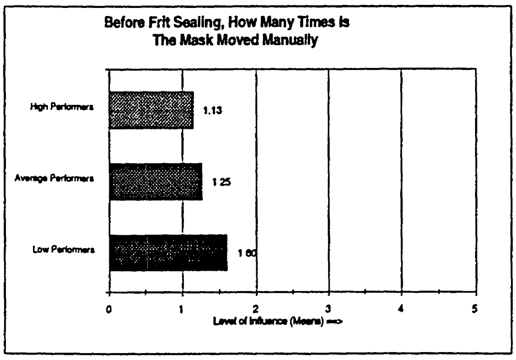
A brief description of each of these seven practices is given in the following pages.

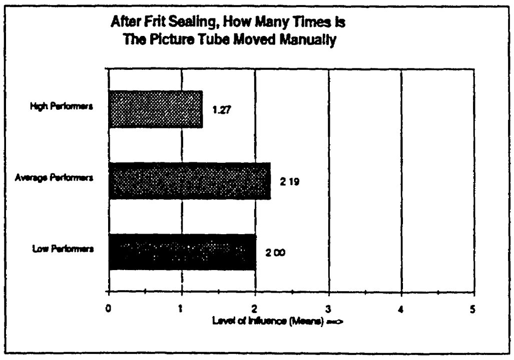
1. Automated Materials Handling Processes.

Factories that have higher material handling automation in the production process also achieve higher quality and productivity. In fact, statistical analysis of the data indicated that at least 10% of the variation in performance was explained by differences in automated material handling. As the figure below indicates, low performers had higher *manual* material handling than the high or average performers. **Compared to the numbers in this figure, your factory's score was 1.1.**



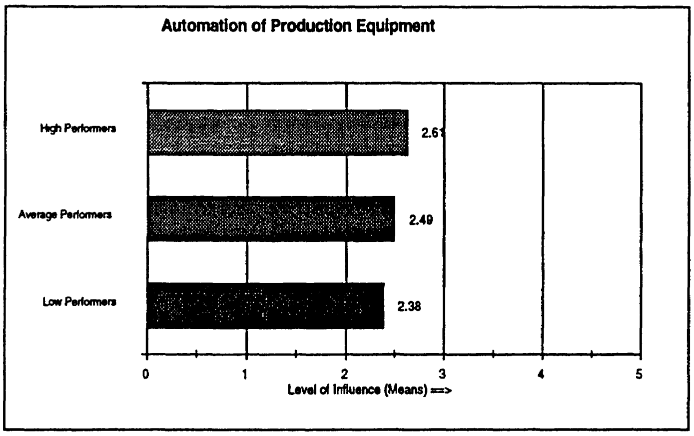
An indication of what aspects of the process may be important is provided by graphing two of the components of material handling automation: the number of times a picture tube or its components are manually handled before and after the frit-sealing process step. In high performing factories, the number of times a picture tube is manually handled is nearly half the number of times it is manually handled in the average performing factories. **Compared to the numbers in these figures, your factory's scores were 2.0 for manual handling of the mask before the frit-seal step, and 1.5 for manual handling of the picture tube after frit-sealing.**



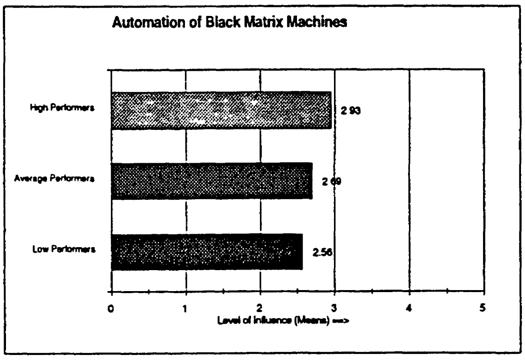


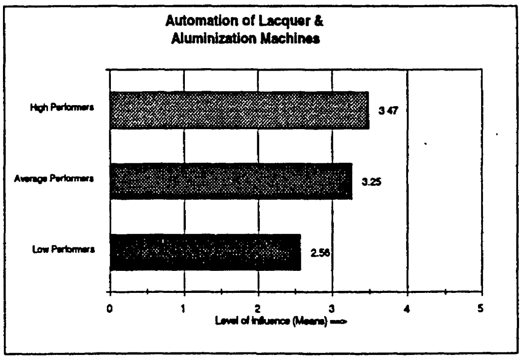
2. *Use of Process Automation*

The **second** key factor that explains quality and productivity differences across color picture tube factories, is the degree to which the production equipment and process control are automated. That is, what percentage of production equipment is programmable, self monitoring, and possibly self correcting? High-performing color picture tube factories are 15-30% more automated than low and average performing factories. The figure below indicates this difference. **Your factory's score was 2.6.**



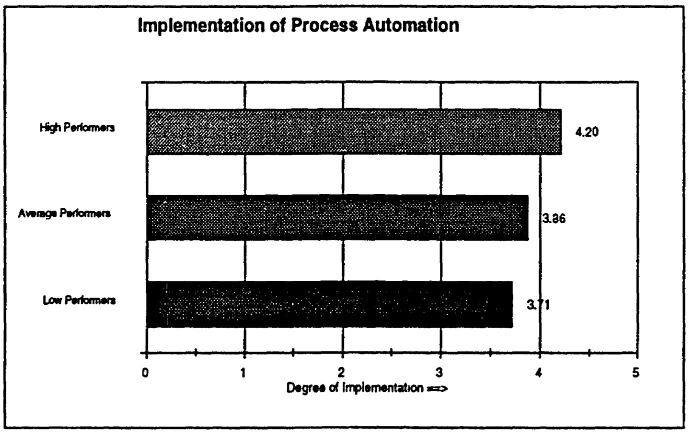
Two key indicators of the degree of production equipment automation are the extent to which black-matrix and lacquer/aluminizing machines are automated. As the figures below indicate, the difference between the low and high performers is particularly large for the extent of automation of lacquer and aluminizing machines. **On these dimensions, your factory's scores were 3.1 and 3.0, respectively.**





3. *Implementation of Process Automation*

The **third** most important factor that influences quality and productivity was also associated with factory automation: the care and attention with which process automation is designed and implemented. The high-performers paid close attention to these tasks, while the low-performers focused fewer resources on these key activities. **<u>You can compare your factory's performance by knowing that your factory's score was 3.6.</u>**



Three examples of how the high-performers implement production automation are:

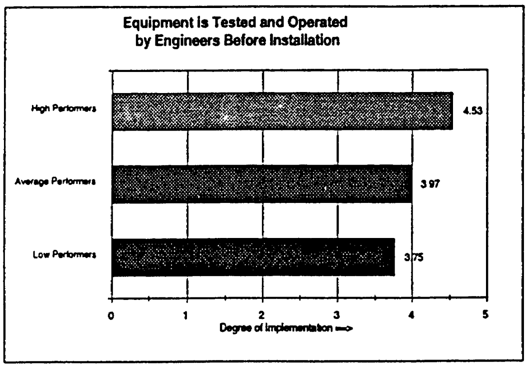
a) the extent to which the production equipment is tested and operated by engineers before installation,

b) the extent to which operating procedures for the production equipment are rewritten and verified before and after equipment installation,

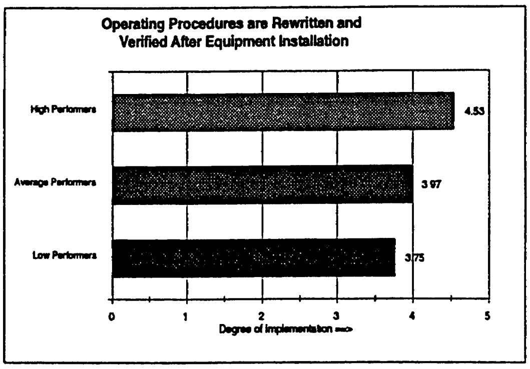
and

c) the degree to which equipment engineers work with factory engineers to specify equipment specifications.

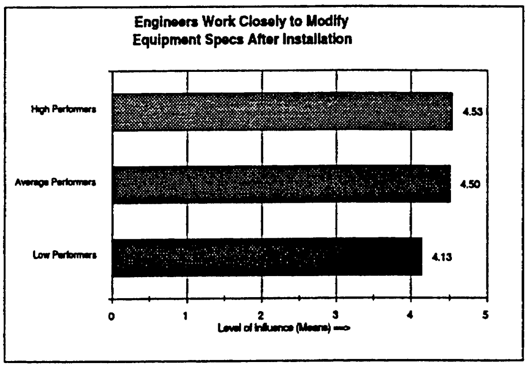
<u>On these dimensions, your factory's scores were 4.0, 5.0, and 5.0 respectively.</u>



(a)



(b)



(c)

Other components of this key factor are:

a) the amount of training production and maintenance workers are given for the operation and care of the new machinery,

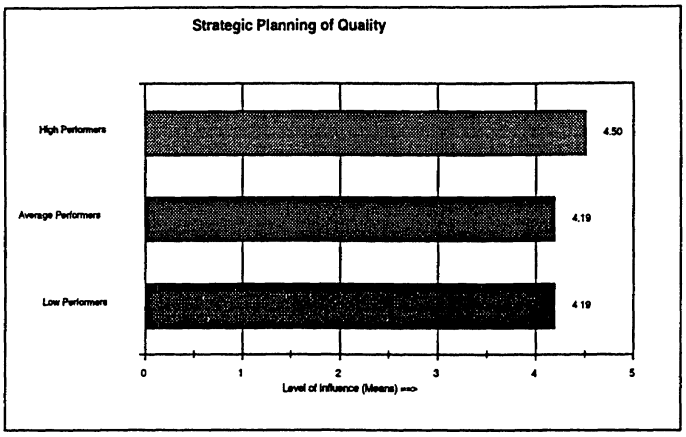
b) the extent to which design, equipment, and factory engineers work together to ensure compatibility of product, process, and equipment designs,

and,

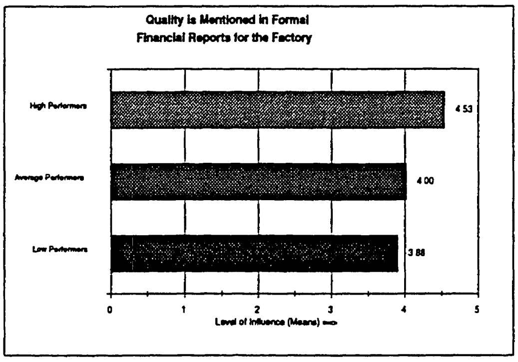
c) the extent to which factories select test equipment which is similar to customer factories.

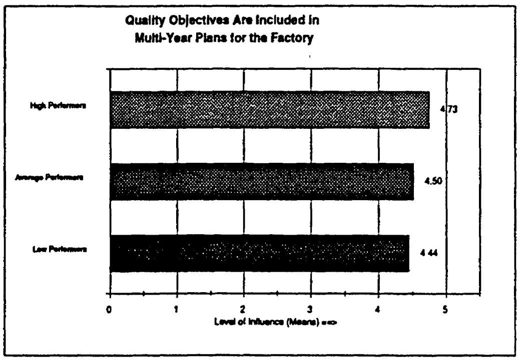
4. Strategic Planning for Quality

An important factor that influences quality and productivity is the manner in which an organization plans for quality. This includes practices such as setting quality objectives for inclusion in long-term planning, including quality managers in strategic planning, and incorporating quality in formal financial reports. The overall measure for this practice indicates that the high-performers do a somewhat better job of planning for quality than the average or low-performing color picture tube factories (please see figure below). **Compared to the mean score of 4.50 for the high-performing factories, your factory's score was 3.0**.



As an example of what particular activities constitute such strategic planning, we present graphs for two of these: the extent to which quality is mentioned in financial reports, and the extent to which quality objectives are included in multi-year plans for the factory. **For the first one, compared to the score of 4.53 for the high-performers, and 3.88 for low-performers, your factory's score was 3.0**. **For the second practice of including quality objectives in multi-year plans, compared to the high-performer score of 4.73, and low-performer score of 4.44 (the difference is not great), your factory's score was 4.5**.





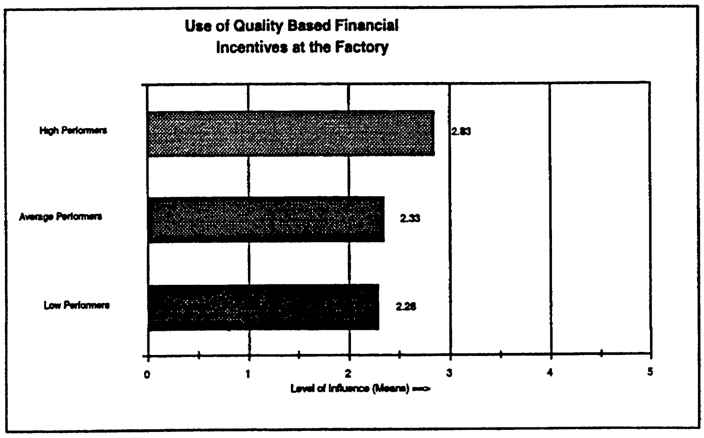
5. *Quality Policies*

We use "quality policies" as a broad description for a set of practices that shape employee incentives, use of quality programs, and the effectiveness of some emerging practices such as the use of work teams. We group these quality policies into three categories:

a) Use of quality-based financial incentives
b) Use of teams.
c) Use of complementary quality programs.

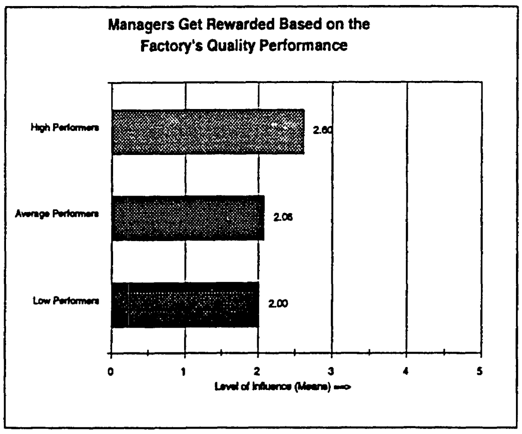
Use of Quality-based Financial Incentives

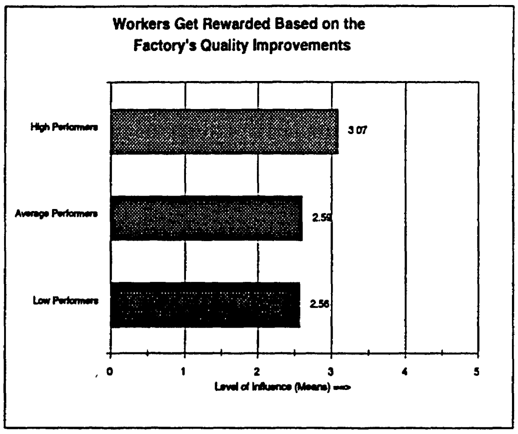
The data reveal that the use of financial incentives for quality is associated with superior quality performance, i.e., the higher the level of quality-related financial incentives, the better the quality performance. Though this should not come as a surprise, it does contradict what some of the quality gurus such as Deming have been saying, e.g. " don't set financial rewards ....". However, as the figure below indicates, the extent to which factories use quality-based financial incentives is limited, and there is certainly scope for improvement. **<u>The score for high-performers on the use of quality-based financial incentives was only 2.83. In comparison to this score, your factory had a score of 1.6</u>**.



Two examples of how factories use financial incentives for quality are the extent to which managers and workers are financially rewarded based on quality performance. **<u>On the first measure, of how managers are rewarded on quality performance, the high performing</u>**

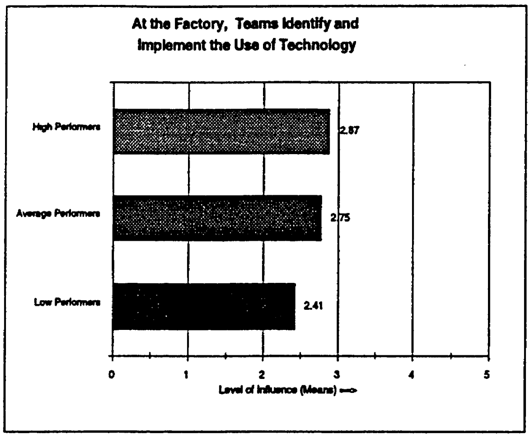
factories had a score of 2.60 whereas your factory scored a 1.0. **On the second measure of worker rewards for quality performance, your factory's score was 3.0 whereas the high-performers scored, on average, a 3.07**.





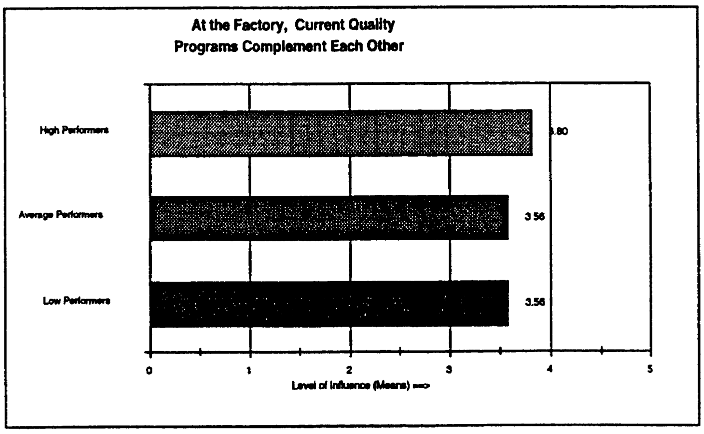
Use of Teams

Quality improvement efforts have long since recognized the importance of teams. The data that we collected for the color picture tube industry also supported this contention. Thus, factories that actively used worker teams had higher quality than factories that did not use teams. Further, we discovered that factories use teams in various ways. Some factories use self-directed work teams, others use quality circles, while still others use customer-focused teams of managers and supervisors. While studying the use of teams, we found that the degree of responsibility given to worker teams often is a strong indicator of how well the factory performs. This is due to two reasons. The first, of course is the fact that when teams are given greater responsibility, team members are able to solve problems quicker, come up with better solutions, and are likely to be more motivated. Second, factories that give greater responsibility to their worker teams, do so because they have faith in the capabilities of their workers. As a result of both these factors, factories that give greater responsibility to their workers are likely to have higher quality. An example is provided in the figure below, which indicates the extent to which teams identify and implement the use of new technology in the factory. At the high-performing factories, teams played a bigger role in selecting and adopting production technologies. **Your factory's score on this dimension was 4.0 compared to the average score of 2.87 for the high-performing factories**.



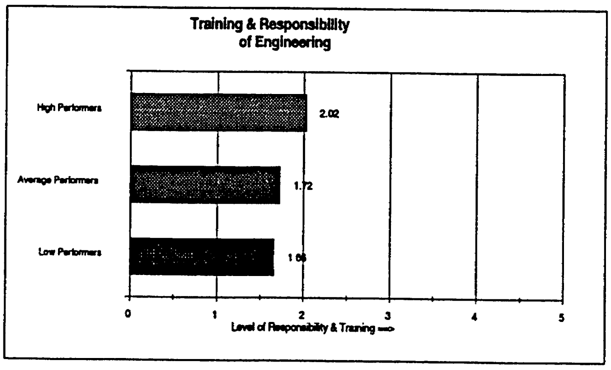
Using Complementary Quality Programs

A key observation that we had made during our interviews with managers at the 10 factories was that maintaining a balance and consistency between different quality programs was important, e.g., between the use of SPC and the focus on work teams. The data from the survey support this observation, in that we found that the high-performing factories tend to implement quality programs such that they are complementary and consistent with each other and the overall factory strategy. The difference, as the figure below indicates, is not great, but that may be because of the bias managers may have while reporting the information pertaining to this issue. In other words, we might expect the better-performers to say that they want more complementarity among quality programs than currently exists, so that they can improve faster. In order to give your factory an idea of how you rank on this criteria, we analyzed these data and found that **your factory's score is 2.9 while the high-performer's score is 3.80**.

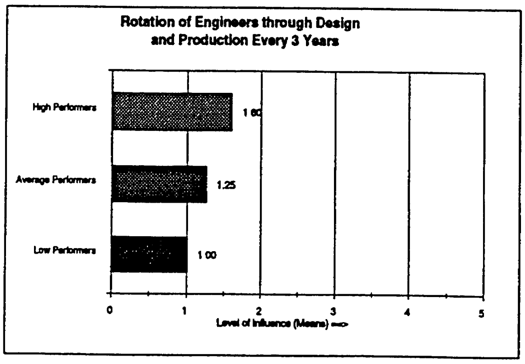


6. Organization of engineers at factories

The **sixth** important factor that influences quality and productivity is the manner in which engineers are organized and work. During our field interviews, we had discovered that, due to the complexity of the production process, engineers benefit greatly by being familiar with technical knowledge in other production areas and functions. Furthermore, the interactions between different process steps and performance dimensions require extensive coordination between technical personnel in different areas. The survey data confirm this observation as the figure below indicates. High-performers had a substantially higher score on this dimension, than the average and low performers. What is even more important is that very few of the factories in the picture tube industry have explored the potential of this factor, as the low scores for **all** the factories indicate. Thus, we find that picture tube factories can reap rich rewards by exploring the potential of this engineering practice. **Your factory's score on this dimension was 2.3.**



An example of a key dimensions of this important factor is the frequency with which design and production engineers are rotated across these functions. This is depicted in the following figure. **On this dimension, your factory's score was 1.0.**

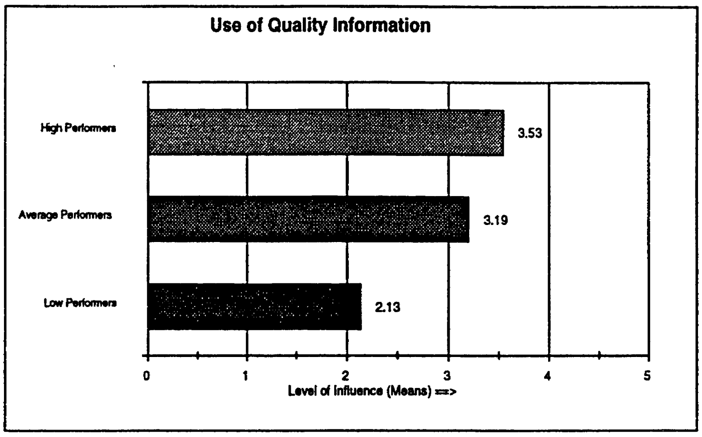


Other important elements of this practice of creating a core of technical knowledge among engineers, as well as production workers, are:

a) Having engineers spend a larger percentage of the time on the production floor,
b) Requiring engineers to train production personnel to solve process and quality related problems, **and**,
c) Ensuring that the results of problem-solving by engineers are communicated to production workers.

7. *Use of Quality Information Systems*

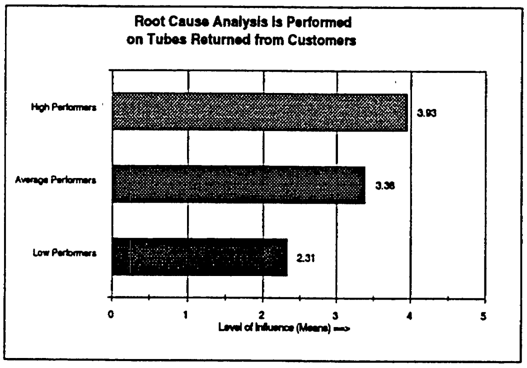
Frequent and factory-wide information use and dissemination influences quality and productivity to a great extent; nearly 20% of the performance differences (quality and productivity) across color picture tube factories in the world are due to differences in the effectiveness with which quality information is gathered and used. **On this dimension, your factory had a score of 4.5; the high-performers scored a 3.53.**

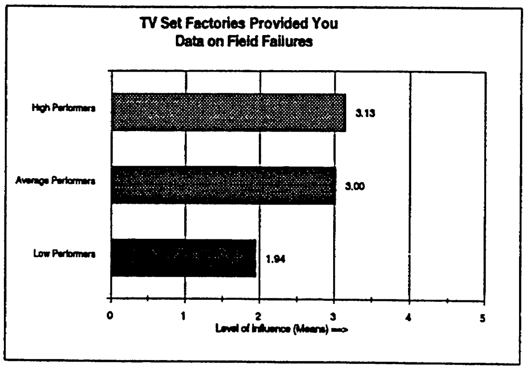


Some of the other individual elements of this factor are shop-floor practices such as:

a) Sharing root cause analysis of customer-returned tubes among factory engineers,
b) Analysis of field failures data provided by TV set factories, **and**,
c) Having production workers and technicians use computers to identify quality problems, and then conduct root cause analysis to resolve them.

The following two figures report the scores for the high, average, and low performers on the first two of these elements. **<u>Corresponding to these figures, your factory's scores were 4.0, and 5.0 respectively.</u>**





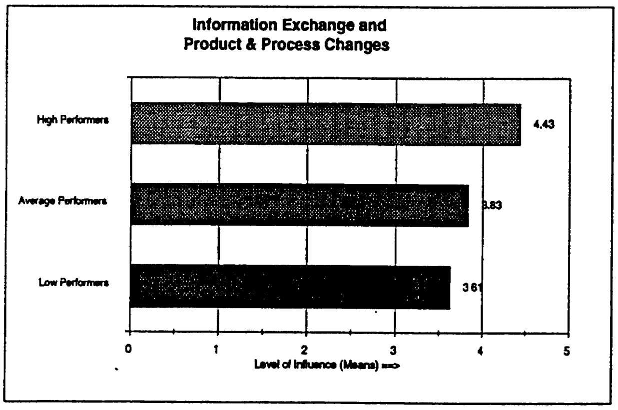
Factory Practices that Influence Quality, but not Productivity

There were two factors among the various factors we studied, that influence quality, but are not strongly associated with productivity. These are:

1. *Product and Process Design Release Practices*

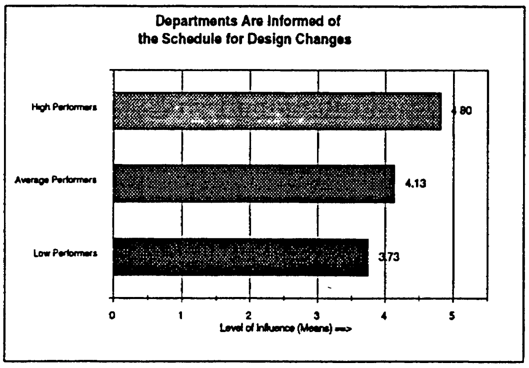
Given the complexity of the production process, and the fact that tube conformance and reliability are highly influenced by tube design, we wanted to focus on design issues and design management practices. This, however, was not possible because only a few of the factories actually design picture tubes. Hence we narrowed our focus to study a typical factory's role in the design process--namely design implementation at the factory.

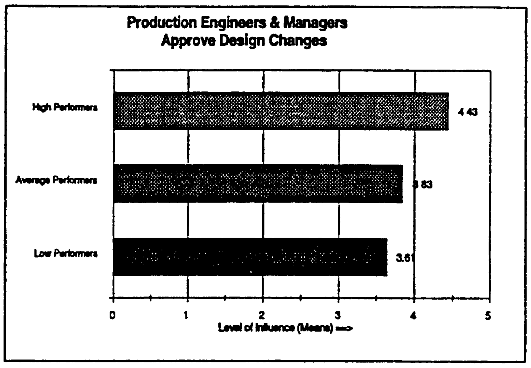
During our field interviews, we found that some factories spent a lot of time and effort creating new product and process designs or modifying existing ones, but when it came to implementation, they seemed to slacken off. We identified a set of practices that we call "<u>Product and Process Design Release Practices</u>." On this dimension, low performers had a mean score of 3.58 while high-performers had a mean score of 4.43. **<u>Your factory scored 4.6 on this dimension.</u>**



In order to give you a better sense of this factor, we have graphed two of the key practices that describe this factor. The **first** is the frequency and care with which various departments are informed of design changes, and the **second** is the frequency with which production engineers and managers have to sign-off and approve design changes before they are implemented.

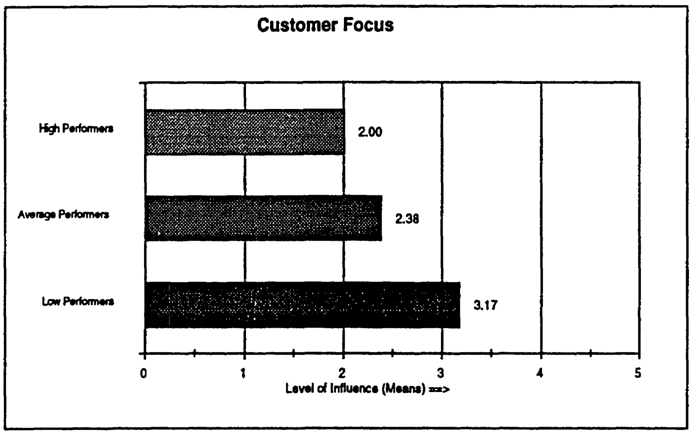
For the figures given below, your factory's scores were 5.0 and 5.0 respectively.





2. *Customer Focus*

Though we measured the degree of focus in a number of different ways, one reasonable definition provided us with an unexpected result. We asked production managers the extent to which they focus on customer quality teams. When we correlated this variable with quality performance, we found a negative correlation. This result is pictorially represented in the figure below. **Your factory's score on this factor was 3.5.**



However, data from production managers do suggest there is a strong positive relationship between quality and the number of visits each engineer and production supervisor makes to customer facilities. Further, there is a weak relationship between the quality and the number of visits each manager makes to customer facilities. On these measures, the difference between the number of visits by high quality plants and low quality plants was very significant. On average, the personnel from the high quality plants were visiting their customers *four times* more often than personnel from low quality plants.

Based on these results, it seems quality is more likely to be affected positively by visiting the customer than establishing and using customer quality teams.

VII. Summary and Conclusions

This study of the global color picture tube industry reveals that regional differences in quality performance are small, compared to a few years ago. A number of non-Japanese factories in our study were among the high-performing factories in the world, whereas many Japanese factories did not perform particularly well.

Thus, the search for best practices can no longer be limited to Japanese companies and factories. It is in this spirit that we analyzed the influence of a variety of quality and manufacturing practices on quality performance, and found that certain practices were associated with higher quality. Key factors include factory automation, effective adoption and implementation of automation, multi-disciplinary organization of engineers at factories, the use of quality information, quality planning, and a number of quality policies.

This study also raises some important questions for managers and researchers. Should color picture tube factories diversify to manufacture color monitors? What should be the approach of factory managers towards adopting a manufacturing strategy that recognizes the emergence of flat-panel technologies? And various other issues!

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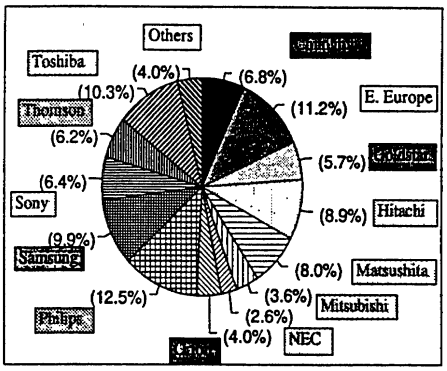
Appendix 1: Industry Characteristics

This section first describes the industry structure - market shares, global demand and supply - and its evolution. Next, the competitive priorities for industry competitors, and also how these priorities have evolved since the commercialization of color television are identified. What is the best strategy for achieving these priorities? Based on managerial interviews, we suggest that a quality-based approach should be adopted. Finally, based on published data and interviews with managers, we speculate on the future of the industry.

Industry Overview

Today, the global color picture tube industry is in its mature phase, marked by cut-throat competition. The main players are European (4), Japanese (7), and Korean (3). **Figure 1** below gives 1992 market shares for the major TV color picture tube competitors, worldwide.



TV color picture tube market shares for leading competitors
Figure 1

Sources: Survey, industry reports, company documents.

Today there are approximately 20 companies in the world that manufacture TV color picture tubes (excluding the old communist bloc - China, ex-Soviet Union, and E. Europe), though at one time the U.S. alone had more than 75 color picture tube manufacturers.

The economics of manufacturing in this industry favor multi-million tube capacity factories. Investments in new factories run into hundreds of millions of dollars (Typical examples are those of

Matsushita's $150 million factory at Troy, OH built in 1988 with an annual capacity of 2 million tubes, and Toshiba's Horseheads factory whose 3 million unit capacity cost $220 million in 1986). Given high scale economies, high capital requirements, and the competitive nature of this industry, it is no surprise that there are very few players in the industry, and few factories in the world. There are approximately 70 factories in the world today; of these 20 are in China, Eastern Europe, and the former Soviet Union.

The industry is also marked by high levels of vertical integration[1]. Except for an Indian firm, and some of the Chinese and ex-U.S.S.R. firms, all other picture tube manufacturers also assemble and sell TVs and half of the sixty odd TV set makers in the world have their own picture tube factories. Upstream integration is also high: most of the picture tube business units also own their own glass and gun manufacturing units. Further, due to requirements for high quality and flexible delivery, picture tube business units typically have very close relationships with their suppliers[2]. Another very important characteristic of the industry is the extent of cross-flows of picture tubes among competitors. Thus, for example, Matsushita sells color picture tubes to Hitachi and buys from Philips and Toshiba, among others.

Global markets: Demand and Capacity

The lion's share of the worldwide demand for televisions originates in N. America and W. Europe. Together, they consume half the world's production of TVs *(but manufacture only 33%).* Over the past few years, TV production capacity first moved overseas - to Japan and Korea - and then, as a result of increasing tariffs and trade disputes, is moving back into N. America and Europe. Due to relatively inexpensive dedicated automation, and low wages, Korea still produces 15 million TV sets (about 13% of worldwide production). Also, much of the production capacity even in N.

1 Vertical integration was important for survival in the TV industry because it enabled lower costs, and control over supply of key components. The same is true of the picture tube industry: many surviving companies have their own glass factories that can meet all or part of their glass demand (or, in the case of Japanese manufacturers, long-standing relations and stock ownership with the glass manufacturers).

2 Economists and business researchers contend that the more mature, stable, and competitive the industry (e.g. the TV and picture tube industries), the greater the desire for tighter control over the value chain among surviving firms in the industry.

America and Europe is Japanese and Korean owned. A similar situation exists for TV color tubes, as **Table 1** shows. Again, Korea produces a major share of TV color picture tubes; in fact, at 24 million tubes *(29 million if computer monitor tubes are also included)*, it has the largest TV tube production capacity (21% of world production). N. America produces enough tubes to supply domestic TV assembly plants, but W. Europe imports approximately 6 million tubes for TV sets assembled in W. Europe[3]. Production capacity for both TV sets and TV color tubes in N. America is expected to increase: to satisfy increased demand, in response to the North American Free Trade Agreement (NAFTA), and prepare for HDTV markets.

Table 2 presents the same data in terms of net exports and imports. From the first 4 columns, we see that Japan, Korea, Taiwan, China, and S.E. Asia are net exporters. Korea and China are expected to play an increasingly important role in the next few years. An interesting observation comes from looking at the last 2 columns of **Table 2;** there appears to be a regional imbalance in the location of picture tube and TV assembly plants, possibly due to different labor intensities and different wage levels for the manufacturing processes for picture tubes and TV assembly. Korea has a much higher picture tube capacity than TV assembly capacity, while W. Europe has a much smaller tube capacity than its TV assembly capacity, possibly because W. Europe emphasizes production of large size tubes. This imbalance has an important implication for this study: *specifications and conformance standards are quite similar across the world.* Certainly there are differences: NTSC (in the U.S.) and PAL/SECAM (in Europe) require different screen line counts (525 vs. 635); European set makers emphasize white field purity much more than others; and the U.S. and Japan were the first ones to use black matrix - Europe followed a few years later. However, overall requirements are somewhat similar, as our field interviews, and the survey data reveal.

3 This difference is probably because of different tariff rates. The United States and Canada impose heavy duties of 5-10%, (and 15% under NAFTA), whereas European duties are lower (<5%).

Country/ Region	Worldwide TV Demand: Actual 1992 millions of units	Actual 1992 percent %	Forecast 1996 millions of units	Forecast 1996 percent %	Worldwide TV Capacity: Actual 1992 millions of units	Actual 1992 percent %	Forecast 1996 millions of units	Forecast 1996 percent %	Worldwide TV Tube Capacity: Actual 1992 millions of units	Actual 1992 percent %	Forecast 1996 millions of units	Forecast 1996 percent %
N. America	21.7	22.75	24.8	21.27	18.0	15.93	22.0	16.79	19.5	16.70	21.0	15.97
S. America	5.0	5.24	6.5	5.57	4.0	3.54	4.0	3.05	4.0	3.42	4.0	3.04
W. Europe	24.8	26.00	28	24.01	21.0	18.58	23.0	17.56	15.0	12.84	18.0	13.69
E. Europe	9.1	9.54	11.5	9.86	9.0	7.96	13.0	9.92	9.0	7.71	11.0	8.37
Japan	9.0	9.43	9.0	7.72	11.0	9.73	11.0	8.40	13.0	11.30	11.0	8.75
Korea	1.5	1.57	2.0	1.72	15.0	13.27	13.0	9.92	24.0	20.55	21.0	15.97
Taiwan	1.0	1.05	1.5	1.29	3.0	2.65	3.0	2.29	3.0	2.57	2.0	1.52
China	9.2	9.64	13	11.15	12.0	10.62	15.0	11.45	13.0	11.13	17.0	12.93
S.E. Asia	7.0	7.34	9.0	7.72	18.0	15.93	23.0	17.56	14.0	12.07	23.0	17.49
Other Asia	1.5	1.57	2.5	2.14	2.0	1.77	4.0	3.05	2.0	1.71	3.0	2.28
Africa	5.6	5.87	8.8	7.55	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	95.4	100.00	116.6	100.00	113.0	100.00	131.0	100.00	116.8	100.00	131.5	100.00

Worldwide demand and production capacity for color TVs and color TV tubes

Table 1

Source: Survey, industry reports, company documents

Country/ Region	Net TV exports (imports) TV capacity - demand: Actual 1992	Net TV exports (imports) TV capacity - demand: Forecast 1996	Net TV tube exports (imports) Tube capacity - TV demand: Actual 1992	Net TV tube exports (imports) Tube capacity - TV demand: Forecast 1996	Net outbound tubes (inbound) Tube capacity - TV capacity: Actual 1992	Net outbound tubes (inbound) Tube capacity - TV capacity: Forecast 1996
	millions of units	millions of units	millions of units	millions of units	millions of units	millions of units
N. America	(3.70)	(2.80)	(2.20)	(3.80)	1.50	(1.00)
S. America	(1.00)	(2.50)	(1.00)	(2.50)	0.00	0.00
W. Europe	(3.80)	(5.00)	(9.80)	(10.00)	(6.00)	(5.00)
E. Europe	(0.10)	1.50	(0.10)	(0.50)	0.00	(2.00)
Japan	2.00	2.00	4.20	2.50	2.20	0.50
Korea	13.50	11.00	22.5	19.00	9.00	8.00
Taiwan	2.00	1.51.50	2.00	0.50	0.00	(1.00)
China	2.80	2.00	3.80	4.00	1.00	2.00
S.E. Asia	11.00	14.00	7.10	14.00	(3.90)	0.00
Other Asia	0.50	1.50	0.50	0.50	0.00	(1.00)
Africa	(5.60)	(8.80)	(5.60)	(8.80)	0.00	0.00

Worldwide trade in color TVs & picture tubes, and transportation of color TV tubes

Table 2

Source: Survey, industry reports, company documents

Competitive Priorities

Industry competitive priorities - quality and others

In today's market, conformance quality, manufacturing costs, and tube design performance are all important priorities. Data from the past few years' Consumer Reports were compiled and analyzed with the objective of identifying major competitive priorities. The Consumer Reports data are available for TV sets, but some of the performance dimensions are primarily picture tube characteristics.

An analysis of these data indicates that features such as *interface* (as exemplified by input-output devices), *convenience* (as reflected in the ease of use of the set and remote), and *receiver sophistication* (which comprises color correction, color control, and adjacent channel interference protection capabilities), explain a substantial fraction of price variance. However, picture tube performance characteristics (clarity, color fidelity, contrast, brightness), reflecting design and manufacturing excellence, do explain about 15-20% of the variance before correcting for TV size, and 25-30% after correcting for TV size, and are significant predictors of the price of TV sets. Since tube performance is evaluated using actual sets, these scores (for tube performance) actually represent a combination of tube design performance and tube manufacturing conformance (further, tube conformance also affects costs).

The above analysis does not identify all the competitive priorities for picture tube manufacturers. For one, customers see a composite product: a TV's performance is the net result of the individual performances of the picture tube, the receiver circuitry, the display circuitry, and design and inclusion of certain features. Second, some of the demands placed on picture tube manufacturers may be important only to TV set makers, and never have significance for the customer; for example, picture tube delivery and flexibility requirements do not have much to do with final customer needs. Thus, the following few paragraphs attempt to specify the important dimensions on which tube manufacturers compete.

Earlier we mentioned that TV and picture tube manufacturers have close relationships with suppliers, possibly resulting from a desire to control cost and quality in the upstream stages of the value chain. Given this desire to control the value-chain, it is interesting to observe the relationships between TV set manufacturers and picture tube supplier plants. The initial decision by a TV assembly plant to source picture tubes is based on a number of factors, the most important of which are issues pertaining to product performance, quality, cost, and delivery. Discussions with managers revealed that during the sourcing decision, product performance and delivery are ***order qualifiers***, whereas conformance and price are ***order winners***[4,5].

Once the customer-supplier relationship is established, TV set factories resist changing picture tube suppliers. The perceived cost of switching picture tube suppliers is high because TV chassis designs may need to be modified, new testing procedures have to be established, and new logistical arrangements must be made. As a result, during the later stages of the customer-supplier relationship, the distinction between ***order winners*** and ***order qualifiers*** disappears; picture tube plants must not only improve conformance and maintain low prices, but also remain at par with other tube manufacturers on tube designs and the ability to make deliveries quickly and flexibly.

Thus, in today's market, conformance quality, manufacturing costs, and tube design performance are all important priorities. These requirements are reflective of the industry's current position along the product life cycle: both industry demands and management emphasis change as a result, as the next section shows.

Changes in competitive priorities

Along with the evolution of product and process technology, evolution of the product life cycle, and changes in industry organization, competitive priorities have also changed in the color picture tube industry. Initially (***1928-1959***), the focus was on product innovation. In the next stage (***1959-1969***), product performance became a primary goal. In the mature stage (***1969-1985***), conformance and cost became important[6]. And in the present stage of possible industry decline

4 We asked this question of plant managers at 9 tube plants in 5 companies in the U.S., Europe, and Japan during our field interviews.

5 This is possibly because TV set manufacturers believe that product performance and delivery characteristics are the most dynamic requirements - *tube designs may change every few months and so may market conditions that govern delivery* - whereas high conformance quality and low costs are reflective of a plant's basic capabilities and cannot be easily improved over a short period of time.

6 Continuous improvement efforts, especially by Japanese tube manufacturers, have led to improved conformance and lower cost. Customer returns have come down from about 70,000 ppm in 1980 to less than 5,000 ppm in 1992. And this, inspite of tightening conformance specifications and increasing product performance requirements.

(*1986-present*), product innovations along with conformance and cost have all become important; conformance requirements, which have become much more stringent, are seen as a prerequisite for cost reduction and customer satisfaction, as exemplified by the growing importance of "customer line efficiency" as a performance objective[7]. The above evolution represents *changing definitions of quality* over the product life cycle.

Changing quality requirements are naturally accompanied by an evolution of management practices. In the ***initial trajectory stage***, the focus was on tube development and launching of new processes. Management paid close attention to the performance of the R&D group, and the emphasis was on tube development, and refining manufacturing processes that could make proposed product features feasible. During the ***market growth*** **stage**, engineers focused on pushing picture tube performance as far as possible within a reasonably stable "envelope" of technology, i.e., without making major changes in the basic concept of the CRT. Thus engineers sought improvements in brightness, contrast, corner focus, and other aspects of tube performance without changing the basic CRT design. On the production side, pressured by marketing, the emphasis was on shipping tubes of reasonable quality as fast as possible. Not having much time to invest in process improvements such as SPC, plants resorted to inspection to ensure a minimum level of product quality; this was primarily the responsibility of the quality engineering department. Thus, many of the quality testing and inspection procedures were developed during this phase.

Most process improvements, such as the use of SPC, and the tightening of process specifications, occurred during the early stages of ***maturity***. Later, process optimization and continuous improvement through detailed engineering, problem-solving and employee involvement were carried out. The entry of most Japanese tube manufacturers in world and U.S. markets coincided with the late market growth and early maturity phases of the product life cycle for TV and picture tubes (late 1960s); Sony was the first one to enter the U.S. market. As in automobile and TV industries, Japanese companies have played a major role in changing the nature of competition in

7 Customer line efficiency is a measure of the degree to which TV assembly plants have to reprocess or retest TV sets if tube parameters are not **at** nominal specifications, even if they do fall within the specifications limits. Thus, it measures the amount of rework or extra effort at the set factory caused by tube parameters not being at nominal values. It is conceptually similar to Taguchi's loss function. The Sony (San Diego) factory has adopted this measure as a key indicator of customer focus.

color picture tube manufacturing. Realizing that automation would give them quality and cost advantages, they invested their resources into the development of automated manufacturing equipment, and tube designs that would be a force to reckon with. They have redefined what conformance means. For example, the Sony factory in San Diego (which is located next to their TV set assembly factory) has three measures of conformance: in-house rejects, returns from TV factory, and customer line efficiency (based on publicly available information).

At present, the industry is in the ***declining*** stage: sales are growing slowly or stagnating, and competition is tougher. At the same time, alternate technologies pose an immediate threat to the future of picture tubes. In today's competitive picture tube market, characterized by a number of alternate technologies, the emphasis by the best companies is on world class designs, world class manufacturing, and world class innovations. The market wants everything. The question is: can the efforts to improve design and manufacturing performance enable picture tubes to survive longer that they otherwise would?

The maturity and decline phases of the product life cycle for TV and picture tubes also happen to coincide with the quality movement that has revolutionized manufacturing all over the world during the last 10-15 years. Thus, the adoption of higher quality standards, extensive use of statistical process control, and emphasis on manufacturability also reflect this quality emphasis.

Achieving competitiveness

Given that conformance and price are both key competitive dimensions, it immediately becomes evident that a quality-driven approach is arguably the preferred one. A factory can try to follow an approach of cutting costs on materials and process refinement, and inspect all outgoing tubes, but it is likely to end up spending more money. *First*, yields will still be low, especially since little rework or rectification is possible in picture tube manufacturing. *Second*, if conformance efforts are relaxed, tubes are likely to have high variability around the nominal values even if tubes are within specifications. This will result in high costs of rework at the TV set assembly plant *(since many of the process steps in TV assembly and testing involve matching picture tube to the chassis,* *larger deviations from nominal lead to rework loops during assembly*[8]*).* *Finally,* if tube conformance is poor, TV assembly plants are expected to inspect all incoming tubes; otherwise, they would not need to have 100% inspection, thus cutting costs. Thus, efforts to improve quality are a key to manufacturing and business performance[9].

Environmental concerns for the CRT industry

The picture tube manufacturing process uses a number of solvents and coatings, phosphor compounds, aluminum and other metal sprays. Many of these are toxic and cause problems during manufacturing - ground seepage, atmospheric exhaust, and skin problems. As a result, manufacturers have devised many solutions to reduce their impact, though not always cost-effective solutions. Also, a the major problem arises when the CRT has to be disposed either because it was rejected at the plant or after its life is over[10]. Not only do the chemicals and toxic materials used during manufacture need to be taken care of, the lead in the CRT glass must also be treated or reused. Industry members and governmental regulatory bodies have contradictory opinions about the impact of lead in display glass. Whereas governmental bodies claim that the lead in the glass is a threat to the atmosphere and people, industry members claim that the lead in the glass is in a form that prevents it from being dissolved into the ground (in landfills). A few countries, notably Germany, have already initiated legislation that makes the picture tube or TV/monitor manufacturer

8 This is the rationale behind using the customer line efficiency performance measure for picture tube manufacturing conformance. This issue may require a study of the economics of the situation: How much does a defective tube "really" cost the TV set assembler, either for retesting, or due to a line interruption? How much does it cost the tube manufacturer to inspect the outgoing tubes more thoroughly? And what is the nature of the "loss function" for a difficult-to-assemble tube, as compared to the potential investment in equipment to improve process capability (unless that can be done without any investment)?

TV set assemblers can easily determine this cost. First, they can correlate costs with tube defects, and the number of times a tube goes through a recycle or retest loop. Based on the cost-of-quality system or other accounting data, the direct and overhead costs for each stage of the production process can be determined. The cost of the inefficient interface can be estimated by correlating stage-wise costs with incoming tube defects, and the number of times a tube goes through recycle or retesting.

9 This approach to manufacturing competitiveness - cost through quality - is applicable to a cluster of industries and manufacturing processes, especially where rework is limited, and thus yields are important. Examples include display glass manufacturing, semi-conductors, plastics, and chemicals.

10 In the U.S. alone, 200 million CRTs are in use; the problem is worse if we add the 20 million TVs that are sold annually. Thus, in 10 years we will have more than 400 million CRTs to dispose off.

responsible for disposal of their products after they have been used (the widely-discussed 1991 Product Responsibility Act).

For CRTs, there are two alternatives to disposal: remanufacturing and recycling. Tubes that cannot be remanufactured must be recycled. Some companies have come up with the necessary innovations to resolve the two issues in safe recycling: discovering a restorative or recycling technology, and finding a market for the recycled material. For example, for CRT glass, Digital Equipment Corporation (DEC) supplies the glass to be recycled, Envirocycle has developed a patented process, and Corning Asahi has developed the technology to use recycled glass in the manufacture of color picture tube glass; the recycling technology also allows the glass to be freed of all chemicals and lead.

Industry projections

Today, the total market for electronic displays is $15 billion; by 1997, it is expected to reach $24 billion. Flat panel displays are expected to grow from about 25% ($3.75 billion) today to 36% by 1997 ($9 billion). Brightness, contrast, display size, pixel count and resolution are expected to remain the primary measurements of quality, but will increasingly be redefined for flat-panel displays.

CRT industry projections

As mentioned above, the share of flat-panel displays will increase at the expense of CRTs. Even though the absolute market for CRT's will increase from $11.25 billion in 1993 to $15 billion by 1997, the CRT market share will drop from 75% to 65% of the total display market. The cost-effectiveness of CRTs will not be enough of an asset to enable CRTs to maintain their current hold on the market (though if picture tube manufacturers are unable to maintain or improve cost and conformance performance, and reduce the environmental side effects of tubes, the demise of the CRT may be hastened). The bulk and weight of CRTs is heavy baggage in many current and potential applications, and CRTs are being gradually replaced by flat-panel displays, or are not even being considered for new display applications.

Neither is the CRT environmentally friendly: as mentioned earlier, leaded glass is used to minimize the effect of harmful X-ray radiation, and various toxic chemicals are used in manufacturing. The manufacturing process is energy intensive, if environmental concerns pertaining to its disposal increase, and CRT manufacturers are required to set up disposal and recycling systems, tube costs are likely to go up. The same will be the case if pollution prevention requirements for the picture tube manufacturing process become stricter.

On the other hand, the benefits of the mature CRT technology are its simplicity, broad utility, high luminance, excellent image quality, and cost-effectiveness. Some of the large market segments - business systems, industrial products, medical equipment, computer products, and TV receivers - are expected to continue to use CRTs into the foreseeable future, and thus support CRT sales.

HDTV and picture tubes

For color picture tubes, as for color TV, the potential emergence of high definition television (HDTV) as an industry standard is likely to change the nature of business strategies. Some firms that would not have otherwise survived, continue to exist because of the potential returns from participating in HDTV markets. In some cases, they have been able to raise enough capital to survive for a while longer. In other cases, they have teamed up with stable firms that want to enter the market. At the same time other firms are waiting in the wings to enter the high-definition TV and picture tube markets by taking advantage of the window of opportunity resulting from this technological change.

The point to be made here is that HDTV is a technological change event that comes both as an opportunity and a threat. If CRT tubes continue to be used for HDTV, it will be an opportunity to rejuvenate the product life cycle for TV and picture tubes, in which case it will be competence-enhancing for current TV and picture tube manufacturers. If CRT manufacturers are unable to make substantial advances to compete with flat-panel and other display alternatives, CRT tubes will become obsolete, and HDTV will end up destroying the competence of existing competitors. It is at present unclear what the impact of HDTV on the color picture tube industry will be.

Picture tubes and alternate display technologies

This section on industry projections will be incomplete without a brief discussion of some of the alternate display technologies for television, which are quite likely to be competence-destroying technological discontinuities. Essentially, the objective of these alternate technologies is to develop flatter and lighter displays that also consume lesser power. There are clearly problems with the older CRT technology: thick, heavy glass is required to withstand the partial vacuum in the CRT; problems with wide-angle focus mean that the picture tube is fairly long; due to active emission technology, power consumption is high; and environmental concerns are increasing. In contrast to the miniaturization that is ongoing in the electronics and computer worlds, the CRT is a dinosaur, and not a very "green" one either! But the alternatives are also not very attractive at this moment.

Nearly everyone agrees that LCDs, especially active matrix LCDs, are the technology of the future; active matrix LCDs are expected to grow in revenues from 0.8% in 1987 to about 10% in 1997. What is not so evident is the manner in which the LCD should be triggered by the input signal. Thin-film transistors (TFTs) are the popular solution, but there are dozens of different TFTs, each with different problems of response speed, temperature stability, cost, and manufacturability. Examples include: amorphous-Silicon (or a-Si) TFTs, polycrystalline TFTs, Cadmium-based TFTs, and magnetic or MAG LCDs. None of these is dominant yet: none of them is the clear performance leader; all of them have embarrassingly low yields; and none of them is particularly friendly to the glass substrate to be used to hold these TFTs. Some are more manufacturable than others, others have slightly higher yields, and others can be repaired with some ease. The dominant TFT is still to be found!

Ferroelectric LCDs provide a faster and thinner alternative to AMLCDs, but have not yet been developed to the point where they are reliable. Electroluminiscent displays (ELDs), though better than LCDs in that they are not light filters, have posed problems while trying to control the electric current and capacitance that are required while breaking down the phosphor electrically . Plasma display panels (PDPs) are similar to ELDs, except that the phosphors are not excited directly but through creation of ultraviolet light by breaking down the gas molecules. Field emitter displays

(FEDs) are promising, but still being developed. FEDs provide all the advantages of CRTs - brightness, robustness, and purity - while being flat, thin, light-wright, and robust.

Most of the problems with AMLCDs and most display devices arise from having poor brightness, low yields, and high costs: an LCD consumes 10 times more energy than a light bulb and still cannot attain the luminosity of a CRT; yields are still in the low 30 percentage range for smaller LCDs (<12") and 10-20% for LCDs of 14" or so.

As a result of these problems, and the uncertainty of the impact of HDTV, the CRT is likely to dominate the display industries - for most TV displays, and for most desktop monitors - for at least a few years. Most industry managers are ready to bet its survival for another 20 years. And nearly all the leading competitors have backed up this projection by introducing larger tubes, flatter tubes, and 16x9 tubes[11].

Process Complexity

Picture tubes have often been described as "*the most complex and difficult consumer product ever made by mankind*", primarily because the production process is complex. Color picture tubes have only about 2 dozen components, none of them complex by themselves, except for the electron gun which is generally manufactured by suppliers or in a separate factory. However, these components do have somewhat complex and multiple interactions, as also mentioned by managers during our interviews. The manufacturing process consists of more than 200 major operation steps, not counting suppliers' manufacturing steps *(a majority of these are processing steps and not simply assembly tasks)*. It brings together more than two dozen process technologies, including chemical, electrical, optical, and physical. Identifying problems at each process step may either be too difficult or too expensive. Thus, the process is difficult to *analyze*. Second, different process steps also have multiple and difficult-to-understand interactions. It is difficult to understand the independent contribution of each step of the process to tube conformance and performance; each individual processing step may appear to be correct, but the combination of process steps could

11 Philips, Matsushita, Toshiba, and Thomson-RCA already manufacture 16x9 tubes. All the U.S., European, and Japanese competitors manufacture jumbo-sized (>31") tubes. And nearly everyone is in a race to manufacture a reasonably-priced perfectly "flat" tube.

reveal the existence of problems. Third, little rework is possible; the only form of recovery is reprocessing, which entails additional material and capacity usage. Furthermore, the manufacturing and testing equipment requires an understanding of state-of-the-art technologies, implying constant demands on engineers and designers, as in most high-tech processes. Finally, driven by intense competition on cost, conformance, and tube performance, the process is in a continuous state of change.

Examples of observations made by managers during our field interviews are:

"..... Picture tube manufacturing is like black magic".
- **European Quality Manager**

"...... we probably should have only engineers to run the plant".
- **U.S. Engineering Manager**

"..... knowledge is the basis for process control in picture tube manufacturing".
- **Japanese Production Manager**

"..... A change in one part of the process has unexpected effects on other parts of the process. There is a strong 'ripple effect'. ....".
- **European Production Manager**

"..... It takes years to understand the process".
- **Japanese Engineering Manager**

"..... By the time we optimize a particular process parameter, some other process dimensions have changed and due to the 'ripple effect', we have to start all over again. ......".
- **U.S. Engineering Manager**

Further, heavy capital investments mean that there are strong incentives to maintain high capacity utilization. Thus, line speeds are high - a typical picture tube line produces 300 to 1000 tubes per hour. Competitive industry pricing makes the challenge of maintaining high capacity utilization even more important. Margins are small, and managers must do everything to cut costs and minimize waste while maintaining quality standards. Thus, managers and workers do not have the luxury of being able to shut down the line for a few hours while resolving problems. This requires timely preventive maintenance and extensive engineering knowledge and capabilities.

Such complex processes require a higher knowledge at different stages of the process. Consequently, they benefit from multiskilling, place a premium on complex engineering knowledge, and highlight the need to share knowledge and data.

Appendix 2: Derivation of Formulas

Throughout this report we have referred to productivity and quality. Appendix 2 explains the derivation of these performance variables.

a.) Productivity - Labor Productivity

For this study, productivity refers specifically to labor productivity (hence, it does not measure capital productivity or other partial input factor productivities). The productivity rankings assigned to each plant were based on the following formula for labor productivity:

Labor Productivity = **Total Volume for 1992** / **Total Employment**

Total Employment = (T-D) x (((Weeks/Yr) - 1) x (Hours/Week) x (1 - Absenteeism Rate) + (Avg. Overtime/Yr/Employee))

where, T = Total Number of Employees
D = Direct Employees in Black Matrix, Gun or Component Manufacturing, Band Manufacturing, Yoke Manufacturing, Yoke Matching, Salvage and Regun, and Life Testing. Not all factories carry out these activities.

Formulas and Data

The sources of all these variables are taken from responses by the production managers. The individual questions are from the production manager's questionnaire Pages 2, 3, and 5 and are equivalent to the preceding variables as follows:

Total Volume for 1992 = G18. **TOTAL**
or
the sum of G18a. through G18i. Volume for 1992, whichever was larger

Total Employment = (T-D) x (((G6. Weeks/Yr) - 1) x (G7a.) x (1 -(.01 x W5a.)) + (G8.))

where, T = G5a. Total number of employees working at your factory in 1992
D = G17a. + G17b. + G17c. + G17d. + G17e.+ G17f. + G17g.

b.) Quality - Internal Quality

For this study, quality refers specifically to internal quality. The quality rankings assigned to each plant were based on the following formula for internal quality:

Internal Quality = (MATCONS Panels + MATCONS Masks + MATCONS Funnels + MATCONS Guns) / **4**

where, MATCONS indicates overall material consumption per 1000 good tubes.

MATCONS Panels, MATCONS Masks, and MATCONS Funnels are all derived from the same basic formula. As such variable "Y" will represent:

Y = Panels, Masks, or Funnels

MATCONS Y = (# of purchased Y material to make 1000 good units) + (reclaimed Y after salvage) + (1 - Y Yields - Y Rejects) x (1 - Y Yields) x 1000)

Y Yields = (3 - √(9 - (4 x (3 (# of purchased Y material to make 1000 good units + reclaimed Y after salvage)/1000))))/2

Y Rejects = (# of purchased Y material to make 1000 good units -1000)/1000 / (2 - Y Yields)

Because guns are not reclaimed, the formula is much simpler:

MATCONS Guns = # of purchased gun material to make 1000 good units

Formulas and Data

The sources of all these variables are taken from responses by the engineering managers. The individual questions are from the engineering manager's questionnaire Page 7 Question P5. and are equivalent to the preceding variables as follows:

Internal Quality = (MATCONS Panels + MATCONS Masks + MATCONS Funnels + MATCONS Guns) / 4

MATCONS Panels, MATCONS Masks, and MATCONS Funnels are all derived from the same basic formula. As such variable "Y" will represent:

Y = a., b., or c.,

where, P5a. represents panels, P5b. represent masks, and P5c. represents funnels.

MATCONS Y = (P5 Y Purchased materials used) + (P5 Y Salvaged materials used) + (1 - Y Yields - Y Rejects) x (1 - Y Yields) x 1000)

Y Yields = (3 - √(9 - (4 x (3 (P5 Y Purchased materials used + P5 Y Salvaged materials used)/1000))))/2

Y Rejects = (P5 Y Purchased materials used -1000)/1000 / (2 - Y Yields)

Again, for guns, the formula is much simpler:

MATCONS Guns = P5d. Purchased materials used

Appendix 3: Summary Statistics

On the following pages are the summary results of the questionnaires addressed to the plant directors, engineering managers, production managers, and quality managers. Reduced photocopies of the original questionnaires have been returned with this report to the plant director. You may wish to refer to these when examining the summary results.

Your Plant Response: This column provides unique, individual responses to each of the questions on the questionnaire. No other facility will see the responses to these questions, they are unique to your facility's report. For Yes/No questions a response of "0" is No and "1" is Yes. On those questions where you can respond "unknown", and your response was "unknown" it was recorded as "0". For questions that ask for a percent, the raw number is shown without the "%" (i.e., 32% is recorded as 32). Finally, if the question does not follow any of these formats, a key is provided immediately preceding the question.

α: This column highlights the questions that show a statistically significant relationship with quality. As expected most responses are blank, reflecting that most do not have a strong mathematical correlation with quality. However, if there is a numeric response in the row, it can be interpreted as follows:

- **0.05** means there is less than a 5% chance the *positive* relationship between this question and quality is due to mere chance.
- **0.01** means there is less than a 1% chance the *positive* relationship between quality and this question is due to mere chance.
- **(0.05)** means there is less than a 5% chance the *negative* relationship between this question and quality is due to mere chance.
- **(0.01)** means there is less than a 1% chance the *negative* relationship between quality and this question is due to mere chance.

For a positive relationship, as the values for an individual question increases, quality *increases*. For a negative relationship, as the values for an individual question increases, quality *decreases*.

Overall Average: This column provides the mean of all the responses to a question. For Yes/No questions, this column provides the percentage of respondents who responded "Yes".

Productivity Averages: As was discussed on pages 9 and 10, all factories were ranked from lowest to highest on labor productivity. This ranked list was then divided into three equal groups: lowest 1/3, middle 1/3, and highest 1/3. The means of each of these groups are reported, respectively under low, average, or high productivity averages.

If "ERR" is in a column, there were no responses by any members of the subdivision. For Yes/No questions, the percentage for each subdivision is the percentage of respondents who responded "Yes".

Quality Averages: As was discussed on pages 7 and 8, all factories were ranked from lowest to highest on quality. This ranked list was then divided into three equal groups: lowest 1/3, middle 1/3, and highest 1/3. The means of each of these groups are reported, respectively under low, average, or high quality averages.

If "ERR" is in a column, there were no responses by any members of the subdivision. For Yes/No questions, the percentage for each subdivision is the percentage of respondents who responded "Yes".

Exception

Question G2 under Plant Director/VP (Operations)/General Manager Seniormost Manager at Plant is an exception to this normal format. Instead of providing a significance level and various averages, it lists the number of results by respondents who did not know where to rank a plant, or ranked it in the top 6. For further explanation, please see Example 3 below.

Examples

Immediately following are some hypothetical examples of questions and possible interpretations:

<u>Hypothetical Example 1</u>
Engineering Manager
Using the data you provided and the productivity and quality formulas in Appendix 2, your plant falls in the following categories for productivity and quality. Please refer to these rankings when interpreting the summary data.

Productivity: High
Quality: Low

	Your Plant Response	α	Overall Average	Productivity Average			Quality Average		
				Low	Average	High	Low	Average	High
III. Technology and Automation									
T2. E3T2	45	0.01	58%	58%	40%	74%	41%	64%	70%

The first thing to do is look in the upper left hand corner of the page to determine which questionnaire to cross reference. From this, we determine we are analyzing Question T2. of the Engineering Manager, which asks *What percent of equipment in the FRONT END (before frit seal) can run unmanned (i.e., without operator attention)?*

Productivity: This hypothetical plant is ranked as having high labor productivity.

Quality: This hypothetical plant is ranked as having low quality.

Your Plant Response: For this hypothetical plant, the response was 45% of the equipment in the front end (before frit seal) can run unmanned.

α: There is less than a 1% chance the positive relationship between quality and the percent of front end equipment that can run unmanned is due to mere chance.

Productivity Average:

Low: 58% is the arithmetic mean of responses by plants regarded as low labor productivity performers.

Average: 40% is the arithmetic mean of responses by plants regarded as average labor productivity performers.

High: 74% is the arithmetic mean of responses by plants regarded as high labor productivity performers.

Quality Average:

Low: 41% is the arithmetic mean of responses by plants ranked in the bottom third of quality performers

Average: 64% is the arithmetic mean of responses by plants ranked in the middle third of quality performers

High: 70% is the arithmetic mean of responses by plants ranked in the top third of quality performers

Because there is less than a 1% chance the positive relationship between quality and the percentage of front end equipment that can run unmanned is due to mere chance, this is an important question to analyze. Two columns suggest this is an area of possible improvement for this hypothetical plant. First, the overall average is 58% and the plant's response was 45%. Obviously, this plant's front end automation is less than average. Second, this plant has a level of equipment automation as the plants ranked in the bottom third for quality (45% versus 41%). This is consistent with this hypothetical plant's ranking as a low quality performer. These interpretations suggest that increasing the automation of the front end would be a likely way to increase overall quality.

<u>Hypothetical Example 2</u>

Engineering Manager

Using the data you provided and the productivity and quality formulas in Appendix 2, your plant falls in the following categories for productivity and quality. Please refer to these rankings when interpreting the summary data.

Productivity: High
Quality: Low

	Your Plant Response	α	Overall Average	Productivity Average			Quality Average		
				Low	Average	High	Low	Average	High
I. Engineering Input and Problem Solving									
E4. E1E4	1		93%	100%	92%	87%	93%	100%	86%

Again, the first thing to do is look in the upper left hand corner of the page to determine which questionnaire to cross reference. From this, we determine we are analyzing Question E4. of the Engineering Manager that asks *Yes/ No Does <u>rotation</u> of engineers give them a broad process understanding?*

Productivity: This hypothetical plant is ranked as having high labor productivity.

Quality: This hypothetical plant is ranked as having low quality.

Your Plant Response: For this hypothetical plant, the response was 1, which means the plant felt rotation of engineers gives them a broad process understanding.

α: Because there is no value in this column, it does not appear as if there is a statistically significant relationship between quality and this question.

From this information, it can be inferred 93% of all respondents agreed with this hypothetical plant's response to this question. Further, 87% of the respondents in the same productivity ranking as this plant agreed rotation of engineers gives them a broad process understanding. Finally, 93% of the respondents in the same quality-ranking as this plant agreed rotation of engineers gives them a broad process understanding.

Hypothetical Example 3

Plant Director/VP (Operations)/General Manager Seniormost Manager at Plant

Using the data you provided and the productivity and quality formulas in Appendix 2, your plant falls in the following categories for productivity and quality. Please refer to these rankings when interpreting the summary data.

Productivity:	High
Quality:	Low

	Your Plant Response	α	Unknown	1	2	3	4	5	6
III. Global Comparisons									
G2. Rank of Tube Design Manufacturability (0 = Unknown)									
Sony, USA	0		19	4	4	1	1	0	2

This question is an example of the exception mentioned earlier on page 47.

Productivity: This hypothetical plant is ranked as having high labor productivity.

Quality: This hypothetical plant is ranked as having low quality.

Your Plant Response: This hypothetical plant's response to the question was "0", which means "unknown" (i.e., this plant did not know where to rank Sony, USA).

α: Because there is no value in this column, it does not appear as if there is a statistically significant relationship between quality and this question.

Unknown: A total of 19 respondents did not know where to rank Sony, USA.
1: Four plants thought it should be ranked first for design manufacturability.
2: Four plants thought it should be ranked second for design manufacturability.
3: One plant thought it should be ranked third for design manufacturability.
4: One plant thought it should be ranked fourth for design manufacturability.
5: No plants thought it should be ranked fifth for design manufacturability.
6: Two plants thought it should be ranked sixth for design manufacturability.

Seniormost Manager at: A Picture Tube Company - Plant Number 1

Using the data you provided and the productivity and quality formulas in Appendix 2, your plant falls in the following categories for productivity and quality.
Please refer to these categories when interpreting the summary data.

Productivity: High
Quality: Average

I. Quality Practices

Q1. KEY DETERMINANTS

	Your Plant Response
P1Q11A	Production Technology
P1Q11B	Equipement Capability
P1Q11C	Workmanship

Summary Results of KEY DETERMINANTS:	Number of Responses
Product Design	14
Process Control	8
Product and Process Technology	6
Equipment Reliability	6
Factory Automation	5
Training	5
Equipment Maintenance	4
Equipment Capability	3
Skilled Manpower	3
Top Management/Mgt Commitment	3
Standardization	3
Customer Orientation	3
Human Resources	3

MAJOR BARRIERS

	Your Plant Response
P1Q12A	Parts quality
P1Q12B	Preventive maintenance
P1Q12C	Design capability

Summary Results of MAJOR BARRIERS:	Number of Responses
Insufficient Skills	14
Unreliable Equipment/Maintenance Performance	14
Parts Quality	7
Lack of Money	6
Too Many Models	5
Contamination Prevention/Circumstance Control	5
Quantitative Orientation	4
Low Mechanization Levels	4
Poor Design	4
Lack of Top Management Commitment	3

		Your Plant Response	α	Overall Average	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
Q2.	**Relative Benefits During Last 2 years**									
	SPC charts			3.38	3.69	3.00	3.53	3.60	3.38	3.08
	Factorial experiments			2.37	2.08	2.53	2.46	2.50	2.13	2.64
	Cross-functional teams			3.67	3.54	3.60	3.67	3.60	3.13	4.31
	Customer teams			3.32	3.38	3.07	3.38	3.07	3.25	3.55
	Work teams, quality circles, etc.			3.33	3.31	3.60	3.07	3.40	3.19	3.31
	Job rotation			2.85	2.62	2.87	3.00	2.67	2.94	3.15
	Broad worker responsibilities			3.04	3.15	2.87	3.20	2.67	3.07	3.46
	Preventive maintenance			3.72	4.08	3.27	3.93	3.33	3.81	4.15
	Equip. & Mat. Handling Automation			3.48	3.23	3.33	3.87	3.33	3.75	3.54
	Factory information systems			3.63	3.54	3.40	4.00	3.40	3.50	4.00
	Bar coding systems			2.13	1.75	3.00	1.60	3.29	2.00	1.15
	Degree of Emphasis During Next 2 years									
	SPC charts			4.13	4.46	3.93	4.13	4.27	3.94	4.15
	Factorial experiments			3.56	3.90	3.53	3.38	3.64	3.53	3.45
	Cross-functional teams			4.26	4.23	4.13	4.33	4.13	4.19	4.38
	Customer teams			4.16	4.38	3.93	4.15	4.00	4.25	4.18
	Work teams, quality circles, etc.			4.04	4.38	4.07	3.87	4.40	3.81	3.85
	Job rotation			3.38	3.23	3.07	3.67	2.93	3.31	4.08
	Broad worker responsibilities			3.96	3.92	3.87	4.07	3.67	3.94	4.31
	Preventive maintenance			4.57	4.77	4.27	4.67	4.47	4.50	4.77
	Equip. & Mat. Handling Automation			3.96	3.92	3.80	4.00	3.93	3.75	4.23
	Factory information systems			4.43	4.46	4.33	4.47	4.47	4.38	4.38
	Bar coding systems			3.71	3.75	4.00	3.40	4.29	3.69	3.15
II. Strategy										
S1.	P2S1			4.52	4.54	4.50	4.64	4.36	4.73	4.54
S2.	Tube Performance (design)			2.42	3.18	2.21	2.20	3.23	2.38	1.75
	Conformance Quality at delivery			1.93	2.23	1.67	1.87	1.93	1.56	2.46
	Factory Yields			2.78	2.77	2.67	2.80	2.60	3.00	2.62
	On-time delivery			3.17	3.92	2.93	2.53	3.20	3.25	3.00
	Flexibility, even in small batches			3.96	3.92	4.20	3.87	3.93	3.63	4.23
S3.	P2S3			112596	36	219105	133353	36405	198930	94645
S4.	P2S4A (0 =No and 1=Yes)			23%	9%	25%	21%	23%	14%	33%
	P2S4B (0 = No and 1 = Yes)			18%	18%	25%	7%	23%	21%	0%
	P2S4C (0 = No and 1 = Yes)			85%	91%	75%	87%	85%	73%	100%
S5.	P2S5A			21%	20%	15%	28%	12%	22%	29%
	P2S5B			12%	14%	11%	11%	7%	13%	14%
	P2S5C			10%	12%	7%	10%	6%	10%	14%
	P2S5D			23%	28%	19%	23%	22%	23%	25%
S6.	P2S6A			63%	64%	60%	64%	59%	63%	67%
	P2S6B			12%	8%	15%	11%	14%	12%	9%
	P2S6C			7%	6%	9%	5%	9%	5%	6%
	P2S6D			18%	21%	15%	19%	18%	20%	17%

Seniormost Manager at: A Picture Tube Company - Plant Number 1

III. Global Comparisons

		Your Plant Response	α	Overall Average	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
G1.	**Customer Rejects**									
	W. Europe			3158	4318	3143	2467	4143	1629	3692
	Japan			4530	5583	4577	3960	5107	2820	6042
	Korea/Taiwan			3438	4208	3150	3029	3154	1889	5292
	Rest of Asia			3279	4875	2627	2587	3583	1597	5042
	N. America			2934	3200	3646	2173	3875	1553	3542
	S. America			2699	3111	3045	2131	3200	1329	3542
	Yields									
	W. Europe			91%	87%	92%	93%	88%	95%	89%
	Japan			89%	84%	91%	91%	86%	92%	88%
	Korea/Taiwan			91%	86%	93%	93%	88%	93%	90%
	Rest of Asia			91%	87%	93%	94%	88%	94%	91%
	N. America			91%	88%	93%	93%	90%	93%	91%
	S. America			93%	90%	93%	94%	90%	95%	92%

		Unknown	1	2	3	4	5	6
G2.	**Rank of Tube Design Manufacturability (0 = Unknown)**							
	Chungwa, Taiwan	17	0	1	0	2	0	1
	Goldstar, Korea	18	1	0	1	1	0	1
	Hitachi	5	9	6	6	6	2	3
	JCT, India	32	0	1	0	1	0	0
	Matsushita/Panasonic	9	8	6	6	4	2	2
	Mitsubishi	12	0	1	2	3	6	5
	Nokia, Germany	27	0	1	1	0	2	0
	Orion, Korea	20	0	1	0	1	0	1
	Philips, Netherlands	12	2	3	9	3	6	3
	Philips, U.S.A.	22	0	2	3	1	2	2
	Thomson/RCA, U.S.A.	14	3	6	5	2	2	5
	Samsung, Korea	19	0	0	0	1	1	0
	Samtel, India	31	0	0	1	1	0	0
	Sony, Japan	9	12	6	2	3	0	0
	Sony, U.S.A.	19	4	4	1	1	0	2
	Thomson, France	18	0	2	2	3	3	5
	Toshiba	5	4	3	10	7	6	1
	Zenith	15	2	3	0	2	2	0
G2.	**Rank of Manufacturing Process Capability (0 = Unknown)**							
	Chungwa, Taiwan	20	0	1	0	0	2	0
	Goldstar, Korea	15	0	2	1	0	1	5
	Hitachi	6	12	5	10	4	1	0
	JCT, India	32	0	1	0	1	0	0
	Matsushita/Panasonic	10	9	7	5	4	1	2
	Mitsubishi	13	0	2	5	4	3	5
	Nokia, Germany	29	1	0	2	0	2	0
	Orion, Korea	26	0	0	0	1	0	1
	Philips, Netherlands	13	1	5	2	1	9	6
	Philips, U.S.A.	23	0	1	2	0	0	2
	Thomson/RCA, U.S.A.	19	0	3	4	2	3	2
	Samsung, Korea	22	0	0	1	1	2	1
	Samtel, India	34	0	0	0	2	0	0
	Sony, Japan	13	6	3	3	7	5	2
	Sony, U.S.A.	23	4	5	0	1	0	0
	Thomson, France	19	0	1	3	4	2	2
	Toshiba	9	6	7	7	3	4	0
	Zenith	17	0	0	0	1	3	0

IV. Performance

			Overall Average	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
P1.		1989	83%	69%	87%	87%	80%	88%	74%
		1990	84%	72%	88%	91%	79%	92%	75%
		1991	88%	82%	89%	92%	82%	93%	88%
		1992	89%	84%	90%	92%	85%	93%	89%
P2.		1989	72%	56%	70%	82%	67%	78%	65%
		1990	72%	56%	70%	86%	63%	83%	66%
		1991	77%	70%	73%	87%	68%	84%	79%
		1992	80%	76%	75%	87%	72%	84%	83%
P3.		1989	5832	4719	6551	5873	6216	5109	6787
		1990	5563	7956	5797	3971	7843	4434	4617
		1991	6495	13539	5074	3206	10774	3900	4207
		1992	4039	5992	4008	2562	5948	2979	3224
P4.	P4P4A		3.67	3.69	3.67	3.73	3.93	3.63	3.46
	P4P4B		3.09	2.77	3.33	3.13	3.13	3.00	3.15
P5.	P4P5A		3.51	3.64	3.40	3.57	3.43	3.57	3.92
	P4P5B		3.24	3.30	3.27	3.21	3.29	3.14	3.58
	P4P5C		3.03	3.00	3.07	2.92	2.79	3.00	3.60
	P4P5D		3.15	3.25	3.67	2.71	3.77	3.00	3.00
	P4P5E		3.51	3.60	3.33	3.62	3.50	3.75	3.62
P6.	P4P6		85%	83%	84%	88%	88%	83%	88%
P7.	P4P7		31%	24%	12%	58%	14%	49%	49%
P8.	P4P8		7.00%	4.17%	11.66%	2.38%	11.32%	1.15%	3.00%
P9.	P4P9		3.96%	1.77%	7.08%	1.41%	9.86%	0.98%	-0.36%

Production Manger at: A Picture Tube Company - Plant Number 1

Using the data you provided and the productivity and quality formulas in Appendix 2, your plant falls in the following categories for product quality. Please refer to these categories when interpreting the summary data.

Productivity: High
Quality: Average

		Your Plant Response	α	Overall Averages	Productivity Average			Quality Average		
					Low	Average	High	Low	Average	High
I. General										
G1.	P1G1			1975.28	1977.267	1967.933	1979.733	1972.125	1977.533	1976.8
G2.	P1G2			1978.78	1982	1973	1980.667	1976.733	1979.467	1980.733
G3.	P1G3A			2311170	1277233	3071500	2522933	2019688	2373100	2658267
	P1G3B			2158542	1608836	2708700	2192453	1702221	2388433	2545294
G4.	P1G4			266	247	281	268	266	260	273
G5.	**TOTAL**			1378	1547	1728	890	1402	1402	1379
	DIRECT PRODUCTION			861	792	1131	666	937	840	854
	Before the frit-oven			332	300	415	283	326	339	351
	INDIRECT EMPLOYEES									
	Quality Control & Inspection			71.87	72.20	85.33	60.20	43.50	116.73	61.73
	Production supervision			49.09	44.40	71.80	33.07	50.38	55.33	44.53
	All engineering			80.70	62.27	115.13	63.00	83.88	78.00	84.73
	Management			27.91	19.40	43.87	22.13	18.31	46.27	21.33
	Others			76.09	85.67	95.40	51.53	60.44	91.20	79.93
	P1G5B1 (0 = No and 1 = Yes)			51%	27%	53%	73%	44%	53%	53%
G6.	WEEKS/YEAR			48.23	48.97	48.90	46.63	48.57	47.97	48.03
	DAYS/WEEK			12.08	5.85	24.76	6.05	5.89	24.90	5.94
	HOURS/DAY			22.32	20.88	22.40	23.48	22.13	22.95	22.88
G7.	P1G7A			44.15	47.83	40.25	44.11	41.57	44.83	46.46
	P1G7B			252	256	249	248	250	245	264
G8.	P1G8			128	148	167	83	118	110	153
G9.	P1G9			23%	13%	17%	35%	7%	16%	47%
G10.	P1G10			2.78	2.57	2.93	3.00	2.72	2.53	3.00
G11.	P1G11			4.17	1.73	4.47	6.40	3.13	5.27	4.36
G12.	P1G12			12.08	4.10	8.79	24.27	4.00	20.80	12.10
G13.	P1G13			7.64	3.07	9.43	11.14	8.27	6.00	8.80
G14.	P1G14A			74779976	60405456	81572515	75480108	84369733	59190596	83297514
	P1G14B			156175197	101612523	229770559	126808333	241312500	103900508	145567514
G15.	P1G15			17668351	18178679	29133252	7166727	31294644	7299341	15225388
G16.	P1G16			22.42	18.64	18.60	29.40	18.27	18.86	31.13
G17.	P1G17A			60.67	40.50	97.27	46.27	70.75	64.64	50.27
	P1G17B			67.20	85.57	73.33	45.53	69.50	51.86	54.33
	P1G17C			28.35	6.14	44.73	28.07	40.25	9.07	35.53
	P1G17D			21.30	18.79	25.20	22.60	22.63	19.64	22.87
	P1G17E			68.11	33.64	101.07	46.40	79.94	49.64	77.00
	P1G17F			33.46	24.93	45.80	17.53	47.88	16.07	36.47
	P1G17G			8.72	16.93	7.20	2.20	17.06	2.21	6.40
G18.	**TV Tube Size**									
	P1G181A Smallest size			40.29	43.64	43.33	37.57	46.19	41.67	34.43
	P1G181B			45.96	54.36	47.77	42.27	51.77	46.54	41.65
	P1G181C			51.89	54.00	56.08	51.69	55.18	51.17	52.27
	P1G181D			50.26	38.67	61.45	43.50	62.57	45.89	47.50
	P1G181E			50.74	30.50	59.67	49.30	61.83	45.71	48.50
	P1G181F			52.08	38.00	62.20	51.20	63.50	49.57	50.33
	P1G181G			52.39	43.00	69.25	43.50	66.00	52.50	45.25
	P1G181H			58.75	63.00	73.67	53.67	68.00	57.80	56.50
	P1G181I Largest size			73.25	68.00	87.00	65.83	89.00	75.00	62.75
	TV or computer monitor (1 = TV ,2 = Monitor, and 3 = HDTV)									
	P1G182A Smallest size			1.20	1.00	1.13	1.47	1.06	1.29	1.27
	P1G182B			1.21	1.00	1.23	1.23	1.15	1.17	1.31
	P1G182C			1.14	1.00	1.00	1.31	1.00	1.25	1.18
	P1G182D			1.26	1.00	1.18	1.38	1.14	1.33	1.33
	P1G182E			1.35	1.50	1.22	1.40	1.17	1.57	1.33
	P1G182F			1.33	2.00	1.20	1.20	1.00	1.43	1.33
	P1G182G			1.33	2.00	1.00	1.33	1.00	1.33	1.50
	P1G182H			1.38	1.00	1.33	1.33	1.00	1.60	1.00
	P1G182I Largest size			1.17	1.00	1.00	1.33	1.00	1.33	1.00
	Volume for 1992									
	P1G183A Smallest size			709404	471715	824256	848796	600095	630779	962187
	P1G183B			546304	425956	523689	513673	351183	323452	1021981
	P1G183C			535676	144234	751435	533554	481336	697287	460174
	P1G183D			367393	4701	411844	396945	440097	354938	357232
	P1G183E			232085	20669	170067	386000	201667	348433	80000
	P1G183F			154517	ERR	90034	219000	212000	25195	485000
	P1G183G			391571	ERR	320000	487000	361000	392000	420000
	P1G183H			352300	ERR	175333	529267	494000	104950	1200000
	P1G183I Largest size			204060	ERR	28000	321433	4000	138767	600000
	Invar mask? (0 = No, 1 = Yes, and 2 = Sony Aperture Grill)									
	P1G184A Smallest size			0.31	0.08	0.33	0.53	0.06	0.67	0.21
	P1G184B			0.47	0.22	0.54	0.69	0.23	0.92	0.25
	P1G184C			0.55	0.20	0.62	0.69	0.27	0.92	0.40
	P1G184D			0.77	0.50	0.82	0.88	0.57	1.00	0.67
	P1G184E			0.50	0.00	0.67	0.40	0.33	0.86	0.00
	P1G184F			0.75	1.00	0.80	0.80	0.50	0.86	0.67
	P1G184G			0.78	1.00	0.75	1.00	0.00	1.00	0.50
	P1G184H			0.88	1.00	1.00	1.00	1.00	1.00	0.50
	P1G184I Largest size			1.17	1.00	1.50	1.00	1.00	1.67	0.50

Production Manger at: A Picture Tube Company - Plant Number 1

		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
G18.	**Screen Radius?**									
	P1G185A Smallest size			1.36	1.50	1.13	1.50	1.09	1.52	1.50
	P1G185B			1.38	1.39	1.41	1.33	1.23	1.53	1.38
	P1G185C			1.40	1.40	1.35	1.46	1.25	1.38	1.56
	P1G185D			1.77	4.00	1.78	1.48	1.40	2.19	1.46
	P1G185E			1.80	ERR	2.29	1.12	1.63	2.13	1.15
	P1G185F			1.55	ERR	1.50	1.60	1.50	1.42	2.00
	P1G185G			1.79	ERR	2.38	1.00	1.50	2.00	1.00
	P1G185H			1.70	ERR	1.57	1.83	2.00	1.55	2.00
	P1G185I Largest size			1.76	ERR	1.75	1.77	1.50	1.77	2.00
	TOTAL			2019117	874352	2673828	2447643	1704185	2061227	2436392
G19.	P1G19A			589.49	15.63	1672.50	5.00	3.93	1928.96	6.25
	P1G19B			106.57	3.77	301.73	0.67	2.67	348.70	0.67
	P1G19C			7.59	23.25	1.40	1.25	1.67	2.77	1.82
G20.	P1G20			26.85	22.30	31.88	23.39	17.94	40.00	24.57
II. Strategic Quality										
S1.	P2S1A			4.23	4.27	3.87	4.53	4.19	3.93	4.53
	P2S1B			4.68	4.73	4.53	4.80	4.56	4.67	4.80
	P2S1C			4.34	4.20	4.20	4.53	4.25	4.00	4.73
	P2S1D			3.96	3.73	3.73	4.33	3.75	3.93	4.20
	P2S1E			4.45	4.47	4.07	4.73	4.06	4.60	4.67
S2.	P2S2A			4.36	4.20	4.25	4.60	4.23	4.40	4.40
	P2S2B			4.23	4.07	4.20	4.40	3.88	4.27	4.53
	P2S2C			4.66	4.47	4.60	4.93	4.44	4.80	4.73
	P2S2D			4.41	4.20	4.37	4.67	4.47	4.40	4.33
S3.	P2S3A			2.67	2.20	2.79	3.00	2.73	2.73	2.67
	P2S3B			2.99	2.80	3.23	3.20	3.09	2.80	3.20
	P2S3C			3.17	3.13	3.20	3.13	3.19	3.00	3.33
	P2S3D			4.13	4.07	3.93	4.40	4.06	4.13	4.27
S4.	P2S4			3.87	3.77	3.80	4.00	3.75	3.87	4.00
S5.	P2S5A (0 = No and 1 = Yes)			83%	73%	93%	80%	88%	87%	73%
	P2S5B			48%	65%	44%	37%	47%	48%	46%
	P2S5C			38%	51%	38%	28%	33%	38%	40%
	P2S5D			9.63	18.46	3.09	7.43	2.45	6.54	11.97
	P2S5E			5.25	7.95	2.32	5.43	2.15	4.28	8.45
	P2S5F			2.60	4.07	1.29	2.68	0.64	2.31	4.10
	P2S5G			39%	40%	35%	39%	38%	36%	38%
	P2S5H (0 = No and 1 = Yes)			73%	73%	77%	79%	64%	69%	85%
S6.	P2S6A			3.72	3.71	3.53	4.07	3.56	3.56	4.07
	P2S6B			2.89	3.00	2.87	2.73	2.75	2.69	3.21
S7.	P2S7A			4.27	4.33	4.20	4.33	4.25	4.25	4.33
	P2S7B			3.46	3.73	3.33	3.33	3.31	3.25	3.80
	P2S7C			3.78	3.67	3.70	4.00	3.91	3.19	4.27
	P2S7D			3.79	3.67	3.60	4.13	3.50	3.81	4.07
	P2S7E			2.38	2.13	2.47	2.47	2.63	2.56	1.93
	P2S7F			3.53	3.13	3.70	3.73	3.66	3.63	3.40
	P2S7G			2.53	2.47	2.60	2.50	2.63	2.31	2.57
	P2S7H			3.61	3.40	3.54	3.87	3.30	3.81	3.67
S8.	P2S8A			23%	24%	24%	23%	22%	21%	27%
	P2S8B			23%	25%	24%	18%	26%	25%	17%
	P2S8C			16%	19%	13%	15%	12%	16%	18%
	P2S8D			15%	17%	12%	14%	12%	15%	17%
	P2S8E			22%	16%	21%	29%	25%	23%	18%
III. Selection & Training, and Work Organization										
W1.	P3W1			59%	73%	51%	54%	60%	59%	63%
W2.	P3W2			50.90	55.40	52.13	48.33	43.38	59.94	50.00
W3.	P3W3A			121.13	345.96	20.38	25.40	20.15	25.13	310.20
	P3W3B			25.43	47.36	10.12	21.07	12.35	19.50	30.13
W4.	P3W4			5.62	4.53	6.87	5.80	7.19	4.27	5.47
W5.	P3W5A			6.46%	8.44%	6.29%	4.54%	8.06%	3.56%	7.57%
	P3W5B			5.55%	6.24%	6.42%	4.16%	6.66%	4.38%	5.54%
W6.	P3W6			3.25	3.27	3.27	3.20	3.00	3.56	3.20

Production Manger at: **A Picture Tube Company - Plant Number 1**

		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
W7.	P3W7A			2.56	2.67	2.67	2.40	2.63	3.06	2.00
	P3W7B			3.52	3.67	3.80	3.13	4.06	3.31	3.13
	P3W7C			3.85	3.93	3.87	3.93	3.94	3.75	3.80
	P3W7D			3.46	3.00	3.20	4.07	3.00	4.00	3.47
	P3W7E			3.55	3.20	3.57	3.93	3.34	4.00	3.47
W8.	P3W8A			4.33	4.47	4.07	4.47	4.25	4.25	4.47
	P3W8B			3.45	3.07	3.50	3.67	3.34	3.56	3.40
	P3W8C			3.20	2.67	3.43	3.60	3.09	3.13	3.27
W9.	P3W9A			2.38	2.40	1.93	2.73	1.94	2.56	2.73
	P3W9B			3.79	3.60	4.07	3.93	3.81	3.81	3.67
	P3W9C			3.52	3.40	3.73	3.47	3.75	3.31	3.53
W10.	P3W10A			2.31	2.33	2.40	2.20	2.25	2.38	2.20
	P3W10B			2.40	2.40	2.47	2.40	2.38	2.63	2.20
	P3W10C			3.33	3.33	3.47	3.33	3.13	3.31	3.67
	P3W10D			2.58	2.07	2.93	2.67	2.38	2.94	2.47
W11.	P3W11 (0 = No and 1 = Yes)			94%	86%	100%	93%	81%	88%	113%
W12.	P3W12			25.13	52.27	7.32	17.25	11.63	10.25	18.61
W13.	P3W13			64%	62%	59%	71%	59%	75%	56%
W14.	P3W14			47%	40%	51%	53%	46%	49%	46%
W15.	P3W15			4.52	3.67	5.03	4.93	3.13	5.47	5.23
W16.	P3W16			4.11	4.63	3.90	3.87	3.72	4.73	4.10
W17.	P3W17A			48%	52%	37%	57%	38%	61%	48%
	P3W17B			38%	32%	30%	49%	24%	46%	47%
	P3W17C			37%	41%	38%	36%	38%	42%	35%
	P3W17D			34%	35%	33%	35%	27%	41%	37%
	P3W17E			41%	45%	34%	49%	35%	51%	39%
W18.	P3W18A			2.83	2.27	2.87	3.40	2.44	3.63	2.53
	P3W18B			3.25	3.00	3.00	3.80	3.06	4.06	2.73
	P3W18C			3.15	2.93	3.07	3.53	2.66	3.78	2.93
	P3W18D			3.36	3.27	3.50	3.47	3.25	3.84	2.93
	P3W18E			3.69	3.13	4.00	3.93	3.69	4.06	3.27
W19.	P3W19A			4.35	4.27	4.47	4.47	4.50	4.25	4.27
	P3W19B			3.53	3.13	3.77	3.73	3.47	3.44	3.60
	P3W19C			2.93	2.47	2.90	3.40	2.50	3.78	2.60
W20.	P3W20A			51%	31%	62%	61%	50%	43%	64%
	P3W20B			5.65	4.57	6.03	6.60	4.68	4.32	8.17
	P3W20C			19.57	18.11	16.57	22.21	15.80	15.36	27.27
	P3W20D			3.75	2.90	4.97	3.42	4.06	3.69	3.60
	P3W20E			5.38	5.07	6.47	4.67	4.06	8.27	4.20
W21.	P3W21A			3.73	3.50	4.10	3.67	3.83	3.27	4.07
	P3W21B			3.50	3.50	3.67	3.53	3.53	3.20	3.73
	P3W21C			2.77	2.64	2.70	3.00	2.57	2.93	2.87
	P3W21D			2.87	2.93	2.80	2.87	3.00	2.80	2.93
	P3W21E			3.39	3.50	3.53	3.20	3.47	3.20	3.47
	P3W21F			3.68	3.43	3.97	3.67	3.87	3.37	3.80
	P3W21G			2.59	2.71	2.47	2.40	2.60	2.47	2.67
	P3W21H			2.95	2.93	2.97	2.73	3.00	2.77	3.00
	P3W21I			1.76	2.00	1.47	1.87	1.47	1.80	2.00
	P3W21J			1.42	1.57	1.23	1.47	1.33	1.37	1.60
IV. Technology and Automation										
T1.	P4T1A			3.04	3.00	2.70	3.75	2.59	3.27	3.37
	P4T1B			3.49	3.40	3.37	3.96	2.91	4.00	3.70
	P4T1C			3.04	3.07	2.77	3.46	2.84	3.40	2.97
	P4T1D			3.06	2.93	2.90	3.39	2.91	3.27	3.10
T2.	P4T2A			4.01	3.73	3.97	4.47	3.66	4.13	4.20
	P4T2B			3.65	3.40	3.87	3.87	3.75	3.81	3.27
	P4T2C			3.68	3.67	3.57	3.80	3.34	4.00	3.60
	P4T2D			3.26	3.33	2.83	3.53	2.91	3.31	3.53
	P4T2E			3.39	3.53	3.03	3.47	3.22	3.31	3.53
	P4T2F			3.38	3.20	3.40	3.40	3.31	3.50	3.33
T3.	P4T3A			4.03	3.93	4.03	4.20	4.09	4.00	4.00
	P4T3B			4.03	4.07	4.03	4.13	3.97	4.00	4.07
	P4T3C			3.68	3.80	3.47	3.86	3.63	3.81	3.57
	P4T3D			4.14	4.13	4.10	4.27	4.16	4.13	4.07
T4.	P4T4A			3.97	3.38	3.96	4.53	3.81	4.13	3.87
	P4T4B			3.28	3.23	3.33	3.27	3.29	3.38	3.13
	P4T4C			3.47	2.69	3.83	3.73	3.54	3.75	3.20
	P4T4D			3.03	2.85	3.03	3.20	3.04	3.19	2.93
	P4T4E			3.89	3.69	4.07	3.87	4.07	3.81	3.79
	P4T4F			2.20	2.15	1.93	2.27	2.29	2.13	2.27
	P4T4G			2.21	2.08	2.27	2.27	2.21	2.50	2.00
	P4T4H			2.61	2.54	2.57	2.67	2.46	2.73	2.73
	P4T4I			2.54	2.23	2.40	2.87	2.14	2.94	2.40
	P4T4J			2.24	1.92	2.20	2.60	2.14	2.80	1.87
	P4T4K			4.23	3.85	4.37	4.53	4.18	4.38	4.13
T5.	P4T5A			3.54	3.85	3.47	3.40	3.64	3.38	3.60
	P4T5B			3.61	3.85	3.53	3.47	3.57	3.63	3.60
	P4T5C			2.61	2.54	2.67	2.40	2.86	2.88	2.13

Production Manger at: A Picture Tube Company - Plant Number 1

		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
T6.	P4T6			17%	16%	17%	18%	21%	13%	18%
T7.	**Number of breakdowns**									
	Screening/flowcoat			89.81	52.19	189.27	33.00	46.16	175.64	56.27
	Frit-lehr			23.95	8.68	63.47	1.73	45.38	24.14	2.43
	Exhaust machine			14.52	3.82	35.60	4.88	15.31	24.45	5.10
	Conveyors			33.24	8.71	76.00	17.67	10.63	89.86	6.73
	Number of MAJOR breakdowns									
	Screening/flowcoat			3.98	2.69	4.33	4.21	3.38	4.29	4.33
	Frit-lehr			0.47	0.39	0.63	0.39	0.47	0.77	0.17
	Exhaust machine			0.65	0.29	1.13	0.33	1.00	0.78	0.20
	Conveyors			2.84	1.25	2.67	4.96	2.25	5.65	1.23
V. Performance										
P1.	P5P1			8371	6752	10537	8147	7234	8736	9643
P2.	P5P2			212	120	335	192	135	390	105
P3.	P5P3			361	295	578	219	415	410	284
P4.	P5P4A			4.78	1.34	4.71	8.11	0.48	1.82	13.12
	P5P4B			51%	48%	52%	49%	52%	53%	54%
P5.	**Tube Size**									
	P5P51A Smallest size			39.43	43.64	43.73	34.47	46.50	38.93	34.47
	P5P51B			47.21	55.55	48.00	41.85	55.10	45.31	44.75
	P5P51C			52.06	54.17	56.08	49.85	59.63	49.00	53.00
	P5P51D			51.41	32.67	61.64	48.14	62.60	45.57	51.29
	P5P51E			52.67	30.50	61.11	53.00	64.50	50.00	41.50
	P5P51F			55.38	38.00	58.33	69.00	59.00	59.20	44.00
	P5P51G			58.80	43.00	76.50	49.00	ERR	74.33	35.50
	P5P51H Largest size			62.00	68.00	85.00	73.00	22.00	79.00	68.00
	Invar mask? (0 = No, 1 = Yes, and 2 = Sony Aperture Grill)									
	P5P5SA Smallest size			0.34	0.08	0.33	0.53	0.14	0.71	0.21
	P5P5SB			0.49	0.22	0.46	0.69	0.10	1.00	0.27
	P5P5SC			0.58	0.20	0.69	0.62	0.38	1.00	0.30
	P5P5SD			0.65	0.00	0.64	0.86	0.20	1.33	0.43
	P5P5SE			0.77	0.00	0.78	1.00	0.75	1.20	0.00
	P5P5SF			1.00	1.00	1.00	1.00	0.00	1.50	0.50
	P5P5SG			0.80	1.00	1.00	0.50	ERR	1.00	0.50
	P5P5SH Largest size			1.50	1.00	2.00	1.00	2.00	1.50	1.00
	TV or computer monitor (1 = TV ,2 = Monitor, and 3 = HDTV)									
	P5P52A Smallest size			1.18	1.00	1.20	1.27	1.08	1.21	1.27
	P5P52B			1.16	1.00	1.23	1.21	1.10	1.25	1.08
	P5P52C			1.03	1.00	1.00	1.08	1.00	1.08	1.00
	P5P52D			1.27	1.00	1.36	1.29	1.20	1.57	1.14
	P5P52E			1.27	1.50	1.22	1.33	1.25	1.33	1.50
	P5P52F			1.50	2.00	1.33	1.67	1.00	1.60	1.50
	P5P52G			1.80	2.00	1.50	2.00	ERR	2.00	1.50
	P5P52H Largest size			1.00	1.00	1.00	1.00	ERR	1.00	1.00
	Factory Yield									
	P5P53A Smallest size			88%	82%	89%	92%	81%	92%	90%
	P5P53B			87%	83%	86%	91%	79%	90%	91%
	P5P53C			89%	89%	87%	89%	85%	88%	91%
	P5P53D			90%	94%	89%	89%	87%	88%	93%
	P5P53E			89%	89%	91%	80%	90%	86%	94%
	P5P53F			88%	85%	82%	88%	98%	ERR	ERR
	P5P53G			79%	90%	72%	83%	84%	71%	83%
	P5P53H Largest size			85%	87%	84%	83%	92%	90%	88%
	Customer rejects?									
	P5P54A Smallest size			4302	6264	3872	2453	6262	2748	3982
	P5P54B			3808	5327	3878	2554	5511	2941	3201
	P5P54C			3210	3308	3847	2577	3750	3221	2641
	P5P54D			4232	10067	4249	1707	4125	3783	1736
	P5P54E			4729	6850	4636	3533	3900	3825	2700
	P5P54F			2425	3150	2350	2233	2500	2133	2825
	P5P54G			3480	4200	4800	1800	ERR	3567	3350
	P5P54H Largest size			3700	1000	2300	3000	8500	2650	1000
P6.	Tube size			49.19	50.36	52.00	50.13	52.14	50.67	45.93
	Invar or not (0 = No and 1 = Yes)			37%	0%	36%	73%	0%	87%	27%
	Panel radius			1.42	1.25	1.62	1.40	1.27	1.57	1.42
P7.	P5P7A			1986.30	1987.57	1984.93	1986.13	1987.43	1986.60	1986.07
	P5P7B			1983.87	1984.54	1984.00	1982.73	1986.92	1983.07	1983.20
	P5P7C			1989.38	1990.56	1989.21	1988.71	1989.70	1990.14	1988.57
P8.	P5P8			21.68	17.52	18.47	25.93	22.32	26.43	18.10
P9.	P5P9			14851	21907	14780	9782	16779	14214	13502

Production Manger at: A Picture Tube Company - Plant Number 1

		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
P10.	P5P10A			927	937	915	950	904	963	919
	P5P10B			51.85	55.23	54.17	41.14	71.31	22.64	59.87
	P5P10C			932	912	936	948	915	947	934
	P5P10D			59.09	72.69	57.07	49.07	77.29	44.62	53.80
	P5P10E			952	965	952	971	926	973	956
	P5P10F			28.28	21.38	42.93	19.93	36.79	18.50	29.13
	P5P10G			982	974	988	982	988	984	972
	P5P10H			983	975	989	982	992	984	970
	P5P10I			27.24	79.62	4.65	4.60	4.50	2.92	76.36
	P5O10J			979	971	987	974	989	976	968
	P5P10K			6.83	6.12	3.77	10.73	4.65	5.46	11.43
	P5P10L			4.84	7.54	3.46	4.27	3.54	4.54	7.14
	P5P10M			899	853	959	885	946	804	935
	P5P10N			57.15	115.15	34.23	30.23	44.54	18.04	106.21
	P5P10O			933	910	924	958	906	963	933
	P5P10P			30.12	49.23	28.92	15.27	36.79	13.23	32.36
	P5P10Q			26.03	19.08	37.85	17.36	41.36	15.00	23.15
	P5P10R			951	944	941	975	942	963	947
	P5P10S			18.24	14.71	18.83	12.60	19.55	10.10	19.60
	P5P10T			17.75	12.91	38.03	7.40	37.78	7.30	11.20
P11.	P5P11.1			10.63	8.45	13.54	10.69	9.48	12.19	8.82
	P5P11.2			9.30	8.55	8.23	10.74	7.52	10.50	9.04
	P5P11.3			2.90	3.52	2.92	2.43	2.20	2.79	2.79
	P5P11.4			2.60	2.81	1.77	3.33	2.58	3.11	2.46
	P5P11.5			21.45	18.42	25.62	20.87	20.73	21.07	23.14
	P5P11.6			10.78	10.02	12.46	8.25	13.52	10.04	9.07
	P5P11.7			17.03	18.72	16.77	14.61	20.66	13.92	17.35
	P5P11.8			8.67	6.87	10.12	9.28	5.69	10.06	7.07
	P5P11.9			11.94	12.51	8.58	15.25	8.95	16.11	12.39
VI. Product and Process Design										
PD1.	P6PD1A			4.29	4.14	4.32	4.47	3.88	4.44	4.33
	P6PD1B			3.73	3.64	3.82	3.73	3.29	3.56	4.00
	P6PD1C			3.49	3.46	3.36	3.80	3.08	3.56	3.64
	P6PD1D			4.15	4.07	4.21	4.13	4.00	4.19	4.07
	P6PD1E			4.07	4.15	3.71	4.47	3.50	4.06	4.43
	P6PD1F			3.93	3.71	4.00	4.27	3.50	3.94	4.07
	P6PD1G			2.88	2.79	3.32	2.60	3.04	3.13	2.53
PD2.	P6PD2A			4.18	3.92	4.21	4.47	3.75	4.25	4.36
	P6PD2B			4.30	4.38	4.18	4.40	4.13	4.25	4.36
	P6PD2C			4.09	4.08	3.93	4.27	3.67	4.38	4.07
	P6PD2D			4.31	3.92	4.57	4.40	4.08	4.31	4.36
	P6PD2E			4.34	4.31	4.46	4.27	4.21	4.31	4.36
PD3.	P6PD3A			2.93	2.73	3.11	2.96	2.79	2.67	3.23
	P6PD3B			3.51	3.80	3.29	3.43	3.17	3.53	3.80
	P6PD3C			3.23	3.47	3.07	3.25	3.08	3.33	3.23
	P6PD3D			3.48	3.53	3.46	3.57	3.21	3.40	3.73
	P6PD3E			3.32	3.47	3.11	3.50	2.79	3.40	3.67

Engineering Manager at: A Picture Tube Company - Plant Number 1

Using the data you provided and the productivity and quality formulas in Appendix 2, your plant falls in the following categories for productivity and qualit
Please refer to these categories when interpreting the summary data.

Productivity: High
Quality: Average

		Your Plant	α	Overall	Productivity Average			Quality Average		
I. Engineering Input and Problem Solving		Response		Averages	Low	Average	High	Low	Average	High
E1.	E1E1A			22.61	29.00	13.93	21.27	9.88	31.07	27.73
	E1E1B			27.70	35.43	25.00	16.53	29.13	24.63	29.47
	E1E1C			30.30	28.79	36.53	21.07	21.81	41.44	27.47
E2.	E1E2			56%	64%	56%	47%	56%	59%	53%
E3.	E1E3			14%	15%	8%	15%	7%	15%	20%
E4.	E1E4 (0 = No and 1 = Yes)			93%	100%	92%	87%	93%	100%	86%
E5.	E1E5			3.84	4.07	3.46	3.87	3.33	4.03	4.13
E6.	E1E6			96.57	127.43	65.21	84.67	91.47	108.44	89.00
E7.	E1E7			14%	18%	11%	9%	17%	12%	11%
E8.	E1E8			58%	70%	56%	50%	67%	52%	54%
E9.	E1E9			8.22	7.82	10.63	6.66	10.44	7.56	6.57
E10.	E1E10			28%	26%	23%	35%	26%	29%	27%
E11.	E1E11			23%	26%	13%	28%	21%	19%	31%
E12.	E1E12A			16%	13%	15%	19%	14%	15%	20%
	E1E12B			23%	26%	25%	18%	28%	19%	23%
	E1E12C			26%	27%	27%	25%	26%	33%	20%
	E1E12D			10%	10%	13%	8%	10%	11%	10%
	E1E12E			24%	24%	20%	30%	22%	23%	27%
E13.	E1E13			25.55	17.19	20.81	39.93	15.44	17.54	43.81
E14.	E1E14			44%	52%	34%	47%	40%	48%	44%
E15.	E1E15			15.09	10.77	23.60	10.80	16.06	17.50	11.21
E16.	E1E16A			2.79	3.07	2.38	2.67	2.67	2.77	2.93
	E1E16B			2.40	2.50	2.07	2.20	2.00	2.31	2.93
	E1E16C			4.89	5.00	4.87	4.93	5.19	4.50	5.00
	E1E16D			6.40	7.21	6.27	6.00	6.69	6.50	6.00
	E1E16E			5.53	5.43	5.87	5.33	6.06	6.13	4.33
	E1E16F			4.91	4.57	5.07	5.00	5.19	5.31	4.20
	E1E16G			3.74	3.21	4.07	3.87	3.44	3.31	4.53
	E1E16H			4.43	5.21	3.80	4.21	4.38	3.67	5.27
II. Product/Process Design and Engineering										
DE1.	E2DE1A			45.34	39.09	35.15	64.43	23.54	43.44	71.50
	E2DE1B			168	117	172	222	145	180	176
DE2.	E2DE2			6%	2%	3%	9%	2%	4%	14%
DE3.	E2DE3			17%	28%	15%	12%	31%	11%	10%
DE4.	E2DE4A			3.11	3.00	3.13	3.20	3.09	3.16	3.07
	E2DE4B			3.29	3.50	2.83	3.53	3.03	3.19	3.67
	E2DE4C			3.26	3.57	2.87	3.47	2.94	3.38	3.47
	E2DE4D			3.67	4.07	3.37	3.73	3.44	3.84	3.73
	E2DE4E			3.24	3.29	3.03	3.47	2.81	3.34	3.60
DE5.	**Design change**									
	E2DE51A			35.20	10.70	32.11	62.08	32.18	61.38	9.61
	E2DE51B			314	103	683	188	606	294	67
	E2DE51C			3.75	4.17	3.69	3.46	3.64	3.07	4.67
	E2DE51D			12.52	13.17	11.15	10.80	12.79	9.87	15.31
	E2DE51E			8.67	10.54	9.88	6.33	12.71	6.87	6.38
	New Design									
	E2DE52A			118.90	21.00	136.88	225.60	91.83	263.91	13.05
	E2DE52B			1124.80	120.55	2440.70	1018.64	2154.00	1343.45	66.71
	E2DE52C			4.59	4.90	4.27	5.00	4.00	4.42	5.25
	E2DE52D			22.08	16.50	21.91	27.23	19.00	18.92	27.62
	E2DE52E			23.47	27.45	16.42	24.62	22.45	22.08	25.73
DE6.	E2DE6			3.63	3.46	3.17	3.93	3.54	3.75	3.57
DE7.	E2DE7A			4.13	4.08	4.29	4.20	4.00	4.25	4.14
	E2DE7B			3.22	2.69	3.47	3.53	2.94	3.50	3.21
	E2DE7C			4.34	4.38	4.30	4.47	4.09	4.75	4.14
	E2DE7D			3.62	3.62	3.57	3.73	3.73	3.75	3.36
	E2DE7E			4.00	3.77	3.93	4.33	3.67	4.13	4.21
	E2DE7F			4.30	4.62	4.54	4.13	4.57	4.31	4.00
	E2DE7G			3.99	4.15	4.03	4.07	4.25	3.78	3.93
	E2DE7H			4.71	4.77	4.50	5.00	4.47	4.88	4.79
	E2DE7I			3.33	3.23	3.00	3.67	2.93	3.50	3.57
	E2DE7J			4.11	3.46	4.43	4.40	4.20	4.00	4.14
	E2DE7K			3.70	3.92	3.54	3.80	3.47	3.97	3.64
	E2DE7L			4.34	4.38	4.32	4.47	4.27	4.41	4.36
	E2DE7M			2.89	2.54	2.71	3.27	2.44	3.20	3.07
	E2DE7N			2.94	2.77	2.96	3.07	3.13	2.84	2.86
DE8.	E2DE8A			4.24	4.38	3.86	4.47	4.20	4.06	4.50
	E2DE8B			4.47	4.31	4.36	4.80	4.40	4.38	4.64
	E2DE8C			3.91	4.38	3.29	4.33	3.40	4.25	4.07
	E2DE8D			4.68	4.77	4.54	4.80	4.67	4.53	4.86
	E2DE8E			4.24	4.46	4.21	4.27	4.40	4.19	4.14

Engineering Manager at: A Picture Tube Company - Plant Number 1

		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
III. Technology and Automation										
T1.	E3T1			9.78	7.93	11.20	10.37	10.56	9.19	9.57
T2.	E3T2			58%	58%	40%	74%	41%	64%	70%
T3	E3T3			7.52	7.96	9.43	3.30	11.28	5.34	5.83
T4.	E3T4			5.66	8.27	4.00	5.87	3.87	2.34	11.00
T5.	E3T5			7.43	7.82	8.73	3.70	10.38	6.16	5.63
T6.	E3T6			10.05	13.46	9.20	9.73	7.50	2.22	21.13
T7.	E3T7			6.35	7.43	5.63	3.60	8.75	5.16	5.07
T8.	E3T8A			29%	30%	33%	25%	42%	18%	26%
	E3T8B			48%	57%	38%	50%	38%	52%	56%
	E3T8C			26%	19%	34%	25%	26%	29%	24%
T9.	E3T9A			2.98	3.00	2.85	3.00	2.73	3.31	2.93
	E3T9B			2.83	3.00	2.67	2.80	2.63	2.94	2.93
	E3T9C			3.09	3.29	2.60	3.40	2.56	3.25	3.47
T10.	E3T10			0.75	0.92	0.75	0.68	0.80	1.05	0.41
T11.	E3T11			7.95	7.23	10.92	6.38	6.14	13.42	4.68
T12.	E3T12			33%	19%	27%	44%	20%	47%	32%
T13.	E3T13			48%	49%	45%	54%	45%	46%	53%
T14.	E3T14A			3.00	3.00	2.67	3.53	2.50	3.56	2.93
	E3T14B			3.40	3.57	3.07	3.80	2.94	3.75	3.53
	E3T14C			2.97	3.14	2.50	3.40	2.47	3.31	3.13
	E3T14D			3.03	3.00	2.77	3.50	2.78	3.25	3.07
T15.	E3T15A			4.43	4.57	4.00	4.73	4.13	4.75	4.40
	E3T15B			4.04	4.21	3.53	4.33	3.63	4.38	4.13
	E3T15C			4.07	4.07	3.77	4.27	3.75	3.97	4.53
	E3T15D			3.53	3.50	3.20	3.87	3.44	3.50	3.67
	E3T15E			3.65	4.00	3.00	3.87	3.27	3.88	3.80
	E3T15F			3.43	3.50	3.20	3.47	2.94	3.63	3.73
T16.	E3T16A			4.38	4.14	4.33	4.73	4.13	4.50	4.53
	E3T16B			4.15	4.07	3.93	4.47	3.94	4.13	4.40
	E3T16C			3.61	3.64	3.37	3.73	3.50	3.28	4.07
	E3T16D			4.32	4.21	4.33	4.40	4.25	4.38	4.33
T17.	E3T17A			4.24	4.21	3.83	4.73	4.13	4.41	4.20
	E3T17B			2.99	3.07	2.77	3.07	2.69	3.34	2.93
	E3T17C			3.56	3.29	3.43	3.87	3.00	4.03	3.67
	E3T17D			2.90	2.50	2.57	3.47	2.56	3.47	2.67
	E3T17E			3.77	3.50	3.61	4.20	3.60	3.97	3.73
	E3T17F			2.59	2.21	2.29	3.00	2.53	2.63	2.60
	E3T17G			2.43	2.14	2.43	2.60	2.60	2.56	2.13
	E3T17H			2.41	2.29	2.65	2.47	2.14	2.91	2.13
	E3T17I			2.90	2.79	3.04	2.87	3.00	2.97	2.73
	E3T17J			2.52	2.50	2.36	2.67	2.07	2.69	2.79
	E3T17K			4.28	3.93	4.29	4.53	4.27	4.38	4.20
T18.	E3T18A			3.64	3.58	3.58	3.80	3.31	3.91	3.64
	E3T18B			3.64	3.91	3.62	3.47	3.67	3.50	3.79
	E3T18C			2.68	2.67	3.00	2.40	3.14	2.44	2.50
T19.	E3T19			18%	21%	19%	11%	19%	16%	18%
T20.	E3T20			2.88	3.00	2.68	2.93	2.80	2.97	2.87
IV. Performance										
P1.	E4P1A			55.02	56.07	58.80	53.40	60.06	52.19	52.67
	E4P1B (0 = No and 1 = Yes)			39%	15%	40%	67%	13%	69%	33%
	E4P1C			1.44	1.29	1.60	1.50	1.28	1.60	1.46
	E4P1D			1987.23	1988.29	1985.40	1988.13	1986.00	1988.13	1987.60
	E4P1E			1984.83	1986.08	1983.53	1985.40	1983.31	1985.44	1985.86
	E4P1F			1989.37	1990.36	1989.79	1988.47	1989.93	1989.13	1989.08
P2.	E4P2			3.07	2.79	3.15	3.43	2.64	3.44	3.07
P3.	E4P3			3670	4777	3718	2455	5330	2664	3043
P4.	Particles			1104	1520	965	818	1604	524	1222
	Other screen defects			322	326	341	271	341	286	340
	Surface defects such as scratches			264	300	418	108	338	260	195
	Emission			649	842	525	242	939	601	412
	Convergence			192	184	245	122	313	147	120
	Purity			238	295	324	119	331	155	234
	Focus			235	306	225	159	298	134	281
	Miscellaneous			565	500	ERR	630	ERR	500	630
P5.	**Purchased materials used**									
	E4P51A			1040	1033	1065	1021	1079	1034	1005
	E4P51B			1074	1077	1122	1023	1160	1049	1009
	E4P51C			1051	1024	1118	1013	1119	1024	1007
	E4P51D			1072	1062	1119	1038	1118	1068	1027
	Salvaged materials used									
	E4P52A			36.05	30.93	46.25	28.73	52.56	30.30	24.20
	E4P52B			25.76	21.00	31.57	25.27	29.22	23.50	24.33
	E4P52C			31.04	29.86	43.99	20.73	48.02	26.37	17.60

Engineering Manager at: A Picture Tube Company - Plant Number 1

		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
P7.	E4P7A1			81%	87%	73%	89%	72%	84%	87%
	E4P7A2			6.64	6.86	6.56	6.56	6.62	6.52	6.86
	E4P7B			22482	17767	21000	23133	26086	21688	19786
	E4P7C			2505	2040	4555	1398	2858	3214	1385
P8.	E4P8A			4.34	4.50	4.53	4.07	4.75	4.06	4.20
	E4P8B			3.90	4.14	3.83	3.87	4.19	3.66	3.87
	E4P8C			3.73	3.57	3.70	3.80	3.56	3.78	3.87
	E4P8D			4.26	4.43	4.20	4.13	4.31	4.31	4.13
P9.	E4P9			1.47%	1.99%	0.90%	1.34%	1.34%	2.06%	0.97%
V. External Learning										
EX1.	E5EX1			27%	46%	18%	21%	29%	28%	26%
EX2.	E5EX2A			12%	9%	16%	12%	12%	18%	5%
	E5EX2B			29%	38%	36%	20%	39%	25%	25%
	E5EX2C			21%	24%	22%	20%	24%	16%	24%
	E5EX2D			13%	15%	6%	16%	8%	11%	18%
	E5EX2E			8%	9%	7%	8%	5%	9%	8%
	E5EX2F			5%	6%	5%	3%	5%	7%	2%
EX3.	E5EX3A			35%	43%	37%	32%	38%	30%	39%
	E5EX3B			16%	11%	22%	14%	15%	21%	11%
	E5EX3C			13%	11%	17%	10%	17%	11%	10%
	E5EX3D			15%	9%	18%	15%	12%	15%	16%
	E5EX3E			10%	24%	4%	7%	12%	10%	9%
	E5EX3F1			1%	2%	0%	1%	0%	2%	0%
EX4.	E5EX4A			37%	44%	41%	32%	34%	46%	29%
	E5EX4B			22%	25%	22%	22%	27%	17%	25%
	E5EX4C			12%	16%	10%	13%	10%	11%	17%
	E5EX4D			7%	3%	8%	8%	7%	7%	5%
	E5EX4E			6%	6%	5%	6%	6%	9%	4%
	E5EX4F1			6%	7%	11%	3%	13%	4%	3%
EX5.	E5EX5A			4%	5%	2%	4%	3%	4%	4%
	E5EX5B			4%	5%	3%	5%	3%	5%	5%
	E5EX5C			6%	9%	2%	7%	3%	7%	8%
	E5EX5D			5%	6%	2%	5%	3%	8%	5%
	E5EX5E			6%	7%	2%	7%	3%	8%	6%
	E5EX5F			1%	1%	1%	1%	1%	2%	1%
	E5EX5G			3%	2%	1%	2%	1%	5%	1%
EX6.	E5EX6			3.85	3.90	4.38	3.37	5.54	3.22	3.08
EX7.	E5EX7A (0 = No and 1 = Yes)			49%	60%	46%	47%	42%	63%	38%
EX8.	E5EX8 (0 = No and 1 = Yes)			96%	100%	87%	100%	88%	100%	100%
EX9.	E5EX9			7.59	4.54	4.55	11.00	5.00	12.79	4.43
VI. Strategic Quality										
S1.	E6S1A			4.28	4.36	3.87	4.67	4.38	3.88	4.60
	E6S1B			4.60	4.79	4.33	4.73	4.38	4.63	4.80
	E6S1C			4.30	4.57	4.20	4.20	4.19	4.19	4.53
	E6S1D			3.89	3.86	3.47	4.33	3.63	4.06	4.00
	E6S1E			4.49	4.64	4.40	4.47	4.50	4.44	4.53
S2.	E6S2A			4.27	4.36	4.10	4.47	4.31	4.09	4.40
	E6S2B			3.78	4.00	3.50	3.87	3.63	3.78	3.93
	E6S2C			4.44	4.71	4.17	4.60	4.19	4.53	4.60
	E6S2D			4.24	4.50	4.10	4.27	4.38	4.09	4.27
S3.	E6S3A			2.26	2.14	2.13	2.57	2.00	2.20	2.60
	E6S3B			2.73	2.43	2.90	2.80	2.56	2.59	3.07
	E6S3C			3.01	2.93	3.10	3.20	3.00	2.78	3.27
	E6S3D			3.50	3.79	3.25	3.50	3.40	3.37	3.73
S4.	E6S4			3.94	4.07	3.73	4.13	3.75	4.06	4.00
S5.	E6S5A (0 = No and 1 = Yes)			94%	86%	100%	93%	100%	88%	93%
	E6S5B			54%	72%	38%	51%	58%	41%	65%
	E6S5C			36%	36%	28%	36%	33%	29%	45%
	E6S5D			20.95	21.46	13.05	18.90	17.79	3.85	42.57
	E6S5E			7.14	5.93	5.51	7.58	5.84	3.65	12.23
	E6S5F			4.45	2.46	1.97	6.17	2.38	2.34	8.90
	E6S5G			41%	35%	32%	56%	32%	45%	46%
	E6S5H (0 = No and 1 = Yes)			85%	71%	87%	93%	88%	81%	87%
S6.	E6S6A			4.00	4.00	3.93	4.13	4.06	4.00	3.93
	E6S6B			2.78	2.64	2.70	2.93	2.44	2.78	3.13
S7.	E6S7A			4.16	4.36	3.97	4.27	4.06	4.28	4.13
	E6S7B			2.98	3.36	2.80	2.87	3.06	2.75	3.13
	E6S7C			3.72	3.86	3.73	3.73	3.81	3.63	3.73
	E6S7D			3.91	4.00	3.87	3.87	3.88	4.00	3.87
	E6S7E			2.87	2.71	2.87	2.93	3.00	2.81	2.80
	E6S7F			3.60	3.86	3.47	3.47	3.63	3.56	3.60
	E6S7G			2.65	2.57	2.57	2.67	2.63	2.53	2.80
	E6S7H			3.49	3.71	3.13	3.67	3.19	3.44	3.87
S8.	E6S8A			31%	36%	30%	27%	37%	23%	33%
	E6S8B			24%	22%	20%	30%	25%	25%	21%
	E6S8C			16%	16%	14%	16%	12%	20%	15%
	E6S8D			14%	15%	11%	16%	10%	17%	15%
	E6S8E			7%	7%	7%	9%	6%	10%	7%

Quality Manager at: **A Picture Tube Company - Plant Number 1**

Using the data you provided and the productivity and quality formulas in Appendix 2, your plant falls in the following categories for produ and quality. Please refer to these categories when interpreting the summary data:

Productivity: High

Quality: Average

I. Strategic Quality		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
S1.	Q1S1A			4.50	4.40	4.47	4.67	4.56	4.19	4.80
	Q1S1B			4.50	4.73	4.47	4.27	4.69	4.38	4.47
	Q1S1C			4.31	4.53	4.27	4.27	4.44	4.31	4.20
	Q1S1D			3.83	3.60	3.67	4.13	3.81	4.00	3.60
	Q1S1E			4.50	4.53	4.53	4.47	4.81	4.56	4.20
S2.	Q1S2A			4.25	4.40	4.27	4.20	4.44	4.38	3.93
	Q1S2B			3.76	3.87	4.00	3.27	4.07	3.93	3.20
	Q1S2C			4.38	4.47	4.27	4.40	4.31	4.81	3.93
	Q1S2D			4.04	4.27	4.20	3.80	4.38	4.31	3.40
S3.	Q1S3A			2.60	2.79	2.33	2.80	2.13	2.80	3.00
	Q1S3B			3.47	3.57	3.67	3.13	3.50	3.40	3.67
	Q1S3C			3.30	3.43	3.33	3.20	3.31	3.53	3.20
	Q1S3D			3.77	3.87	3.93	3.53	3.75	3.88	3.73
S4.	Q1S4			4.11	4.23	4.13	3.87	4.31	4.13	3.85
S5.	Q1S5A (0 = No and 1 = Yes)			90%	93%	100%	73%	100%	94%	80%
	Q1S5B			51%	57%	50%	44%	61%	48%	43%
	Q1S5C			36%	35%	37%	30%	37%	41%	32%
	Q1S5D			18.06	24.98	6.56	22.07	5.90	12.54	31.47
	Q1S5E			8.24	9.23	4.87	8.47	5.06	5.44	11.83
	Q1S5F			5.27	4.93	2.21	6.00	1.27	4.05	9.87
	Q1S5G			43%	50%	36%	43%	36%	45%	45%
	Q1S5H (0 = No and 1 = Yes)			89%	69%	100%	93%	87%	94%	86%
S6.	Q1S6A			3.55	3.64	3.67	3.40	3.63	3.69	3.29
	Q1S6B			2.72	2.71	2.60	2.93	2.44	2.88	2.93
S7.	Q1S7A			4.42	4.13	4.67	4.60	4.31	4.56	4.47
	Q1S7B			3.21	3.13	3.20	3.27	3.25	3.06	3.27
	Q1S7C			3.77	3.73	3.93	3.67	4.00	3.25	4.00
	Q1S7D			3.98	3.80	4.13	4.07	4.00	4.19	3.73
	Q1S7E			2.29	2.20	2.20	2.40	2.38	2.50	2.07
	Q1S7F			3.65	3.73	3.80	3.47	3.56	3.50	3.87
	Q1S7G			2.60	2.60	2.67	2.60	2.94	2.19	2.60
	Q1S7H			3.63	3.47	3.80	3.60	3.56	3.63	3.67
S8.	Q1S8A			29%	32%	28%	26%	31%	24%	31%
	Q1S8B			9%	11%	10%	7%	10%	10%	7%
	Q1S8C			23%	21%	23%	25%	22%	25%	22%
	Q1S8D			21%	22%	20%	22%	18%	22%	23%
	Q1S8E			17%	15%	15%	21%	15%	19%	18%
II. Vendor Quality Management										
V1.	Q2V1A Glass Panels			18%	22%	31%	4%	23%	19%	7%
	Q2V1B Funnels			19%	18%	31%	3%	27%	18%	5%
	Q2VIC Masks			33%	33%	28%	43%	23%	33%	40%
	Q2V1D Electron guns			83%	68%	96%	83%	88%	77%	83%
V2.	**(1=None, 2=Sample, 3=100%)**									
	Q2V2A Glass Panels			1.50	1.67	1.50	1.36	1.41	1.40	1.60
	Q2V2B Funnels			1.36	1.47	1.33	1.29	1.25	1.27	1.47
	Q2V2C Masks			1.59	1.60	1.63	1.57	1.47	1.33	1.87
	Q2V2D Electron guns			1.94	2.40	1.73	1.79	1.56	1.73	2.47
V3.	**Discovered at incoming inspection**									
	Q2V31A Glass Panels			5308	7756	7911	251	10745	580	346
	Q2V31B Funnels			513	857	0	151	1000	40	253
	Q2V31C Masks			2890	4456	3650	571	5025	1900	1191
	Q2V31D Electron guns			6708	10664	1725	3520	1000	2244	6600
	Discovered in-process									
	Q2V32A Glass Panels			2992	2450	2362	3375	3010	3476	2547
	Q2V32B Funnels			726	423	888	787	611	1352	306
	Q2V32C Masks			2994	2636	2899	3531	3062	2400	3673
	Q2V32D Electron guns			4144	3150	3468	5032	2505	3354	6550
V4.	Q2V4			2.73	2.80	2.83	2.64	3.03	2.63	2.50
V5.	Q2V5			61%	56%	67%	52%	69%	55%	60%
V6.	Q2V6			42.87	56.50	29.87	44.86	42.19	63.14	27.40
V7.	Q2V7			13.47	11.67	14.53	12.14	19.06	16.07	5.60
V8.	Q2V8			8.30%	5.20%	14.53%	6.14%	7.20%	12.07%	2.87%
V9.	Q2V9			3.87	3.93	3.50	4.14	3.40	4.33	3.87
V10.	Q2V10			4.04	4.07	4.27	3.64	4.38	3.80	3.93
V11.	Q2V11			4.09	3.87	3.93	4.57	3.80	4.33	4.20
V12.	Q2V12			2.30	2.20	2.40	2.36	2.06	2.73	2.00

Quality Manager at: A Picture Tube Company - Plant Number 1

III. Quality Information Systems		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
Q1.	Q3Q1			120	79.60	177.00	96.93	126.00	130.31	104.40
Q2.	Q3Q2			57%	67%	33%	63%	46%	71%	56%
Q3.	Q3Q3A			47%	49%	29%	59%	30%	54%	54%
	Q3Q3B			57%	59%	49%	56%	61%	55%	54%
Q4.	Q3Q4			40%	37%	26%	52%	26%	50%	42%
Q5.	Q3Q5A			3.81	3.87	3.87	3.67	3.88	3.81	3.67
	Q3Q5B			3.13	3.00	3.20	3.07	2.94	3.44	2.93
	Q3Q5C			4.17	4.07	4.47	4.00	4.50	4.25	3.67
	Q3Q5D			4.33	4.47	4.53	4.13	4.56	4.38	4.00
	Q3Q5E			2.67	2.67	2.67	2.60	2.81	2.44	2.73
	Q3Q5F			2.98	3.00	2.67	3.20	2.63	3.25	3.00
	Q3Q5G			3.48	3.69	3.73	3.00	3.75	3.71	2.93
	Q3Q5H			2.71	2.70	2.69	2.67	2.54	3.07	2.46
Q6.	Q3Q6A			3.40	3.47	3.60	3.07	3.44	3.44	3.27
	Q3Q6B			2.52	2.47	2.60	2.33	2.63	2.56	2.33
	Q3Q6C			2.12	2.00	1.82	2.27	1.97	1.88	2.47
	Q3Q6D			2.80	2.73	2.77	2.80	2.59	2.88	2.93
	Q3Q6E			3.54	3.33	3.73	3.47	3.88	3.38	3.33
Q7.	Q3Q7			59%	55%	36%	79%	40%	65%	73%
Q8.	Q3Q8 (0 = No and 1 = Yes)			48%	31%	73%	40%	60%	50%	29%
Q9.	Q3Q9			39.22	24.60	68.69	29.07	51.79	45.56	23.07
Q10.	Q3Q10A			219	190	332	177	296	168	191
	Q3Q10B			2.81	3.24	3.75	1.81	5.41	1.20	1.37
	Q3Q10C			156	137	154	197	160	161	159
Q11.	Q3Q11			18.34	13.58	23.73	16.08	29.00	10.17	16.17
IV. Product and Process Design										
PD1.	Q4PD1A			4.35	4.27	4.40	4.47	4.38	4.56	4.07
	Q4PD1B			4.38	4.53	4.33	4.33	4.44	4.63	4.00
	Q4PD1C			4.06	3.87	4.33	3.93	4.00	4.38	3.73
	Q4PD1D			4.25	4.13	4.33	4.40	4.25	4.31	4.20
	Q4PD1E			4.77	4.73	4.87	4.67	4.88	4.81	4.60
	Q4PD1F			4.60	4.60	4.53	4.60	4.63	4.56	4.67
	Q4PD1G			4.67	4.33	4.87	4.73	4.69	4.75	4.60
	Q4PD1H			3.54	3.13	3.60	3.93	3.19	4.00	3.40
	Q4PD1I			4.13	3.80	4.40	4.27	4.31	4.38	3.73
	Q4PD1J			3.96	3.80	4.00	4.00	4.00	3.94	3.93
	Q4PD1K			2.75	2.60	2.80	2.60	2.69	2.81	2.73
PD2.	Q4PD2A			4.38	4.27	4.53	4.27	4.56	4.69	3.80
	Q4PD2B			3.96	3.67	3.93	4.20	3.88	4.38	3.67
	Q4PD2C			4.50	4.47	4.47	4.60	4.44	4.69	4.47
PD3.	Q4PD3A			3.21	3.33	3.13	3.20	3.38	3.19	3.07
	Q4PD3B			3.40	3.53	3.20	3.53	3.31	3.56	3.40
	Q4PD3C			3.29	3.33	3.27	3.40	3.19	3.63	3.07
	Q4PD3D			3.67	3.60	3.53	4.00	3.56	3.88	3.53
	Q4PD3E			3.54	3.73	3.33	3.67	3.44	3.38	3.87
V. Performance										
P1.	Tube size			52.31	51.67	53.73	53.13	54.00	54.13	50.73
	Invar or not (0=No,1=Yes)			37%	14%	36%	67%	13%	69%	27%
	Panel radius			1.39	1.39	1.33	1.43	1.28	1.37	1.53
P2.	Q5P2			1987.40	1988.60	1986.13	1987.67	1986.94	1988.25	1987.27
P3.	Q5P31			1985.44	1986.07	1985.27	1985.40	1985.50	1986.88	1984.87
	Q5P32			1989.95	1990.22	1989.54	1990.00	1990.36	1990.43	1989.08
P4.	Q5P4A1			88%	86%	91%	89%	91%	89%	85%
	Q5P4A2			6.89	6.96	7.17	6.65	7.37	6.40	6.89
	Q5P4B			20501	20091	21335	21267	19068	24800	17429
	Q5P4C			2962	1680	5118	2008	2739	3884	2279
P5.	Q5P5			4089	4252	5221	2860	4856	4019	3147
P6.	Particles			1180	1282	1228	1020	1660	888	940
	Other surface defects			623	909	778	257	542	710	425
	Emission			514	744	427	330	761	311	388
	Convergence			234	214	272	167	326	174	211
	Purity			262	323	286	166	369	167	241
	Focus			745	349	1583	333	307	1516	478
	Miscellaneous			450.00	400	500	ERR	500	500	300
P7.	**(0 = Lower, 1 = Higher, and 2 = Unchanged)**									
	Q5P7A1			4401.43	942	7436	3494	1375	6504	5650
	Q5P7A2			0.91	1.00	1.00	0.70	1.10	0.77	0.90
	Q5P7B1			899.85	1333	1000	540	500	375	1300
	Q5P7B2			1.00	0.50	2.00	0.50	2.00	0.67	0.33
P8.	Q5P8A Tubes			70%	62%	89%	59%	93%	51%	62%
	Q5P8B Panels			72%	77%	79%	65%	81%	67%	67%
	Q5P8C Masks			60%	70%	65%	54%	66%	59%	57%
	Q5P8D Funnels			70%	79%	74%	63%	82%	62%	66%

Quality Manager at: A Picture Tube Company - Plant Number 1

VI. External Learning		Your Plant Response	α	Overall Averages	Productivity Average Low	Productivity Average Average	Productivity Average High	Quality Average Low	Quality Average Average	Quality Average High
EX1.	Q6EX1			26%	30%	15%	29%	23%	31%	24%
EX2.	Q6EX2A			14%	15%	13%	16%	13%	15%	15%
	Q6EX2B			26%	35%	34%	15%	36%	24%	19%
	Q6EX2C			18%	10%	19%	17%	10%	12%	31%
	Q6EX2D			13%	18%	12%	12%	15%	11%	14%
	Q6EX2E			8%	8%	5%	9%	3%	13%	5%
	Q6EX2F			7%	5%	3%	11%	4%	7%	9%
EX3.	Q6EX3A			34%	42%	38%	29%	43%	29%	33%
	Q6EX3B			17%	21%	14%	18%	15%	20%	17%
	Q6EX3C			11%	13%	7%	12%	6%	15%	11%
	Q6EX3D			16%	11%	20%	16%	13%	15%	20%
	Q6EX3E			10%	11%	2%	10%	3%	11%	13%
	Q6EX3FA			4%	4%	5%	3%	8%	3%	1%
EX4.	Q6EX4A			40%	43%	37%	37%	38%	35%	48%
	Q6EX4B			25%	30%	26%	20%	33%	20%	22%
	Q6EX4C			9%	10%	7%	8%	3%	11%	11%
	Q6EX4D			8%	6%	7%	10%	6%	11%	6%
	Q6EX4E			7%	4%	6%	9%	4%	13%	3%
	Q6EX4F			5%	5%	13%	2%	12%	5%	1%
EX5.	Q6EX5A			3.17	4.42	1.83	3.33	2.27	4.50	2.67
	Q6EX5B			3.74	5.79	2.08	3.87	2.23	3.89	4.90
	Q6EX5C			7.00	13.83	2.13	6.17	1.68	7.89	10.40
	Q6EX5D			4.28	7.25	1.55	3.73	2.64	5.00	4.93
	Q6EX5E			3.49	4.09	2.28	3.86	2.85	4.00	3.53
	Q6EX5F			1.33	1.29	1.64	1.18	0.91	2.27	0.68
	Q6EX5G			4.87	7.30	2.43	5.32	2.60	2.69	8.82
EX6.	Q6EX6			3.90	3.66	3.63	3.77	4.02	3.36	4.31
EX7.	Q6EX7A (0 = No and 1 = Yes)			47%	31%	62%	47%	38%	80%	20%
EX8.	Q6EX8 (0 = No and 1 = Yes)			96%	100%	87%	100%	88%	100%	100%
EX9.	Q6EX9			7.08	5.23	6.10	10.67	4.41	11.84	5.20

Appendix 4: Picture Tube Plants of the World

Plant	Facility Site	Ownership
AMEC (American Matushita Electronics Corp.)	U.S.A	Japan
Beijing Matsushita Color Tube Company	China	China/Japan
Caihong Electronics Company	China	China
Chunghwa Picture Tubes Ltd. (Malaysia)	Malaysia	Taiwan (R.O.C.)
Chunghwa Picture Tubes, Ltd. C-CRT Plant(Taoyuan	Taiwan(R.O.C)	Taiwan (R.O.C.)
Chunghwa Picture Tubes, Ltd.-Yangmei	Taiwan(R.O.C)	Taiwan (R.O.C.)
ETT Videocolor SPA (Thomson)	Italy	France
Foshan Tube Company	China	China
Gold Star Co., Changwon	Korea	Korea
Gold Star Co., Kumi	Korea	Korea
Hitachi Electronics Devices (U.S.A) Inc.	USA	Japan
Hitachi Electronics Devices(S) Pte. Ltd.	Singapore	Japan
Hitachi, Mobara Works	Japan	Japan
Hua Fei Color Display Company	China	China/Holland
JCT Electronics	India	India/Japan
Kineskop	Ukraine	Ukraine
Matushita Electronics Co., Hiraide Plant	Japan	Japan
Matushita Electronics Co., Kiyohara Plant	Japan	Japan
Matushita Electronics Corp (M) Sdn Bhd	Malaysia	Japan
Matushita Electronics Corp., Takatsuki Plant	Japan	Japan
Mitsubishi Electronics Industries	Japan	Japan
Mitsubishi Electronics Industries	Japan	Japan
Mitsubishi Electronics Industries	Thailand	Japan
Mitsubishi Electronics Industries Canada Inc.	Canada	Japan
Nippon Electric Company	Japan	Japan
Nippon Electric Company	Japan	Japan
Nokia Display Technics GmbH	Germany	Germany
Orion Electric Co. Ltd., Gumi Plant	Korea	Korea
Philips Components Display-S.J. Dos Campos	Brazil	Holland
Philips Components GmbH	Germany	Holland
Philips Components Ltd.	Austria	Holland
Philips Components Ltd.	U.K.	Holland
Philips Composants	France	Holland
Philips Display Components Ltd.	U.S.A	Holland
Philips Electronics Industries(Taiwan) Ltd.	Taiwan(R.O.C)	Holland
Philips Components - Miniwatt. S.A.	Spain	Holland
Samsung Electronic Tube Co. (Berlin)	Germany	Korea
Samsung Electronic Tube Co., Buson	Korea	Korea
Samsung Electronic Tube Co., Suwon	Korea	Korea
Samsung Malaysia	Malaysia	Korea
Samtel Color Ltd.	India	India
Shanghai Novel CPT Company	China	China
Shenzhen SEG Hitachi	China	China/Japan
Sony BGD DD Plant	U.K.	Japan
Sony Display Device	Singapore	Japan
Sony Display Tube Corp.	U.S.A	Japan
Sony Inazawa Corp.	Japan	Japan
Sony Mizunami Corporation	Japan	Japan
Thomson Consumer Electronics VLS-Marion	U.S.A	France
Thomson Consumer Electronics, Marion	U.S.A	France
Thomson Consumer Electronics, Scranton	U.S.A	France
Thomson Polkolor	Poland	France/Poland
Thomson Tube Components de Mexico SA de CU	Mexico	France
Toshiba Corp., Himmeji Works	Japan	Japan
Toshiba Corporation Fukaya Display Devices	Japan	Japan
Toshiba Display Devices (Thailand) Co. Ltd.	Thailand	Japan
Toshiba Display Devices, Inc.	U.S.A	Japan
Uptron	India	India
Zenith Electronics Corp., (Rauland Div.)	U.S.A	U.S.A

Note: Multiple listings for the same country and company indicate multiple facilities.