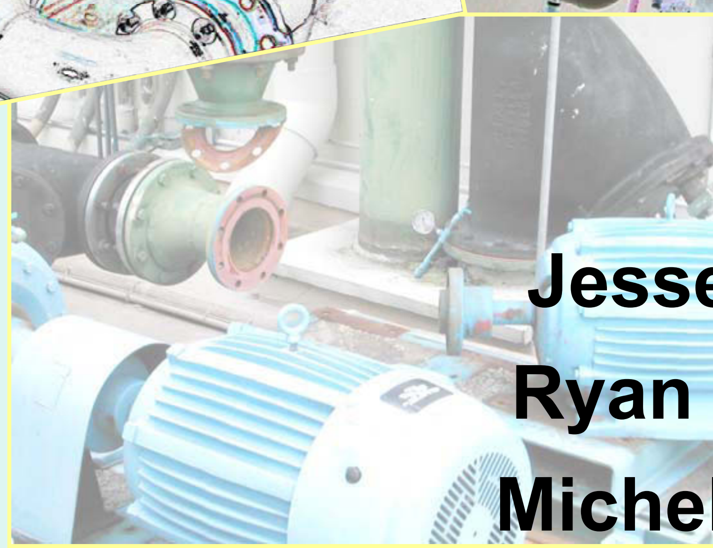
# Sustainable Equipment Replacement Using Electrical Analysis And Local Suppliers



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July 2, 2003

Mr. Luis Chinchilla, Corporate Services Manager
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Intel Corporation of Costa Rica
Belen, Heredia
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Dear Mr. Chinchilla and Mr. Solis:

Enclosed is our report entitled Model of Sustainable Equipment Replacement Using Electrical Analysis and Local Suppliers. It was written at Intel Corporation in Costa Rica during the period May 12 to July 2, 2003. Preliminary work was completed in Worcester, Massachusetts, prior to our arrival in Costa Rica. Copies of this report are simultaneously being submitted to Professors Vernon-Gerstenfeld and Gerstenfeld for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time that you have devoted to us.

Sincerely,

Jesse Elbin

Ryan Johnson

Michelle Porter

Report Submitted to:

Professor Susan Vernon-Gerstenfeld

Professor Arthur Gerstenfeld

San José, Costa Rica Project Center

By

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# SUSTAINABLE EQUIPMENT REPLACEMENT USING ELECTRICAL ANALYSIS AND LOCAL SUPPLIERS

July 2, 2003

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of Intel Corporation of Costa Rica or Worcester Polytechnic Institute.

This report is the product of an educational program and is intended to serve as partial documentation for the evaluation of academic achievement. The report should not be constructed as a working document by the reader.

# Abstract

The project between Worcester Polytechnic Institute and Intel came out of a need by Intel Costa Rica for an improved sustainable equipment replacement plan. In order to remain competitive, it was important to create cost effective, efficient models for equipment replacement. The model, used with infrared and vibration analysis, will further reduce operating costs. We also investigated and made recommendations on the development of additional local suppliers.

## Authorship Page

The writing of the report was performed in equal parts by Jesse Elbin, Ryan Johnson, and Michelle Porter. The research for the background was also performed in equal parts, however Michelle Porter focused on economy, education, and history; Ryan Johnson focused on cost benefit analysis and equipment maintenance; while Jesse Elbin focused on the equipment at the Intel plant. The program code was written by Jesse Elbin with planning assistance by Ryan Johnson and Michelle Porter. The local supplier recommendations were developed through brainstorming sessions among all of the group members.

# Acknowledgements

Our team would first like to acknowledge Luis Chinchilla and José Solis, our project liaisons, for sponsoring this project. We would also like to thank our project advisors Professors Susan Vernon-Gerstenfeld and Arthur Gerstenfeld for their advice and guidance. Our team would also like to specially thank and acknowledge Intel Costa Rica Mechanical Engineer Fabian Vargas, Supplier Engineer Jorge Espinoza Gonzalez, for their help in providing information and giving our project direction. Finally, we would like to acknowledge those who gave their time to provide us information through interviews: Intel Electrical Engineer Michelle Vincenti, Universidad de Costa Rica Professor Dr. Juan Carlos Chavez, and Strong International Representative Orlando Fonseca. Finally, our team would like to extend thanks to Professor H.J. Manzari, Maribel Manzari, and Intel Program Analysis Alexander Garcia for their help in translation.

# Table of Contents

# Tables

# Figures

# Executive Summary

The project between Worcester Polytechnic Institute and Intel came out of a need by Intel Costa Rica for an improved sustainable equipment replacement plan. In order to remain competitive, it was important to create cost effective, efficient models for equipment replacement. The model, used with infrared and vibration analysis, will further reduce maintenance costs and Intel's contribution to the local economy. We also investigated and made recommendations on the development of additional local suppliers

This presented report could be important to Intel Corporation in Costa Rica because at the time this report was written, there was no efficient way of scheduling the replacement of the equipment. Intel needs to know when to replace or refurbish equipment so they can keep the equipment always running efficiently without disruptions in production. The model that we derived was based on an electricity analysis that calculates when the equipment is most efficient. When analyzing the operating costs, we noticed the majority of the cost comes from electricity consumption. After performing some preliminary calculations, we realized that a small change in motor or pump efficiency can dramatically increase the operating costs. By implementing our proposed model, Intel Corporation will be able to save thousands of dollars.

The first part of the project was intended to create the model of equipment replacement. This model first analyzes the equipment to determine the theoretical electrical consumption. We developed the model using liquid pumps as they are the simplest of the machines at the plant and are abundant enough to provide us with a large test sample. Since there was a lack of data concerning electricity consumption with each piece of equipment, we developed a computer program to calculate costs using theoretical data.

We obtained the information for the model by studying the specifications sheets and operation manuals of the equipment and interviewing equipment manufactures. The manuals provided us with specifics on electricity consumption while the interviews provided us with information on developing three scenarios using the computer program.

The three scenarios were chosen to model a range of times in which Intel's equipment will degrade. The first scenario modeled the slowest degradation time. This model yielded the lowest savings. The second scenario modeled a moderate degradation time. The third modeled a maximum degradation case. Once Intel starts utilizing the program by inputting real measurements, the program will be able to calculate the actual refurbishing point and amount saved.

The three scenarios resulted in a savings of $860 to $25,630 per year depending on the rate of change for the energy consumption. These results show that the new model will be able to save Intel money regardless of the amount of energy the equipment consumes.

The second part of the project was an investigation and analysis of the potential to develop local suppliers. Currently, seventeen percent of Intel's suppliers that we researched were located locally. Thirty-three percent of Intel's suppliers that we researched were manufacturers who choose to sell products directly to Intel rather than through independent certified dealers. Fifty percent of the suppliers used are foreign, although local suppliers exist for the equipment.

The advantages to switching to local suppliers include increasing the market of industrial equipment in Costa Rica, investing in the Costa Rican economy, and adhering to Intel Corporation's mission statement. By developing local suppliers, Intel Costa Rica will increase the demand and the market for industrial equipment. Such an increase could lead to more industrial operations moving to Costa Rica, a further enlarged market, and lower equipment and service charges. By investing money into Costa Rican business and the Costa Rican economy, Intel will continue its policy of helping its community. Using local suppliers would also fulfill Intel's mission statement and objectives of taking risks and investing in worldwide opportunities. Disadvantages of investing in local suppliers include a large initial investment of training costs, physical expansion, and expedited delivery times, as well as slow initial processing.

After initial research, our team determined that a lack of demand of industrial equipment was the primary cause of the problems experienced with some local suppliers. Many local suppliers specialize in a wide range of equipment, leaving engineers lacking knowledge about some types of equipment. Cultural differences have also acted as a barrier for Intel in receiving the service that they require.

Our team recommended that Intel adopt a Costa Rican Industrial Supplier Plan, or CRISP, in order to gradually educate and develop local suppliers over a five-year period. The CRISP plan focuses on developing and using unutilized local suppliers. Once these suppliers are developed, the market for industrial equipment may increase, making Costa Rica more appealing to manufacturers as well. The plan includes an annual CRISP open house that will feature technical and business seminars and idea exchanges.

The CRISP plan also includes distributing a quarterly or bi-annually newsletter that not only focuses on informing every supplier and potential supplier on Intel news, policies, and rewards such as the "Supplier of the Year" award, but also will act as a method of communication and an incentive for suppliers to meet Intel's needs. The plan also includes paying for engineers working for suppliers to attend technical seminars as well as paying for expedited delivery in order to remedy the long processing times until shipping times improve when the suppliers grow accustomed to Intel’s standards.

# Resumen Ejecutivo

El proyecto entre Worcester Polytechnic Institute e Intel surgió de la necesidad de Intel Costa Rica de detener un plan mejorado y sostenible de reemplazo de equipos. Para poder seguir siendo competitivos, era importante crear modelos eficientes y de bajo costo para el reemplazo de equipo. Desarrollamos el modelo basados parcialmente en recursos locales. El modelo, usado con análisis de vibración e infrarrojos, ayudará más aún a reducidos costos de operación, y su ayuda a la comunidad local. También investigamos y dimos recomendaciones sobre el desarrollo de proveedores locales adicionales.

Este informe podría ser importante para Intel Corporation en Costa Rica porque, cuando lo escribimos, no había una forma eficiente de calendarizar el reemplazo del equipo. Intel necesita saber cuando reemplazar o readecuar equipo de tal forma que se pueda mantener el equipo en funcionamiento eficientemente sin detener la producción. El modelo que obtuvimos lo basamos en un análisis de electricidad que calcula cuando el equipo es más eficiente. Cuando se analizaron los costos de operación, notamos que la mayoría del costo proviene del consumo de la electricidad. Luego de ejecutar algunos cálculos preliminares, deducimos que un pequeño cambio en el motor o la bomba puede incrementar los costos dramáticamente. Al implementar este modelo, que proponemos Intel Corporation podrá ahorrar miles de dólares.

La primera parte del proyecto se dedicó a crear el modelo de reemplazo de equipo. Este modelo analiza el equipo para determinar en teoría el consumo de electricidad. Desarrollamos el modelo utilizando bombas de líquido pues son las más simples de las máquinas en la planta y se encuentran en suficiente cantidad para proveernos con una muestra grande para las pruebas. Debido a que había escasez de datos con respecto a consumo de electricidad con cada pieza de equipo, desarrollamos un programa de computadora para calcular los costos usando datos

teóricos.

Obtuvimos la información para el modelo estudiando las hojas de especificaciones y los manuales de operación del equipo y entrevistando a los fabrcadores del equipo. Los manuales nos proporcionaron aspectos específicos de consumo de electricidad mientras que las entrevistas nos proporcionaron información para desarrollar tres escenarios usando el programa de computadora.

Los tres escenarios fueron escogidos para modelar un rango de tiempos en los cuales el equipo de Intel será degradado. El primer escenario modeló el menor tiempo de degradación. Este modelo proporcionó los ahorros mas bajos. El segundo escenario modeló un tiempo de degradación moderado. El tercer escenario modeló el máximo caso de degradación. Una vez que Intel inicie a utilizar el programa e inserte medidas reales, el programa podrá calcular el punto real de renovación y el monto del ahorrado.

Tres escenarios resultaron en ahorros de $860 a $25,630 por año dependiendo en la frecuencia de cambio del consumo de energía. Estos resultados muestran que el nuevo modelo podrá ahorrar dinero para Intel sin importar la cantidad de energía que el equipo consuma.

La segunda parte del proyecto incluyó la investigación y el análisis del posible desarrollo de proveedores locales. Actualmente, el diecisiete por ciento de proveedores de Intel son locales. Treinta y tres por ciento de los proveedores que investigamos son proveedores que decidieron venderle a Intel directamente en lugar de hacerlo por medio de intermediarios independientes certificados. Cincuenta por ciento de los proveedores usados son extranjeros, a pesar de que existen suplidores locales del equipo.

Las ventajas de cambiar por proveedores locales incluyen el incremento del Mercado de equipo industrial en Costa Rica, inversión en la economía de Costa Rica, y alineamiento con la misión de Intel Corporation. Al desarrollar a los proveedores locales, Intel Costa Rica incrementará la demanda y el Mercado del equipo industrial. Tal incremento podría llevar a más operaciones industriales a moverse a Costa Rica, a un mercado más amplio, y a menores cargos por equipos y servicio. Al invertir dinero en negocios y economía costarricenses ayudará, Intel a continuar su política de ayuda a la comunidad. Usar proveedores locales estaría alineado con la misión y objetivos de Intel de tomar riesgos e invertir en oportunidades al rededor del mundo. Algunas desventajas de invertir en proveedores locales son: un alto costo inicial de entrenamiento, expansión física, y un acelerado tiempo de envío, así como lentos procesos iniciales.

Luego de una investigación inicial, el equipo determinó que una falta de demanda de equipo industrial fue la causa primaria de los problemas experimentados con algunos proveedores locales. Muchos proveedores locales se especializan en una amplia gama de equipo, dejando a los ingenieros con falta de conocimiento acerca de algunos tipos de equipo. Diferencias culturales han sido una barrera para Intel al recibir el servicio que requiere.

Nuestro equipo recomendó a Intel adoptar un Plan de Proveedores Industriales Costarricenses, o CRISP (Costa Rican Industrial Supplier Plan), para poder gradualmente educar y desarrollar proveedores en un periodo de cinco años. El plan CRISP se enfoca en desarrollar y usar proveedores locales que no se están utilizando. Cuando estos proveedores se hayan desarrollado, el mercado del equipo industrial podría incrementarse, haciendo Costa Rica más atractivos a manufactureros también. El plan incluye abrir seminarios técnicos y de negocios e intercambio de ideas.

El plan CRISP también incluye la distribución de una revista trimestral o bianual que no sólo se enfoca en informar a cada proveedor o potencial proveedor acerca de noticias de Intel, políticas y reconocimientos tales como “El Proveedor del Año”, si no que también serviría como un método de comunicación y un incentivo para los proveedores de llenar las necesidades de Intel. El plan incluye también el pago por ingenieros trabajando para proveedores para que asistan a los seminarios técnicos también como pagar por envíos rápidos para resolver el largo tiempo de procesamiento hasta que los tiempos de envío mejoren cuando los proveedores crezcan acostumbrados a los familiares de Intel.

# Introduction

Costa Rica, a country whose exports were once based on coffee beans and bananas, is now a leading technology exporter in the world. Intel's decision to build a company in Costa Rica was the biggest single foreign investment in the country's history (Korea Herald, 2001). Intel moved to Costa Rica in 1998 amid controversy after receiving a series of tax breaks that established, in addition to those already in existence, a "free trade zone" solely for Intel. Intel has a test and assembly plant in Costa Rica that has large equipment to help with production. They are a worldwide supplier of microprocessors, motherboards, and various other computer and electronic equipment. The Costa Rican plant specifically works in the assembly, testing, and distribution of microprocessors. In recent years, exports on agricultural products have decreased and semiconductors have become the leading export of Costa Rica. Unfortunately, this situation has left Costa Rica with an economy based upon producing American goods and importing American goods, resulting in a lack of Costa Rican products and services. As a result, the Costa Rican economy has suffered. The status of the Costa Rican economy and Intel's role are further discussed in Chapter two.

Currently, Intel determines equipment replacement by a system of prediction. Intel Costa Rica is supplied resources and services through various local and foreign suppliers including those in Mexico and the United States. If Intel begins developing and using local suppliers, they may be able to stimulate local small business growth, possibly improving the Costa Rican economy. If local suppliers are further developed, Intel could supply Costa Rica with domestic suppliers and services, triggering a growth of educational and technical skills for Costa Ricans. Our model of equipment replacement may potentially save Intel of Costa Rica thousands of dollars, providing Intel with additional funds to place in the development of local suppliers.

The goal of this project is to research a new model of equipment replacement for Intel Corporation of Costa Rica and research ways to develop local suppliers. The equipment replacement model and our recommendations on local suppliers will both help Intel better understand their maintenance and replacement methods as well as provide more business to local Costa Ricans. There is a need for the project assigned to our group because Intel wants to have a model of equipment replacement in order to help them cut costs and remain competitive. In addition, Intel wants to develop local suppliers in order to save future costs and add the convenience of quick service.

Methodologies for the project included the research of equipment costs and equipment manuals for the equipment our team used in the model. Our team performed interviews with the lead engineer, or "owner", of each piece of equipment investigated. Our team conducted interviews with a supplier engineer working for Intel Costa Rica as well. We also conducted interviews with management of suppliers already in place in Costa Rica as well as representatives from each manufacturer. The manufacturers provided information about equipment that suppliers could not or were not available to answer.

## Background Information

The following chapter is information related to our project completed for Intel Corporation in Costa Rica. The first three subsections cover the economy in Costa Rica, Intel and its effect on the Costa Rican economy, and information pertaining to the education level of Costa Ricans. These subsections are important for further elaboration on the context and purpose of our completed project.

The next subsection supplies information pertaining to preventive maintenance. This chapter is necessary to inform the reader about preventive maintenance, one major operating cost in equipment. Information pertaining to the equipment under investigation for an equipment replacement model is discussed in the next subsection.

Finally, information related to cost-benefit economics is located in the last subsection. Cost-benefit analysis was also used for this project, thus signifying its importance to the reader. A cost-benefit analysis had to be performed on our final equipment replacement model.

### Brief Economic History

Since its independence in 1848 from Spain, Costa Rica has enjoyed a relatively peaceful history and has become the most prosperous of the former Spanish colonies (Costa Rica: Review, 2001). Costa Rican residents benefited from the coffee business by exporting to Europe twenty to thirty years before the other Latin America countries. The Costa Rican economy benefited tremendously from Costa Rica's ability to continue foreign trade. As a result, Costa Rica was able to spend large amounts of funds in education and healthcare (Free Trade, 2001).

During the 1950s and 1960s, Costa Rica experienced strong state-owned economic activity and private-owned investment that led to growth in manufacturing, electricity generation, telecommunications, road building, and health and education facilities. The Costa Rican government adopted the import substitution industrialization (ISI) plan, a plan that was created to expand and protect the domestic market. This plan was successful in attracting foreign investors who established plants in Costa Rica, but in the 1970s, the plan began to fail. The plan affected the stability of the finances because the domestic producers found the domestic market too small. The local producers were highly dependent on the capital goods imports, and the costs of the imports were increasing due to the strict import tariffs forced by the Costa Rican government that was created to protect the domestic economy. By the end of the 1970s, the Costa Rican government had to borrow from other countries because it did not promote exports of domestic goods. With a looming debt crisis, the plan collapsed in the early 1980s (Costa Rica: Country Profile, 2002).

During the 1980s and the 1990s, the Costa Rican government offered companies many fiscal incentives to produce new products for export. This new plan, based on exporting more domestic goods, replaced the import substitution plan. The export promotion plan was successful, increasing the exports to approximately nine percent during the twenty-year period. By the end of the 1990s, Costa Rica was the largest gross domestic income than any other country in Latin America (Free Trade, 2001).

*What is the state of the Costa Rican economy in 2003?*

The new export promotion plan had some economic problems with international commitments to the World Trade Organization. These commitments called for the elimination of the export subsidies and free tax zones (Free Trade, 2001).

By investing in schools in order to educate its people, Costa Rica provided the foundation needed for economic development. The increased education of Costa Ricans also improved foreign investments because companies valued Costa Ricans' skills and abilities (Free Trade, 2001).

Costa Rica wanted and stills wants to attract high quality foreign investment that would not degrade the environment or take advantage of the Costa Rican people. Twenty-five high-tech electronic companies, such as Intel, Microsoft, and Oracle, established offices in Costa Rica (Franklin, 2000). The companies enjoy the advantage of the qualified engineers and technicians in Costa Rica.

Since the arrival of technology-based companies, the Costa Rican economy displayed a slight increase in gross domestic product (GDP). The economy has also benefited from the adjustments from the adverse conditions of trade, increase consumption from lower interest rates, and a recovery in technological exports. The Costa Rican economy has also increased largely since Intel has moved one of their plants into the country. The economy grew 8 percent in the first year in 1998. Intel contributed 5 percent of the increase (China Post, 2001). In 2001, predictions were that the GDP was expected to increase to 3.6 percent over subsequent five years due to the rise of foreign direct investment and increased exports (Financial Times Information Ltd., 2001).

In 1999, Costa Rica experienced the largest surplus trade balance in over forty years. Previous to 1999, the import revenues exceeded the export sales; however the country's different industries produced at an unbalanced rate. The large technology-based corporations grew more than 200 percent, but the livestock and fishing industries dropped nearly 60 percent, agriculture industry dropped 13 percent, textiles fell 3.3 percent, and the food industry reduced by 1.5 percent.

Costa Rica has free trade agreements with many companies, agreements that benefit the country with regards to increased production and revenue; however the agricultural industry has suffered as a result. Even though some families and communities are greatly affected, most countries benefit economically by opening up trade (Free Trade, 2003).

Costa Rica has successfully altered its economy based solely on coffee and banana exports to one based on computer components and services. Their tourism industry has also flourished due to its natural home of rain forests and safe beaches (Swenson, 2001).

*Technology in Costa Rica*

Costa Rica is greatly interested in the future technologies it has to offer. They currently keep energy supply and delivery ahead of schedule. Costa Rica has constructed a dozen hydroelectric power plants. They export some of the electricity to neighboring countries such as Nicaragua. Costa Rica's supply has increased 35 percent within the past three years (Free Trade, 2001).

The government also wants to strengthen communications in the country. In continuing efforts to improve communication, Costa Rica is now going to be using fiber optic connections for voice communications and data transmission. The country's communication and electricity monopoly, Instituto Costarricense de Electridad (ICE), wants to set up broadband internet services in more locations. By using the fiber optic cables and other new technology, Costa Rica is becoming more globally competitive. This increase in technology may open many opportunities for trade with other countries (Becker, 2003).

## Intel in Costa Rica

*Why did Intel choose Costa Rica?*

In 1997, Intel built a $300 million microprocessor test and assembly plant that accounted for half of the Costa Rican economy expansion (Quest, 2001). Intel's decision to build a company in Costa Rica was the biggest single foreign investment in the country's history (Korea Herald, 2001). Choosing Costa Rica was not an easy decision; other countries, such as Mexico, Chile, and Brazil, were also considered. In the end, Costa Rica stood out among the others due to their high standard of living and stable democracy. Intel's move was also based on the fact that Costa Rica had an educated technical work force that costs less to hire than workers in more developed nations (Carl, 2000).

Another reason Intel chose Costa Rica was due to the offer of 400,000 square feet of space in a tax-free industrial zone near the capital city of San José. They also had the assistance of the local schools to train workers and a promise of minimal government bureaucracy (Carl, 2000). Intel was impressed that Costa Rica was eager to welcome them and had permits approved within sixty days. The permits also included a special twelve-year tax break. The first eight years, which began in 1998, were intended to be tax-free and the remaining four years will be half of the usual rate. In addition to all those benefits, Costa Rica offered an energy subsidy at the rate of $0.42 kilowatt per hour and also built Intel Corporation an electrical sub-station (Franklin, 2000).

*Intel's role in the Costa Rican economy*

Intel employs 2,000 people and exports approximately 40 percent of the total Costa Rican exports; about three times that of the banana and coffee exports (China Post, 2001). Since Intel is located in Costa Rica, it has drawn other large corporations such as Proctor and Gamble, Abbott Laboratories, and Western Union. Intel invested several million dollars in the Costa Rican software company ArtinSoft, which develops advanced software that changes one software language into another (Free Trade, 2001). They have set the basis for efficiency and other business standards that have been adopted by Costa Rican companies and contractors (Carl, 2000). Intel has also helped make Costa Rica a player on the global high-tech scene (Rodriguez, 2001).

*Intel's impact in the Costa Rican environment*

Activist groups were adamantly opposed to Intel's arrival in Costa Rica due to the environmental risks imposed by the manufacturing process (Franklin, 2000). Semiconductor manufacturers' questionable environmental performances raised doubts about Intel's new plans for construction. According to the Silicon Valley Toxics Coalition (SVTC), chip making is one of the dirtiest industries in manufacturing. Since over a thousand different chemicals are used to manufacture a computer workstation and the use of these highly toxic materials is widespread, the rate of industrial illness among semiconductor workers is higher than that of other manufacturing sectors (Franklin, 2000). Another reason that the people did not want Intel in their community was because of the high-tension power lines that supply the Intel plant. People filed complaints about the wires, stating that it threatened their health and violated environmental regulations (Franklin, 2000). Due to the speculation, the Costa Rican government sped up the construction process to shield Intel. Since Intel started operations in Costa Rica, it has dispelled many of the original fears of the local people. Intel has the highest environmental standards of any company in the country, but the semiconductor manufacturing industry has a reputation of doing enormous damage to the environment wherever they go (Franklin, 2000).

*Intel's current source of raw suppliers*

Even though Intel has a high level of environmental awareness, environmental groups still worry because of Intel's use of local companies for raw materials. Intel uses local companies to supply them with products such as soldering paste, nitrogen, and photo circuits used to produce printed wire-boards. These suppliers are governed under Costa Rican law, which does not have a strict set of environmental laws. Thus, Intel is not concerned with the methods the local companies use for environmental protection (Franklin, 2000)

Currently, Intel receives its manufacturing equipment and supplies from both foreign and domestic suppliers. They are looking into further developing additional local suppliers in Costa Rica. Some local suppliers that Intel currently uses regularly include Strong International and Electrotecníca. Examples of suppliers based in Costa Rica that Intel does not use include Tecnoaguas and ESCO.

## Education

Education plays a key role in creating a diverse job market and stable economy. Nations such as the United States, Japan, England, and other European nations strive in constantly improving education. A higher education rate often can cause a higher standard in living, technological development, and better healthcare (Free Trade, 2001).

The Costa Rican education is supported by a minimum of 6 percent of government funding by law. Costa Rica is extremely proud that 95 percent of its people are literate, which is the highest literacy rate in Central America. Costa Rica also places immense emphasis on high-tech education (Free Trade, 2001).

The government also wants the education level to improve. As a result, they have been concentrating on educating more citizens at a high school level and have seen an increase of the population attending high school in recent years. Another way the government is improving education is by modernizing the laboratories, updating textbooks, and changing the way the teachers instruct their students. Teachers are teaching students at a young age to learn English or another language, an indication of Costa Rica's improved education system. This will help them to become more competitive in the workforce (Free Trade, 2001).

Costa Rica is applying new measures to improve its educational situation by increasing the number of computers in the school in order to assist in additional access to the new technologies. The Inter-American Development Bank has issued loans to invest in improving the situation (Latin America, 2002).

*Technical skills and knowledge*

Because Costa Rica started to teach the students about information technology at the grammar school level, the students will have enough technical skills and knowledge for the demand of the high-tech companies. Also, by encouraging students to use computers to conduct research and to explore different areas of interest, they benefit more from their schooling. The students have even started to write software at a young age.

Large corporations such as Intel Corporation and Microsoft are interested in Costa Rica because of the high emphasis on education. They are impressed to see that the students are learning about information technology at such a young age. With the students learning about information technology in grammar school, education has served as a foundation in the development of Costa Rica's computer software industry (Free Trade, 2001).

*Availability of skilled technicians*

The digital revolution has had an enormous impact on the industrial world, especially on Costa Rica. Costa Rica has benefited from the digital revolution because it was able to adjust to a technical country. Education is also taken very seriously in Costa Rica, which helped to contribute to highly competitive workforce. Costa Rica now has a large number of qualified engineers and technicians (China Post, 2001).

Some college graduates are becoming entrepreneurs and developing their own high-tech companies and have become engineers and technicians. The fact that Intel invested in a Costa Rican software company is also evidence that Costa Ricans are educated enough to serve high-tech companies (Free Trade, 2001).

## Equipment Maintenance and Replacement

There are three types of maintenance: improvement maintenance, preventive maintenance, and corrective maintenance (Patton, 1983). Improvement maintenance focuses on the modification and redesign of equipment in order to prevent future breakdowns. Often, this form of maintenance is performed on the manufacturing level, whether it is providing an easier way to oil bearings by adding an automatic lubricator to a piece of equipment, or changing rubber belts to chain belts. Corrective maintenance is the most common form of maintenance performed. Corrective maintenance is maintenance that must be performed in order for operations or equipment to run properly. Types of corrective maintenance include breakdown maintenance, repair, and unscheduled (Patton, 1983). As the amount of corrective maintenance performed increases, downtime and costs increase. Preventive maintenance, the third type of maintenance, is designed to reduce the amount of corrective maintenance and save valuable money by extended operating times and improved employee moral.

Preventive maintenance is used every day by a wide range of businesses, corporations, or individuals, whether it is by changing the oil in one's car or reconfiguring sensitive instruments in a nuclear power plant. The idea behind a preventive maintenance plan is to choose the best time to maintain or replace a piece of equipment in order to both prevent catastrophic failure and reduce costs, whether it is downtime costs or repair costs (Salter, 2003). Success of a good preventive maintenance program can only be measured in degrees, as some failures are inevitable.

The quality of the preventive maintenance, however, can work to a disadvantage. All parts maintained and replaced must be done so in a skilled and competent fashion. If the maintenance staff or technicians are unskilled and inept, the maintenance could cause more damage than good, thus leading to more repair costs and possibly more breakdown costs. Thus, education and skill of the technicians involved in maintenance plays an important role in a good preventive maintenance program. Often, maintenance that is contracted out proves to be the only effective way to maintain equipment. Preventive maintenance tasks can often be complicated and time consuming, requiring a dedicated maintenance personnel (Salter, 2003). If the maintenance staff is not dedicated towards performing only preventive maintenance, the result could be unfinished or improperly finished maintenance and increased resultant cost.

*Determination of Maintenance*

Several issues must be addressed when determining whether or not a task needs to be performed at all. In an ideal world, maintenance schedules would be followed precisely according to manufacturer's recommendations at the desired intervals; however in industrial equipment, this method often proves expensive, unnecessary, and unreliable. It is important, then, to determine which preventive maintenance must be performed and which preventive maintenance can wait until the equipment breaks down and requires corrective maintenance (Salter, 2003).

Environmental conditions can often vary manufacturer's recommendations greatly. Manufacturer's recommendations are often calculated in semi-ideal conditions. Some industrial operations, however, may have equipment outside exposed to environmental elements, limiting its maintenance and replacement time while other operations may have equipment in rooms free of all dust, chemicals, static, and moisture extending its maintenance and replacement time beyond manufacturer's recommendations. Thus, a variation of manufacturer recommendations is often created with both usage and environmental conditions in mind.

The first question to ask is whether or not the equipment will affect the safety of workers or customers if it fails due to lack of preventive maintenance performed (Koser, 2003). Certain pieces of equipment in nuclear power plants must always function. If the system for the water pumps fails, for instance, then the core can reach increasingly higher temperatures until it risks meltdown. Such a situation occurred during the Three Mile Island disaster.

Another question to ask is whether or not any laws or company regulations require that certain maintenance must be performed (Salter, 2003). For example, fire alarms and fire systems must be maintained at given intervals by law. In a corporation such as Intel, certain standards must be followed in order to uphold its high safety and quality standards.

The next question to ask is whether or not the system failing will affect workflow greatly and, if so, can it be avoided by maintaining it before the failure (Salter, 2003)? In manufacturing operations, if a piece of equipment causes the operations to stop for a long period of time then thousands of dollars may be lost in failed production. It is important to look at what effect the preventive maintenance will have on the system in comparison to the effect corrective maintenance will have on the system.

Finally, if preventive maintenance is determined to be essential, a determination must be made on how often the maintenance should be performed. For example, maintenance on a diesel backup electric generator is often performed each month. While the risk of the unavailability of the generator increases exponentially over time, the short time to perform preventive maintenance on the generator often results in incomplete risk elimination. As a result, it may be less expensive and more effective to perform complete overhaul maintenance every 12 months instead of a minor preventive maintenance every month (Koser, 2003).

*Maintenance vs. Replacement*

During a lifespan of a piece of equipment, the equipment often begins its life with small amounts of minor preventive maintenance. As the machinery ages, however, the manufacturer's recommendations on preventive maintenance increase drastically. These maintenance schedules often prove to be financially unrealistic.

Thus, it is necessary to determine the present and future costs of preventive and corrective maintenance and compare these costs with equipment replacement. An important question to ask is how long will maintain a piece of equipment cost more than simply buying new equipment and replacing it? New equipment often proves to be updated and more reliable, offering less maintenance costs and less machine downtime.

At the Intel plant in Costa Rica, operations are run continuously. Redundant equipment is in place in the case of failure in order to prevent disruptions in production. However, preventive maintenance is preferred over corrective maintenance to be sure there are no disruptions in production.

Equipment replacement is much more common in systems with moving parts. As a machine ages, friction will wear down parts of the equipment until maintenance costs become financially unfeasible. Electrical systems, such as UPS systems, have a longer lifespan and will be financially feasible for long periods of time considering preventive maintenance schedules are followed closely.

## Equipment at Intel Costa Rica

In order to create an effective sustainability model for the Intel plants in Costa Rica, it is essential to understand what maintenance is required, recommended, or otherwise deemed necessary. Other machine costs, such as electricity consumption, must also be considered in the equipment replacement model. Our contact at the plant provided us with the following listed in Table 1.

**Table 1: Listing of Equipment at Intel Costa Rica**

| Equipment Listing | Product Specifications |
|---|---|
| Liquid pumps | Greater than 100gpm* |
| Electric motors | Greater than 50HP** |
| Air compressors | Greater tham 500cfm*** |
| Vacuum pumps | Greater than 100cfm |
| Air handling units | Greater than 50 tons of cooling capacity |
| Dehumidifiers | Greater than 5000cfm |
| Water chillers | Greater than 250 tons of cooling capacity |

* *gpm – gallons per minute*

** *HP – Horsepower*

*** *cfm – cubic feet per minute*

*Liquid Pumps*

The product specifications of the pumps at Intel require them to be able to pump more than 100gpm (Solis, March 2003). While the exact part number or model is unknown, pumps of this capacity have very similar maintenance and service needs. There are problems common to all pumps regardless of company, model, or materials pumped (DiTaranto, March 2003). Problems can occur with the pump alignment, belts, bearings, seals, impeller blades, and miscellaneous mechanical parts such as bolts, screws, and housings (Higgins, 1977).

Many of these parts can be inspected and then replaced when deemed necessary. The methods for predicting failures are explained in the section on preventive maintenance. A schedule of replacement can be determined by examining the history of the machine and analyzing design specifications (Higgins, 1977).

Some of the most common problems experienced in liquid pumps are due to either misalignment or the incorrect amount of grease used in the bearings (Higgins, 1977). After a certain amount of use (a function of materials pumped and duration of operation), the pump may come out of alignment. Realigning a pump simply adjusts the distance between couplings and aligns the driving unit with the shims (Higgins, 1977). Aligning a pump makes everything fit together properly without there being excess pressure or force applied to one part or another.

Applying grease to the bearings of a can be a tricky process. Most of the problems associated with heated bearings are actually caused by over-greasing (Higgins, 1977). Greasing bearings requires the technician not to only add grease, but to examine how much has been added in the past and how much remains in the machine. Grease does not usually need replacement as it does not evaporate or otherwise disintegrate; however if a seal is faulty, grease can leak out causing further damage to the pump.

It is important to check all seals and grommets (DiTaranto, March 2003). A faulty or damaged seal can cause a sudden or sustained loss of lubricant or it can cause the material being pumped to leak to places it should not. Depending on the material being pumped, this can cause serious health problems.

Large liquid pumps are mainly found in an industrial setting. This can make equipment replacement difficult to schedule and expensive. Problems concerning bearing lubrication and alignment can be performed by properly trained technicians. Bearing replacement could also be performed by a technician if the proper part is available.

*Electric motors*

The motors used in the Intel plant are relatively powerful. They are rated at an output of greater than 50HP (Solis, March 2003). Electric motors are even more standard in design than liquid pumps, and therefore the maintenance is even more standard throughout the industry. Although motors seem very mechanical, only a small part of the spinning armature is in contact with parts that are not spinning (Higgins, 1977). This means the forces created by the motor have to be sustained by only a small amount of metal. The smallest, yet most important part to maintain is the bearings. It is suggested that inspections of the bearings be done on a monthly basis with other maintenance scheduled every six months or a year (Higgins, 1977). Other parts to focus on are the motor brushes and other miscellaneous mechanical parts.

The bearings of a motor that take a large amount of abuse are bathed in grease, and the entire weight of the armature rests on them at all times. When the motor is spinning, the bearings spin with it, and if a part is forced out of alignment, or off balance, the bearings absorb the stress. For this reason, they must be inspected monthly (Higgins, 1977). If a seal starts degrading and there is a loss of lubricant, the temperatures reached due to friction can cause the metals to partially weld together. At this point, the entire motor will have to be replaced. Maintaining the bearings through inspection and service is most cost effective than replacement of the module. The majority of the cost goes into labor and lost production time. Bearings require a change of lubricant annually. The change is needed because some of the grease will become ineffective as it is abused. Some systems of maintenance would suggest replacing parts only when they are about to fail. Bearings are difficult to analyze are do not yield themselves to this type of maintenance. Bearing maintenance should be performed according to schedule (Higgins, 1977).

The brushes of a motor transfer the current from the stationary power cables to the armature. The transfer of current requires the two parts to be in constant contact and can wear significantly if not maintained correctly. Standard maintenance on these parts generally requires only inspection and cleaning; however after sustained periods of time, the parts may require replacement. There is generally no lubricant placed on these parts as there are sections of the armature that must remain electrically separate from the others. A heavy lubricant would act as a partial conductor causing the motor efficiency to decrease.

Electric motors are very common items and relatively simple in design. This makes finding a technician easy and inexpensive. Parts for motors of this size can be designed specifically for one model and parts suppliers can be difficult to locate. Since the design of one motor is similar to that of another motor, substitute parts can be located as long as they do not compromise the safety or security of the operators.

*Air Compressors*

The air compressors used at the Intel plant must be able to process 500cfm. These compressors must withstand huge pressures and strong torques. The processes involved in air compressors are very similar to that of a combustion engine. Since the design is similar, the maintenance required is also similar. The specialized maintenance of an air compressor deals with the foundation as well as filters and suction lines.

It is very important to mount all large air compressors on a proper foundation (Higgins, 1977). This will prevent the machine parts from coming loose over time due to vibrations. The forces associated with these air compressors are very large and the flooring must be designed to handle them. If the compressor is located on a floor without a solid foundation, it is possible to use isolation dampers and flexible hosing to counteract the vibrations and prevent failures (Higgins, 1977).

The air to be compressed must be extremely clean as any contaminants can score the compressor's cylinder walls. If the cylinder walls are scored by contaminants, the cylinder's ability to compress the air will be lowered as there is not a good seal anymore. Severe cases can lower the efficiency of the compressor, possibly rendering it ineffective. Since the cylinder wall is in integral part of the compressor, scoring can only be repaired by replacing the entire unit. These air filters must be inspected and maintained often. If the air filters become dirty, the compressor must work harder to get the air that is to be compressed. A dirty air filter can lower the efficiency of the compressor greatly. This adds cost to production as other compressors must compensate. A 10 percent drop in input pressure can lead to the necessary addition of a 21HP compressor (Perry, 2001). Since a 1000cfm compressor needs approximately at 200HP motor to operate, the 10 percent drop in input pressure decreases efficiency by an equal 10 percent (Perry, 2001).

Large air compressors are mainly used in an industrial setting, and qualified service technicians may not be readily available in all areas; however since the majority of the maintenance concerns the air filter, technicians should be readily available. The parts required for service should also be available.

*Vacuum Pumps*

The vacuum pumps used at the Intel plant must be capable of processing over 100cfm. Vacuum pumps have a much different design than liquid pumps; therefore they require a different maintenance plan. Vacuum pumps must be designed to be air tight and able to withstand the large forces applied by the earth's atmosphere (Higgins, 1977). These forces are generally underestimated as their effects are not normally visible. Some of the forces applied by the earth's atmosphere can also cause some of the parts to fail without regular maintenance (Higgins, 1977). A failure can cause serious consequences as a result of the large forces.

Vacuum pumps of this size are not found in many buildings; therefore technicians and replacement parts would be hard to find.

*Air Handling Units*

Intel uses air handling equipment with a capacity of 50 tons of cooling capacity. Air handlers are usually units comprised of fans, cooling coils, and filters. Since the unit is complicated, the maintenance can be separated into categories focusing on each part. The maintenance can be separated into the following categories: drain pans, air filters, fan bearing and motors, and cooling coils (American Standard Incorporated, 1999).

Drain pans require frequent cleaning, and changing. Water that condenses on the cooling coils drips into a drain pan which either further drains into existing plumbing or evaporates naturally. Either way, the water is left standing in an open area and is easily contaminated. Drain pans often grow bacteria, mold, and mildew. They must be cleaned and checked for contamination.

Air filters become ineffective if they get dirty. Since the air handlers move air from all parts of the building, they routinely process dust, molds, and spores. Without filters in place, the airborne particles can be spread to all parts of the building causing employees to become ill. Depending on the area the air handler is located; filters may need changing more often than others (American Standard Incorporated, 1999). Not all of the filters are high quality HEPA style air filters, as they are very expensive. Conversely not all filters are common foam-based. Buildings will usually have a combination of both

Fan bearings and motors require the least maintenance but are also the most important; if a fan bearing fails, the air handling unit will not function. Fans often require only regular cleaning; however if more severe problems occur, the solution is usually to change the entire fan unit.

The cooling coil maintenance is more for efficiency rather than safety. When the coils become fouled their ability to transfer heat or cold is reduced (American Standard Incorporated, 1999).

Air handing units are very common in commercial buildings; therefore people who have the ability to service them should be easy to find. Parts to serve as replacements should be extremely easy to find as these devices are so common. Some specialty parts or model-specific parts may have to come from the manufacturer or a reseller.

*Dehumidifiers*

The dehumidifiers used in the Intel plant are capable of processing more than 5000cfm. Dehumidifiers are similar to air handling units, as they are made up of fans, filters and condensers (Munters, 2003). These parts are arranged differently and have different capacities. The coiling coils are replaced with coils used to condense the water in the air. This can be done with large banks of cooling coils. The equipment at the Intel plant also has a desiccant based rotary drum that is designed to pull moisture out of the air (Munters, 2003). This type of dehumidifier is very large and also very effective.

Since these large-scale dehumidifiers are not common among businesses, there is a low demand for parts and local suppliers may be difficult to locate.

*Water Chillers*

Water chillers at Intel have a cooling capacity of greater than 250 tons. The chillers function in a similar way to the air handling units; however water chillers tend to be more complicated. They not only use fans and cooling coils, but they also use pumps and sometimes burners. The maintenance required for these types of units is complicated by the fact they include so many different systems. Often it is hard to locate the cause of a problem as the functionality of the device depends on so many factors. Proper maintenance can be achieved with a schedule of inspections and occasional part replacement (American Standard Incorporated, 1999).

Maintenance of these devices is usually complicated and must be completed by a trained technician. Parts for the equipment are largely standard, except for some items such as burners and coils. Pumps, wiring, and piping should be standard and easily replaced (American Standard Incorporated, 1999).

## Cost-Benefit Economics and Sustainability

Sustainability is a term used more often in environmental science and engineering than anywhere else. Sustainability refers to the ability to remain in a stable or sustainable environment. Often, this is applied to what the anthropological affects are upon the environment. For example, the sustainability of the environment may be studied in relation to the building of a new mini-mall in a forested area or the effect of an aerial tram on the sustainability of the rainforest.

In the context of business, sustainability is defined in entirely different terms. Instead of the stable environment being a rainforest or ocean reef, the environment is the costs to and profits of the business. Instead of human effects on this environment, sustainability relates to the effects of maintenance and equipment on cost and profits (Intel, 2003f). The purpose of a sustainability model is to define policies and regulations of equipment replacement and maintenance that will best affect profits in a positive way over a long period of time.

*Cost-Benefit Analysis*

Cost-benefit analysis is a term applied to a systematic method used in determining whether or not initial costs will be justified in terms of future benefit (Sassone, 1994). In our case, we are referring to the cost-benefit of maintenance, electricity consumption, and equipment replacement. There are five steps to a cost-benefit analysis: identification of effects, quantification of effects, monetary quantification, aggregation, and sensitivity analysis (Sassone, 1994).

*Identification of Effects*

The first step of a cost-benefit analysis is the identification of each effect of the project. These effects may include higher output levels, lower maintenance costs, positive environmental repercussions, or social implications. The effects are identified at their current value and all relevant future periods. This step involves estimating the impact of the project on the effects under investigation (Sassone, 1994).

In the context of our project, this step required researching current operating costs and estimating the impact of a new equipment replacement model. Also, the development of local suppliers and the increase of local business and industries have been factored in as an effect. Increased output may also be an effect of a new model, as well as employee moral.

*Quantification of Effects*

The next step for a cost-benefit analysis is a quantification of estimates of each of the effects listed in the previous step (Sassone, 1994). This step is easy to calculate in terms of monetary and physical units but can be much more difficult when attempting to calculate the value of social and intangible effects. For example, a project based on physical goods, or even microchips, may be measured in tons per year. Although social effects are often ruled out of a cost-benefit study, in some instances it may be possible to quantify and consider the social implications. One example of this may be the number of jobs created per year or the amount of expenditures contributed to the local economy.

*Monetary Quantification*

The third step is the monetary quantification of the effects listed in the first and second steps. This step involves determining how much money exactly the extra tons of production will yields. During this stage, the analysis can develop more educated estimates, and the real numbers, in relation to monetary amounts, can be seen (Newnan, 2002).

At this stage, the costs are estimated. Rough estimates are used in initial planning and have accuracy from –30 percent to 60 percent. Semi-detailed estimates usually used for budgeting purposes range from –15 percent to 20 percent accuracy. Finally, detailed estimates, used mostly in contract bidding range –3 percent to 5 percent. Detailed estimates are extremely hard to predict, so semi-detailed estimates are usually used in more practical situations. The accuracy, as shown above, is asymmetrical. The reason behind the lack of symmetry is based on the fact that projects often underestimate costs and result in a project that goes over budget. Usually some factors are not entirely accounted for before the project begins or the project may last longer than originally anticipated (Sassone, 1994).

*Aggregation*

The fourth step to a cost-benefit analysis is aggregation. During the aggregation stage, all estimates and figures are combined into one final number reflecting lower costs. There are three ways to aggregate: by internal rate of return, a benefit-cost ratio, and net present value (Sassone, 1994). Each of the three methods has benefits and disadvantages, though net present value is often the popular approach. Each method, however, focuses on one principal: Money today is more valuable than money tomorrow. The logic behind this idea is that a dollar that is spent today could be placed in stocks and bonds and could mature to a higher dollar amount. Thus, the longer a project takes to return on investment, the less valuable that project is.

One way to determine how much a dollar today is worth in the future is through discounted future costs. Discounted is accomplished by using the formula $W_t = 1 / (1+d)^t$. In this formula, t equals the time period, with years usually used as a unit, and d is the discount rate (Sassone, 1994). The discount rate is a number that is constantly debated by economics but is usually based upon current interest rates. An example of the use of the formula is as follows:

Through a cost benefit analysis, changes in a corporation are discovered that could result in a $10,000 change in profit; however, these results will not be seen for fifteen years. After consulting current interest rates and an economist, a discount rate of 10 percent, or 0.1, is decided. Then, by using the formula, $W = 1 / (1+0.1)^{15}$, a weighted rank of about 0.24 is calculated.  Next, by multiplying the weight by $10,000 it is discovered that $10,000 has a mere equal value of $2400.  Thus, a plan that is implemented today and saves $2,500 immediately is worth more than a plan that will save $10,000 fifteen years from now.

*Sensitivity Analysis*

The last stage of a cost-benefit analysis is sensitivity analysis.  Sensitivity analysis determines which variables are most sensitive to the study over time (Newnan, 2002).  One example of a sensitive variable would be the cost of fuel.  If a cost-benefit analysis depends heavily on the price of fuel for transportation, and fuel is known to fluctuate drastically over time, then sensitivity analysis will determine how much the increase or decrease of the price of fuel will affect your study.

Sensitivity analysis is used to validate a cost-benefit analysis.  It can also be used to present an interactive final model which demonstrates various possible outcomes of a project.  Thus, the final cost-benefit analysis may come in the form of several charts and graphs depicted various changes in variables in the analysis over time.

# Methodology

As stated in the introduction, our two main objectives were to develop and establish a new model of equipment replacement for Intel and to make recommendations for the development of local suppliers. The model created can be applied to nearly every piece of supportive equipment in any Intel plant. Completions of these objectives resulted in the accomplishment of our goal.

## Development of a Equipment Replacement Model

The first objective of our project was to develop a scheduled equipment replacement model that could be applied to equipment over fifteen years. This model included the major operating parts of each piece of equipment. In order to derive a new method in determining when a major component should be replaced rather than maintained, we used equipment manuals and conducted interviews on equipment replacement. Our team performed a cost-benefit analysis after the formation of the model.

In order to determine when a piece of equipment needed to be replaced, we investigated the largest annual costs in that piece of equipment. For some equipment, maintenance may be the highest cost. With most pieces of equipment, such as pumps, electricity is the largest annual cost. Thus, our model, a model derived for a water pump, is based on electrical analysis.

Our team conducted document research in order to gain some knowledge about the equipment. Equipment specifications and identification of major operating components were found in equipment manuals. The amount of Ampere usage based on load size was also recorded from the equipment manuals.

Our team also conducted several interviews with engineers at Intel who were specialized in maintaining certain pieces of equipment. In addition, we interviewed management and engineers of four of the suppliers. Those engineers were chosen due to their expertise in the equipment under investigation. We were able to determine the validity of our findings and theories through the engineers at Intel Corporation Costa Rica and the engineers at each local supplier.

We chose liquid pumps first in order to derive an equipment replacement model. This choice was based on the simplicity of a liquid pump. The liquid pump operates with only three major operating components: the rotor, the impeller, and the motor. Since maintenance on the pump is fairly simple as well, the liquid pump seemed to be a good choice for an example of our model.

## Development of Additional Local Suppliers

Our next objective of the project was to investigate and make recommendations on the development of local suppliers. In order to accomplish this goal, we interviewed three engineers at Intel Corporation and an economist at Universidad de Costa Rica as well as distributed a questionnaire to five local suppliers.

Fabian Vargas, a mechanical engineer responsible for maintaining and ordering parts for liquid pumps and exhaust fans, provided information regarding suppliers of the previously mentioned equipment. Jorge Espinoza Gonzalez, a supplier engineer for Intel Costa Rica, provided more information regarding the issues that Intel has with some local suppliers. Finally, a short interview with Michelle Vincenti, an electrical engineer responsible for UPS systems, provided information regarding local suppliers of electronic equipment.

We also distributed a questionnaire to five local suppliers to determine the cause of Intel's problems. The questionnaire was distributed to two suppliers that Intel uses often, two suppliers that Intel rarely or never uses, and one supplier that Intel uses occasionally. The questionnaire included questions regarding the number of employees and engineers, the specialization of equipment, and the average time of completion for an order.

Our team conducted an interview with a manufacturing engineer, who is a consultant with the industry and a professor at Universidad de Costa Rica, Dr. Juan Carlos Chavez. Dr. Chavez provided information regarding suppliers in Costa Rica and the impact that Intel has on the Costa Rican economy. Dr. Chavez also provided information on the effect that Intel could have on the economy should they do business with more local suppliers.

# Results

After using the methodology of the electrical analysis of equipment replacement on the pumps, we obtained the following results. The results show that the model is versatile enough to save money in all cases tested. The model is also flexible enough to be applied to any piece of equipment that runs on electricity. The three scenarios developed for the two types of electric pumps all yielded savings over the fifteen year period.

## Electrical Analysis

The interviews conducted with engineers working for each supplier helped us develop the equation to model electricity consumption. This equation models how quickly a motor or pump will degrade by showing how the electricity consumption changes. The equation is a simple exponential growth formula taking into consideration only the initial energy consumption and the rate of increase. The equation in Figure 1 is the one used in the analysis model.

$$'\textit{Consumption at month } 0' \cdot e^{(rate \cdot month)}$$

**Figure 1: Model of Energy Consumption**

The *month* variable is simply how long the equipment has been operating and the *rate* is the rate of increase. Once data is collected on the actual amounts of energy consumption, the values can be plotted and a trend line fitted to them. The equation for this trend line will show both the '*consumption at month* 0' and the *rate*. The program created to supplement the model will perform this analysis automatically. Once one year's worth of data has been collected, the program will calculate both the '*consumption at month* 0' and the *rate*.

*Electricity Consumption*

Two categories of pumps were included when developing the model. A large 200HP pump and a small 25HP pump. This was done to exemplify the range of options available to Intel. The theoretical load on the two 25HP pumps located on the roof of building CR1 is 68.9 percent. This load results in a draw of 20.8 A of current. A fully loaded, or 100 percent loaded, motor of this size will draw 29.8 A of current. When the cost of operation is calculated for these two different currents, the result is a difference of $3,529. The specific formulas used to calculate the cost will be explained in the next section. Although the load on the motor should never be allowed to get this high, it is easy to see the possibilities of savings by simply keeping the motor running efficiently.

*Electrical Analysis Savings*

The cost of operation for each of the models was calculated using the formula shown in Figure 2.

$$\frac{(\text{Voltage} * \text{Amperage})}{1000} \text{'Motor Load'} * \text{'Hours of Operation per day'} * \text{'Days of Operation per year'} * \text{'Cost per kilowatt hour'}$$

**Figure 2: Pump Operating Cost Equation**

An example using this equation for the 25HP pumps is shown in Figure 3.

$$\frac{(460V*35A)}{1000}*90.05\%*24*355*\$0.06=\$8,689.85$$

**Figure 3: 25HP Operating Costs for one Year**

Intel chooses to calculate the cost of operation for 355 days per year rather than 365 as the pump is not continuously run throughout the year. For the minimum degradation scenario based on a rate of 0.1 percent, Intel will save roughly $860 per year when considering all of the 25HP and 200HP pumps. The mean model, which closest resembles the model currently in use, has the ability to save Intel $4040 per year on the same pumps. If all of the pumps follow the maximum degradation model, Intel could save $25,630 per year. These savings are based solely on nine of the pumps located at Intel in Costa Rica. When the model is applied to the rest of the equipment at the plant, the savings will greatly increase.

*Electrical Analysis Model Program*

We developed a program based on Microsoft Visual Basic macros in a Microsoft Excel spreadsheet. This program takes statistics based on the motor efficiency and energy consumption and compares them to actual measurements to calculate trends for each piece of equipment. The program takes 12 measurements and calculates a simple exponential trend equation for the piece of equipment. It then uses that trend equation to calculate the total annual cost of operating the machinery. The program runs through a series of loops which calculate the annual cost of operation if the machine is refurbished at any point in its life cycle.

## Local Suppliers

Information regarding local suppliers was acquired through interviews with engineers at

Intel Costa Rica, management of suppliers, and an economist. Engineers at Intel Costa Rica provided opinions and comments on why manufacturers are often used for equipment rather than local suppliers. Managers of five suppliers were also chosen to be interviewed. Intel Costa Rica uses two of the suppliers often, two are never used, and one is used occasionally. This diverse sample allowed us to compare suppliers in order to understand why Intel chooses not to receive supplies locally in many cases. The interview with the economist provided information relating to the market, the demand of industrial equipment, and the effect that Intel of Costa Rica could have on the local economy should they begin to use more local suppliers.

*Engineers at Intel Costa Rica*

The engineers at Intel Costa Rica provided much information relating to why manufacturers are often contacted before a local supplier. Interviews with three different engineers who were familiar with different suppliers yielded the same results. According to engineers at Intel Costa Rica, one reason why foreign manufacturers are often preferred over local suppliers is due to slow processing and delivery times. The average time to receive equipment when ordered through a local supplier is one to two months. The long processing time is due to delays the supplier experiences contacting the manufacturer for price estimates and information regarding the equipment. Also, shipping takes longer and costs more than order directly from the manufacturer due to the fact that Intel is able to use a cheaper and quicker contracted shipping agency when ordering directly from the manufacturer in the United States. Urgency is very important to Intel, and they seek to have the quickest processing and delivery times possible.

Another problem that the engineers at Intel have encountered with local suppliers is their lack of knowledge about equipment. When Intel is seeking to upgrade or add new equipment, sometimes the supplier lacks the technical knowledge to recommend which model would be best suited for their operation. Also, if engineers at Intel have problems with the equipment and need technical advice, the suppliers often lack the knowledge of equipment and are unable to make recommendations or troubleshoot faulty equipment. Therefore, Intel Costa Rica often avoids local suppliers altogether and contacts the manufacturer directly or foreign suppliers instead.

According to engineers at Intel, ordering from local suppliers is often more expensive than simply ordering the equipment directly from the manufacturer. Suppliers often add a small percentage to the order in order to make profit from the equipment. Shipping fees often add to the cost as well, since Intel is unable to use their contracted shipping company when using local suppliers.

*Local Suppliers*

Our team also interviewed five members of management from each of five companies based in Costa Rica in order to determine the cause for Intel's preference for foreign manufacturers. Strong International, a supplier that Intel uses often, has ten employees with five employees being engineers. Electrotécnica, another supplier often used by Intel, has 37 employees with eight being engineers. For unused suppliers, ESCO has 150 employees with an unknown amount being engineers and Tecnoaguas has six employees with three being engineers. Labs de Costa Rica, a supplier occasionally used by Intel of Costa Rica also has six employees with two being engineers.

Each supplier interviewed commented that they send their engineers to training seminars, though all except Strong would not specify how often. Strong International sends engineers to the United States for training seminars two times during a year.

We also asked each supplier which equipment they specialized in. Strong International specializes in pumps, ventilation, and hydraulics. Electrotécnica specializes in electrical equipment including UPS systems, electrical boards, regulators, and suppressors. ESCO specializes in construction equipment and air compressors. Labs de Costa Rica specializes in metal detectors, magnetic traps, pumps, fillers, and chemical products. Tecnoaguas specializes in industrial water equipment including cooling towers, water softeners, and water filtration equipment.

Of the suppliers that Intel uses, delivery times were four to eight weeks for larger equipment and a few days for smaller equipment they have in stock. For the suppliers that Intel does not use, ESCO averages eight to ten weeks to complete an order and Tecnoaguas averages eight weeks to complete an order. Labs de Costa Rica, a supplier occasionally used by Intel of Costa Rica, averages four weeks to complete an order.

Every supplier interviewed receives all of their equipment directly from the factory except Labs de Costa Rica, which receives 80 percent of their equipment directly from the factory and 20 percent from third party sources. Every supplier interviewed maintained little or no stock on their inventory and has the equipment shipped as the order is placed.

*Dr. Juan Carlos Chavez*

An interview with Dr. Juan Carlos Chavez, a professor, an economist, and manufacturing engineer, provided information relating to local suppliers and their effect on the Costa Rican economy. Dr. Chavez is a professor at the Universidad de Costa Rica and is knowledgeable about local suppliers, issues with local suppliers, and the effect that local suppliers could have on the Costa Rican economy should they be fully implemented.

According to Dr. Chavez, there is not much of a market for some of the industrial equipment that Intel requires for their operations. Costa Rica has a large workforce of qualified and educated technicians and engineers, which made establishing a plant in Costa Rica appealing to Intel Corporation. Many suppliers possess the skills to serve Intel; however, cultural differences result in poor business practices and the suppliers become unappealing to Intel of Costa Rica.

Local suppliers are very important to Costa Rica because it gives Costa Rica business and production of their own. Costa Rica is currently a society of buying and selling foreign goods, especially from the United States. If more local suppliers are used, Costa Rica could begin producing quality services of its own, perhaps even expanding globally to serve the world.

Once local suppliers are developed, Costa Rica could become more appealing for other companies to establish plants. Although some of these plants could possibly become competitors of Intel, they will provide more job opportunities and a larger local demand for industrial equipment.

## Analysis of Results

The analysis of our results provides a basis for our conclusions and recommendations. For our electrical analysis, we input three different scenarios into our computer program to demonstrate its functionality and discover a range of savings for Intel.

### Electrical Analysis

When we input values for energy consumption rates into the program, we wanted to model minimum, average, and maximum cases. We chose a consumption rate of roughly 0.12 percent. When this rate was applied to the 25HP and 200HP pumps, we discovered the refurbishing should occur after ninety months and twenty-six months respectively. The savings for this model for all pumps at the Intel plant would be around $8,000 per year. For the minimum case, we used a consumption rate of 0.07 percent. Using this rate, the program found that the 25HP pumps would need to be refurbished again after roughly ninety months. There is a slight difference in the 200HP pumps, where they would still need refurbishing after about thirty-six months. The total savings for this scenario came out to around $2,000. We used a consumptions rate of 0.36 percent for the maximum case. This yielded a refurbishing time of forty-five months for the 20HP pumps and fifteen months for the 200HP pumps. The savings for the maximum scenario came out to nearly $35,000 per year.

The trend we noticed when analyzing these models is that if the equipment at Intel degrades quickly and the electricity consumption goes up at a large rate, Intel will save more money and will also have to refurbish their pumps more often.

There are many advantages and some disadvantages of using the new electrical analysis model. This model can be applied to any piece of equipment that consumes electricity. This model can be applied to any piece of machinery containing electric motors, heaters, and heat exchangers. If the equipment contains a combination of these components, the model can be applied to each component separately to further diagnose a problem or determine the lifespan of the equipment. The trends developed for each piece of equipment can be used to accurately determine the lifespan of each piece of equipment. This information can be used in budgeting or staffing purposes. This model will also prevent unnecessary replacement or refurbishment of a piece of equipment. Currently the plan for pumps is to refurbish after sixty months. With this model, we might determine the pumps can safely run for a much longer time without harm.

There are a few disadvantages to this model as well. One is that this model requires a large amount of initial data collection before it can be fully utilized. At least one year's worth of data is required to develop the trends and initially the trends should be checked with a second year's worth of data. This was done by our team to ensure accuracy when determining the trends. A second disadvantage of this model is that it can be difficult to determine which component of the piece of equipment needs to be maintained. When it is applied to a large piece of equipment with many components, the model will only tell when the entire piece of equipment starts to run inefficiently, not when a certain component starts to fail. This is why we recommend this model be used in conjunction with the current diagnosis methods such as vibration analysis or infrared analysis.

## Local Suppliers

After reviewing data and interviewing engineers and an economist, we discovered that there is a lacking demand in the market for large industrial equipment. Intel Costa Rica is the only industry that uses some of the large equipment at this time. The three main problems are the lack of other large industrial operations, poor supplier customer service, and supplier's lack of knowledge of the equipment.

*Industrial Market*

The first problem is that Intel Costa Rica is the only industry to use certain large pieces of equipment. The local suppliers, as a result, choose to specialize in a wide range of equipment, such as construction equipment, farming equipment, and chemicals. Interviews with management from Strong International and Electrotecníca showed that those companies that have been successful with Intel have specialized in similar equipment. For example, Strong International specializes in air conditioning, ventilation, and liquid pumps. These types of equipment are not only common in many facilities other than industrial operations, but they are also similar to one another. Electrotecníca specializes in electrical boards, transformers, and UPS systems, which are also very similar to one another.

Interviews with companies with which Intel chooses not to do business showed that they often specialize in a wider range of equipment, with industrial equipment often being the less profitable equipment. One example of this is ESCO. ESCO is specialized in construction equipment and air compressors. Since construction equipment is very different than industrial air compressors and construction equipment takes up a very large portion of their sales, ESCO lacks enough technical specializes who are familiar with air compressors. Another example of this is Labs de Costa Rica. Labs de Costa Rica specialize in metal detectors, magnetic traps, chemical products, and pumps. With a very large range of different equipment, it is difficult to possess enough knowledge and technical skill to make recommendations or supply technical advice with some equipment.

*Customer Service*

The second problem is the poor customer service. The problem is the suppliers do not assign high priority to Intel's business. An interview with a member of management of Strong International yielded information regarding how their philosophy of customer service has kept Intel Costa Rica a lasting customer. Strong International responds quickly and completely to any correspondence sent to them, despite only having ten employees. They also have product specialists who are very familiar and knowledgeable about equipment that relates to Intel Costa Rica. The most frequently used suppliers responded to emails and phone calls sooner than those suppliers that were not used. This example can show how customer service values can be an issue for Intel of Costa Rica.

*Time Restraints*

The last problem deals with the length of time it takes Intel to receive a part or a piece of equipment. Of the suppliers interviewed, the most successful suppliers are those that are able to get major equipment to Intel in about a month or less. Time is very important to Intel and processing and delivery times of two months or more is unacceptable.

It is often cheaper and faster for Intel to go directly through the manufacturers to get the parts and equipment. While it may take Intel Costa Rica two to three days to receive a part straight from the manufacturer, it can take one to two months with added shipping and processing fees when using a local supplier.

*Advantages and Disadvantages*

There are several advantages and disadvantages to developing and using more local suppliers. By using more local suppliers, Intel could increase the market of industrial equipment in Costa Rica, invest in the Costa Rican economy, and adhere to Intel Corporation's mission statement. By developing local suppliers, Intel Costa Rica will increase the demand and the market for industrial equipment. Such an increase could lead to more industrial operations moving to Costa Rica, a further increased market, and lower equipment and service charges. By investing money into Costa Rican business and the Costa Rican economy, Intel will continue its policy of helping its community by placing more money into Costa Rican businesses and the economy. Local suppliers also adhere to Intel's mission statement of taking risks and investing in worldwide opportunities. One disadvantage of investing in local suppliers includes a large initial investment of training costs, physical expansion, and expedited delivery times. Another disadvantage to using more local suppliers is a slow initial processing until expedited shipping is implemented.

## Conclusions and Recommendations

After analyzing the results from the program, it is apparent that Intel will be able to save money and reduce equipment downtime by being able to accurately predict when a piece of equipment will fail. Our new electrical analysis model will be able to be applied to every piece of equipment in order to accurately predict when it will need to be refurbished or replaced.

Our plan for developing local suppliers will provide Intel eventually with lower prices and shipping charges from local suppliers. It will increase the appeal of Costa Rica to other large corporations, provide more job opportunities to Costa Ricans, and provide Costa Rica with new domestic services and products.

*Electrical Analysis Model*

Our model for determining equipment replacement will be able to save Intel money and prevent unplanned equipment failures. In order for this plan to be effective, it must be further tested, developed, and implemented. Intel needs only to follow these five recommendations to successfully implement the model.

*Electrical Analysis Model Recommendations*

1) Intel must first validate all of the statements made in developing the model and supplemental computer program. This includes checking the validity of the mathematical equations and trend models.

2) For the first year the model is implemented, Intel must take monthly measurements of the electrical consumption for all equipment included in the model. The data collected

should then be input into the program to determine an initial trend for each piece of equipment. After the first year, measurements can be taken quarterly or semi-annually and the data matched to the trend to test its accuracy. If it is determined that the trend does not accurately predict future equipment degradation, then the program can be changed to include more data points to calculate the trend equation. If the trend equations do accurately predict future energy consumption, Intel can now use the recommended refurbishing time calculated by the program. These recommendations can be customized for each piece of equipment or each category of equipment depending on how the trend equations relate to each other.

3) We recommend Intel install a system of permanent sensors to simplify the process of taking measurements. If permanent sensors are installed in some of the equipment, they can be programmed to automatically take measurements when necessary. These measurements can be automatically stored in the analysis program to further simplify the process.

4) Once the model has been successfully tested and implemented on the first group of equipment, it should be expanded to all equipment running on electricity. This can be accomplished by making small adjustments to the program to accommodate for different pieces of machinery such as heaters or heat exchangers.

5) Our final recommendation is that Intel transfer the current Microsoft Excel based program to a more stable and more versatile program language. Doing this will allow

Intel to expand the program to include features such as memory and alarms to further automate the process of equipment replacement. Intel may also implement automation through Ampere measurements made by sensors into the program.

*Local Suppliers*

After analyzing and reviewing the data, a low demand and market for industrial equipment in Costa Rica was apparent. Since there lacks a large market for industrial equipment here in Costa Rica, we determined to recommend that *Intel of Costa Rica focus on improving and developing suppliers already established in Costa Rica*, thus improving the market and increasing the appeal of Costa Rica for manufacturers and other industrial operations.

First, in order to focus on the suppliers, we recommend that Intel of Costa Rica adopt our Costa Rican Industrial Supplier Plan, or CRISP, which will focus on developing and using more local suppliers each year. CRISP should require a five to ten-year plan focused on adding five to ten percent more local suppliers each year. This goal could focus Intel's resources on bringing each individual supplier up to Intel's needs and standards. One example of a possible timeline is found in Appendix D.

*The CRISP Plan*

1) Intel Costa Rica should use an expedited shipping service with each supplier that is enrolled in the CRISP. A common issue that engineers at Intel have had with local suppliers is long delivery times. If such a service does not exist in the local supplier, we recommend that Intel help that supplier establish such a service. This not only could aid each local supplier to begin to serve Intel better, but it could also establish higher

standards for each supplier, allowing Costa Rica to become more appealing to other industrial operations.

2) Intel Costa Rica should expand their contract to include the suppliers in their shipping service. The shipping service could substitute the shipping company of the supplier in orders that Intel places for parts and equipment. This would cut the costs of shipping as well as provide Intel with the same services offered by their current shipping service.

3) Intel Costa Rica should send technicians to manufacturer's training seminars two to three times a year. Some manufacturers, including Bell & Gossett, host seminars for suppliers free of charge with housing and food included. Intel of Costa Rica would need only to pay for transportation in these cases. This could remedy the problem of engineers working for suppliers who lack knowledge on Intel's equipment. In some cases, Intel of Costa Rica may be able to host technical seminars in Costa Rica rather than send engineers to the United States.

4) Intel Costa Rica should host an annual CRISP open house. All targeted local suppliers should be contacted, and invited to the open house. This open house will focus on exchanging ideas, settling cultural differences, and hosting technical and business seminars. This CRISP open house will be advertised to every current and potential local supplier in Costa Rica. Seminars that help train engineers of each supplier in specific equipment at Intel Costa Rica would be included in the annual open house, as well as business seminars for management of these suppliers in order to improve customer

service and delivery times. Also, we recommend inviting representatives from the Costa Rican Chamber of Industries to aid in the business seminars and idea exchanges.

5) Intel should establish a quarterly or bi-annual newsletter that will be distributed to each potential and used local supplier. The newsletter will contain general information regarding Intel Corporation, some of the equipment, upcoming opportunities and seminars. The newsletter will focus on further opening communication between Intel Costa Rica and local suppliers. The newsletter should be sent in paper form to all of the suppliers as well as be available on the Intel website.

6) As part of the CRISP, we also recommend that Intel Costa Rica establish an "Intel Supplier of the Year" award that will create an incentive for each supplier to develop to Intel's standards. The award could be featured in the CRISP newsletter and also include a monetary or quantitative award as well.

7) The CRISP should be assigned to a specific employee within Intel to maintain the timeline and confirm all tasks are being completed. This person should also be in charge of contacting the targeted suppliers and preparing the newsletter.

## References


American Standard Incorporated. (2002). Applied Central-Station Air Handlers.

American Standard Incorporated (2000). Installation, Owner, and Diagnostic Manuel for IntelliPak Commercial Self-Contained Signature Series, 20 – 80 Ton.

American Standard Incorporated (1999). Series R CentraVac® Rotary Liquid Chillers 130 to 150 Tons Water Cooled.

ANSI. (1986). Pad-Mounted Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers for Use with Separable Insulated High-Voltage Connectors, High-Voltage, 34 500 Grd Y/19 920 Volts and Below; 2500kVA and Smaller. American National Standard for Transformers. 1-27

Atlas Copco (2003). ZR/ZT 110 – 750 & ZR 160 – 900 VSD Oil-free Rotary Screw Compressor Series with Variable Speed Drive Variants.

Baca, K. (2002, September). Hispanics gain ground at the Intel manufacturing site. Santa Fe New Mexican, pp. C-2.

Bagalawis-Simes, J. E. (2001, August). Philippines 1st site for Intel's New Processor Technology. Computerworld.

Becker, E. (2003, January). How Free Trade Will Alter a Hemisphere. The New York Times, pp. 4, C1.

Bell & Gossett (2001). ESP Plus [Computer Software].

Bell & Gossett (2000). Series 1510 Centrifugal Pumps – Technical Bulletin.

Bell & Gossett (1999). Series $HSC^3$ Base Mounted Centrifugal Pump Installation, Operation, and Service Instructions.

Bell & Gossett (2000). Series HSC and HSC-S Vertical Inline Mounted Centrifugal Pump

Installation, Operation, and Service Instructions.

Bounds, A. (2001, February). Intel Invests in Costa Rican Software Group. The Financial Times pp29.

Bustos, S. (1998, August). Costa Rica: Technology Hub. Latin Trade.

Carl, T. (2000, September). Exploring the Global Economy; After Bananas, Coffee and Tourism, Costa Rica Looks to High-Tech. The Associated Press.

Choo, M. (2001, October). Costa Rica - A Flourishing FDI Frontier. The Korea Herald.

CIA – The World Factbook 2002. (March 2003). Retrieved March 20, 2003, from the World Wide Web: http://www.cia.gov/cia/publications/factbook/geos/cs.html

Componentes Intel de Costa Rica. (2003). Retrieved March 20, 2003, from the World Wide Web: http://www.intel.com/CostaRica/costarica

Costa Rica: Review 2000. (2000, September). Americas Review World of Information pp1.

Costa Rica: Country Profile. (2002, September). Americas Review World of Information, pp. 1.

Costa Rica: Economic and Political Overview. Retrieved March 21, 2003, from the World Wide Web: http://www.latinbusinesschronicle.com/countries/costarica/

Costa Rica - Exports Costa Rican Exports Decline 20 Percent. (2002, February). EFE News Service.

Costa Rica Economy: Foreign Investment Likely to Rise this Year. (2003, February). Country ViewsWire pNA.

Costa Rica Economy: Business Climate Overview. (2003, January). Country ViewsWire pNA.

Costa Rica: Review. (2001, August). Americas Review World of Information. pp. 1.

Crane, D. (2002, September). The Lessons of Global Production. Toronto Star, pp. C02.

Evans, James R. (1993). Applied Production and Operations Management (4$^{th}$ ed).

Minneapolis: West Publishing Company.

Exchange Rates. (March 2003). Retrieved March 24, 2003, from the World Wide Web: http://www.x-rates.com

Financial Times Information Ltd. (2001, July). Costa Rica: Feeble Economy Heralds Political Change. Political Risk Services.

Franklin J.,Espinoza M, and Holahan D. (2000, October). Digital Paradise? Latin Trade v8 i10 pp54.

Free Trade: The Key to Success in the Western Hemisphere. (2001, October). Heritage Foundation Reports. No. 717.

Heizer, Jay & Render, Barry. (2004). Operations Management. Upper Saddle River, NJ: Prentice Hall.

Higgins, Lindley R. (1988). Maintenance Engineering Handbook (4th ed). New York: McGraw-Hill Book Company.

Higgins, Lindley R. (1977). Maintenance Engineering Handbook. New York: McGraw-Hill.

Howstuffworks. (2003). "How Does Reverse Osmosis Work?". Retrieved April 3, 2003 from http://www.howstuffworks.com/question29.htm

Intel Corporation. (2003a). Intel Corporation – General Company Information. Retrieved March, 2003. http://www.intel.com/intel/company/corp1.htm

Intel Corporation. (2003b). Componentes Intel de Costa Rica. Retrieved March, 2003. http://www.intel.com/CostaRica/costarica.

Intel Corporation. (2003c). Intel in Your Community – Costa Rica Spotlight. Retrieved March, 2003. http://www.intel.com/intel/community/costarica/spotlight.htm.

Intel Corporation. (2003d). Intel Education: Global Commitment. Retrieved March, 2003.

http://www.intel.com/education/sections/corporate1/index.htm.

Intel Corporation. (2003e). Intel in Your Community – Costa Rica Environmental Involvement. Retrieved March, 2003. http://www.intel.com/intel/community/costarica/environment.htm

Intel Corporation. (2003f). Facilities Sustainability Model. Memo presented for project Proposal. March, 2003. Heredia, Costa Rica.

Intel Corporation. (2003g). Intel y la educacion. Retrieved March, 2003. http://www.intel.com/CostaRica/costarica/educacion.htm.

Intel Sets Sight on Training One Million Teachers. (2002, June). M2 Presswire.

Latin America-Education (Schedule) World Bank: Latin America must link education, technology. (2002, December). EFE News Service.

Liebert Corporation. (1996). Operation and Maintenance Manual. USA.

Muñoz, Néfer. (1999, December). Economy - Costa Rica: Micro-chip Mirage Conceals Downturn. Inter Press Service.

Muñoz, Néfer. (2000, August). Economy - Costa Rica: Intel's Boost to Exports Masks Stagnation. Inter Press Service.

Newnan, Donald G., Lavelle, Jerome P., Eschenbach, Ted G. (2002) .Essentials of Engineering: Economic Analysis ($2^{nd}$ ed).New York: Oxford University Press.

Oscar Alvarez: Wooing Taiwan Investments to Costa Rica. (2001, December). China Post.

Patton, Joseph D. Jr. (1983). Preventive Maintenance. Research Triangle Park: Instrument Society of America.

Perry, Wayne. Maximizing Compressor Maintenance Intervals and Energy Savings. Plant Engineering, July 2001 56-58.

Rattansi, S and Segiguci, K. (2001, April). Digital Revolution Reinvigorates Costa Rica. CNN World Report 14:00, Transcript # 01042911V04.

Sassone, Peter G. (1994). Cost-Benefit Analysis. In Greenwald, Douglas (Ed.), The MacGraw Hill Encyclopedia of Economics (pg. 218 – 221) (2nd ed). New York: MacGraw-Hill, Inc.

Seyfer, J. (2001, April). Costa Rica Semiconductor Industry. Knight Ridder/Tribune Business News pITEM01116163.

Singapore, Central America: Costa Rica. (Costa Rica's Changing Economy). (1997). The Economist( US)

Smith, G. (2001, September). Who Says the Chips are Down? Business Week, pp. 68 E2.

Solution Matrix Ltd. (2002). Cost Benefit Business Case Analysis. Retrieved March, 2003. http://www.solutionmatrix.com/cbin.html.

Swenson, J. (2001, July). A Central American Standout. Latin Finance, pp. 45.

Tenenbaum, D.. (1995, October). The Greening of Costa Rica. Technology Review. V98 n7 pp42 (11).

The World Bank Group (2003). Country Profile Table. Accessed on April 23, 2003. http://devdata.worldbank.org/external/CPProfile.asp?SelectedCountry=CRI&CCODE=CRI&CNAME=Costa+Rica&PTYPE=CP

York, Thomas. (2001, May). Tech Manufacturing Costa Rica Bids To Become A 'Silicon Jungle'. Investor's Business Daily, pp. A, 6.

# Appendix A: Intel Corporate Information

## Mission and Organization of Intel Corporation

Intel Corporation, a leading supplier of microchips, motherboards, and other computer-related electronics, was founded in 1968 as a manufacturer of semiconductors for memory products. In 1971, Intel revolutionized the electronics industry with its introduction of the 4004, the world's first microprocessor. Today, Intel is the leading supplier of microprocessors. Intel currently has more than 78,000 employees in over forty-five different countries throughout the world (Intel, 2003a).

Intel's plant in Costa Rica is located 10 kilometers from San Jose in the province of Heredia. At this plant, Intel focuses on the assembly and testing of microprocessors such as the Pentium and Xeon. Three buildings are located not far from the San Jose airport. Two of the buildings, C1 and C3, are dedicated to assembly and testing, while the third building, C2, is dedicated to distribution operations. Intel Costa Rica currently has 2,000 employees, adding many job opportunities to the Costa Rican economy.

## Intel's Values and Objectives

Intel Costa Rica is proud to be ahead of its competition in the technical market. They value their excellent customer service, working environment, quality products, and loyal employees. Intel is not afraid of taking risks in order to reach their customers needs.

Their objective is to constantly be on top of technology and always improve their products well as to pursue all options technology has to offer its customers and be flexible on all worldwide ideas.

## Intel and the Community

With their various outreach programs, Intel serves the worldwide community through its various education, technology awareness, and environmental awareness programs. Employees of Intel also donate much time towards improving the quality of life around Belen, the county in which they are located. Some community activities include painting schools, planting trees, teaching, and motivating students to learn about technological and environmental issues (Intel 2003c).

Intel creates positive influences with utility companies and government agencies. Intel also shares their business practices and values with these companies. Intel holds workshops at Intel to teach these new techniques. They do not force the companies and government agencies to use their business practices. Intel explains how to incorporate the business practices into the companies' organization (Alterno, 2003).

## Intel and Education

Intel Corporation makes various efforts to improve education around the world, including Costa Rica. With the people of Costa Rica in mind, Intel offers a range of training, education, and qualification seminars to primary, secondary, and university educators. Intel is also involved directly with local schools through conferences, scholarships, and science fairs. Intel also has several objectives in education, for instance, improving the science and math opportunities that the younger generation is exposed too, educating the population that is not fortunate to have access to technology, and increasing the knowledge of technology to the general public (Intel 2003d).

Intel educates the students on safety and recycling because at this time Costa Rica does not have any education available to the public. Intel also tries to extend these ideas to the families of the students, which will educate more Costa Ricans. They have educational books that explain these ideas in a way for them to understand the new ideas (Alterno, 2003). Another person that we spoke with at Intel said that he wished that he was taught safety tips when he was younger. He suffered an accident that could have been prevented if he new about safety. He is very excited about Intel and how they educated him on safety.

## Intel and the Environment

Intel has also implemented a strong policy towards environmental management and environmental education for local Costa Ricans. Intel's Costa Rica site is greatly interested in environmental awareness and has developed a program to educate the community under their Sharing Intel Culture and Values program. This program, named the Environment, Health and Safety (EHS), has gained support from the government. They have discussed their concerns with the Ministry of Labor, Occupational Safety and Health Council, Electricity Costa Rican Institute (ICE), National Bank of Costa Rica, and many other companies and organizations (Intel 2003e). Intel’s EHS has developed many educational tools, including booklets and experimental materials that are distributed to local schoolchildren.

Intel also prides itself in keeping exceptionally high environmental standards, usually not expected of similar industrial plants in Central America. Not only does Intel adhere to any guidelines applied by the Costa Rican government, but they also adhere to any laws and regulations that would be applicable in the United States.

# Appendix B: Visual Basic Code

This appendix includes the visual basic code used to format the spreadsheet and calculate the optimum refurbishing point.

```
Private Sub CommandButton1_Click()

Rem Declaration of Variables
Dim volts As Double
Dim maxamps As Double
Dim meff As Double
Dim elect As Double
Dim total As Double
Dim totalarray(181, 0) As Double
Dim month As Double
Dim temp As Double
Dim refur As Double
Dim sheet As String
Dim a As Integer
Dim b As Integer
Dim c As Integer
Dim x As Double
Dim y As Double
Dim z As Double
Dim ctotal As Double
Dim coefficient As Double
Dim Rate As Double

Rem Assigning Initial Variable States
volts = ActiveSheet.Cells(9, 6)
maxamps = ActiveSheet.Cells(12, 6)
meff = ActiveSheet.Cells(10, 6)
elect = ActiveSheet.Cells(20, 6)
coefficient = ActiveSheet.Cells(21, 6)
Rate = ActiveSheet.Cells(22, 6) / 0.7
ctotal = 0
total = 0
temp = 0
refur = ActiveSheet.Cells(17, 6)
sheet = ActiveSheet.Name
a = 0
c = 0

Rem Clear old data and format cells
```

```
ActiveWorkbook.Worksheets(sheet).Range("x1:z180").Delete
ActiveWorkbook.Worksheets(sheet).Range("y1:z180"). _
     NumberFormat = "$#,##0_);[Red]($#,##0)"


Rem Loop to calculate cost for every refurbishing point
For y = 1 To 180
b = 180 / y
If (180 / y) > b Then
b = b + 1
End If
    For x = 1 To b
        For z = 1 To y

        total = total + ((volts * (coefficient * _
            Math.Exp(0.7 * Rate * z))) / 1000) * 24 * _
            30.41 * elect * meff
        temp = ((volts * (coefficient * Math.Exp(0.7 * _
            Rate * z))) / 1000) * 24 * 30.41 * elect * meff
        a = a + 1
        If a = 180 Then GoTo 20
        If (coefficient * Math.Exp(0.7 * Rate * y)) > _
            maxamps Then
            c = 1
            GoTo 30
            End If
        Next z
        total = total + refur
    Next x
20     totalarray(y, 0) = total
    ActiveSheet.Cells(y, 26) = total / 15
    total = 0
    a = 0
Next y

Rem Store 60 month value in a separate variable
Rem and prepare 'y' for next loop
30 ctotal = totalarray(60, 0)
total = totalarray(x, 0)
y = y - 1

Rem Loop to transfer array data to cells for use in charts
For x = 1 To y
    If total > totalarray(x, 0) Then
        total = totalarray(x, 0)
        z = x
    End If
```

```
    ActiveSheet.Cells(x, 24) = x
    ActiveSheet.Cells(x, 25) = ctotal / 15
Next x

Rem Print totals on main screen
ActiveSheet.Cells(2, 5) = ctotal / 15
ActiveSheet.Cells(3, 5) = total / 15
ActiveSheet.Cells(4, 5) = (ctotal - total) / 15
ActiveSheet.Cells(5, 5) = z & " Months"

Rem Prepare and create chart
ActiveSheet.Cells(1, 1).Activate
ActiveWorkbook.Charts.Add after:=ActiveSheet
With ActiveChart
    .Type = xlXYScatter
    .SeriesCollection.Add Source:=ActiveWorkbook. _
          Worksheets(sheet).Range("z1:z180")
    .SeriesCollection.Add Source:=ActiveWorkbook. _
          Worksheets(sheet).Range("y1:y180")
    .SeriesCollection(1).XValues = ActiveWorkbook. _
          Worksheets(sheet).Range("x1:x180")
    .SeriesCollection(2).XValues = ActiveWorkbook. _
          Worksheets(sheet).Range("x1:x180")
    .SeriesCollection(1).Name = "New Model"
    .SeriesCollection(2).Name = "Old Model"
    .SeriesCollection(1).MarkerStyle = xlMarkerStyleNone
    .SeriesCollection(2).MarkerStyle = xlMarkerStyleNone
    .HasTitle = True
    .ChartTitle.Text = "Optimum Point of Refurbishment"
    .SeriesCollection(1).Points(z).ApplyDataLabels
    .SeriesCollection(2).Points(z).ApplyDataLabels
    .SeriesCollection(1).Points(z).DataLabel.Font.Size = 16
    .SeriesCollection(2).Points(z).DataLabel.Font.Size = 15
    .SeriesCollection(1).Points(z).DataLabel.Position = _
          xlLabelPositionBelow
    .SeriesCollection(2).Points(z).DataLabel.Position = _
          xlLabelPositionAbove
    .SeriesCollection(1).Points(z).MarkerStyle = _
          xlMarkerStyleX
    .SeriesCollection(2).Points(z).MarkerStyle = _
          xlMarkerStyleX
    .SeriesCollection(1).Points(z).MarkerForegroundColor _
          = RGB(255, 0, 0)
    .SeriesCollection(2).Points(z).MarkerForegroundColor _
          = RGB(0, 0, 255)
    .SeriesCollection(1).Points(z).MarkerSize = 10
    .SeriesCollection(2).Points(z).MarkerSize = 10
```

```
    With .Axes(xlValue)
        .HasTitle = True
        .AxisTitle.Caption = "Total Annual Operating Cost"
    End With
    With .Axes(xlCategory)
        .HasTitle = True
        .AxisTitle.Caption = "Months Between Refurbishing"
    End With

End With

Rem return to summary sheet
ActiveWorkbook.Worksheets(sheet).Activate
End Sub
```

# Appendix C: Interview Questions for Local Suppliers

1.) How many employees work for your company?

2.) How many engineers work for you company?

3.) What type of training and education do your employees receive?

4.) What other companies in Costa Rica do you serve?

5.) What type of equipment do you specialize in?

6.) What is the average length of time to complete and ship an order?

7.) Do you receive equipment directly from the manufacturer or do you go through another supplier?

8.) Do you order parts as the order is received, or do you keep a stock of parts on hand?

9.) What extra steps, if any, do you take to ensure that Intel is a satisfied customer

## Appendix D: CRISP Annual Timeline Example

The following is an example of a possible timeline for the CRISP program. A similar timeline should be implemented and continued over a five-year period or until all local suppliers in Costa Rica are developed.

**Table 2: CRISP Annual Timeline Example**

| Month | Task |
|---|---|
| January | Enroll one new supplier in the CRISP Plan |
| | Prepare to send enrolled supplier engineers to seminar |
| Febuary | Distribute CRISP newsletter to all current and potential suppliers |
| March | Host CRISP Open House |
| April | Enroll one new supplier in the CRISP Plan |
| May | Distribute CRISP newsletter to all current and potential suppliers |
| June | Prepare to send enrolled supplier engineers to seminar |
| July | Present "Supplier of the Year" Award |
| August | Distribute CRISP newsletter to all current and potential suppliers |
| September | Enroll one new supplier in the CRISP Plan |
| November | Prepare to send enrolled supplier engineers to seminar |
| December | Distribute CRISP newsletter to all current and potential suppliers |