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A Statistical Based Model to Manage Perishable Goods Within a Cold Supply Chain

Amanda Rhiana Hicks
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Amanda Rhiana Hicks entitled "A Statistical Based Model to Manage Perishable Goods Within a Cold Supply Chain." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

Rapinder Sawhney, Major Professor

We have read this thesis and recommend its acceptance:

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Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Acceptance for the Council:

Vice Chancellor and Dean of Graduate Studies

A STATISTICAL BASED MODEL TO MANAGE PERISHABLE GOODS WITHIN A COLD SUPPLY CHAIN

A Thesis
Presented for the
Masters of Science
Degree
The University of Tennessee, Knoxville

Amanda Rhiana Hicks
December 2005

ABSTRACT

"Cold chain" management, the management of a temperature sensitive supply chain, has its own particular set of logistical challenges and issues when compared to a non-temperature sensitive supply chain. Current supply chain management techniques and tools that are utilized today in industry do not take this unique set of challenges into account. This thesis will focus on how using a model that has been built upon the theories of statistical process control techniques that does take the challenges into account, when monitoring and evaluating in-transit shipment of perishable goods throughout the cold supply chain, can assist in continuously improving the cold supply chain, accomplishing the ultimate goal for every perishables retailer, delivering cheaper, better, and fast moving products, that are not only safe but top quality products to happy end customers world-wide.

The goal of this thesis is to educate individuals involved in cold supply chain management in the deficiencies of the current techniques used in industry to manage a supply chain and how a new statistically based process improvement model, which takes in account the perishable nature of cold supply chain products, can assist in the cold supply chain management and improvement process.

For this expanding market, optimizing the increasing volumes of "temperature-sensitive" material flow through the cold supply chain is not only needed but required due to the fact that the current state of the management of the cold supply chain is negatively affecting product quality and all financial bottom lines in the food industry. In addition, new and emerging pressures, stricter guidelines on quality control, improved methods and technologies for transporting perishable goods, plus tougher food safety and public health regulations, have compounded the need for cold supply chain management tools and models that aid in making cold supply chain improvements. The logistical handling of perishable food products and the quality of a cold supply chain has gained new attention since poor cold chain management can result in billions and billions of dollars of wasted perishable products for businesses.

Beef patties, for example, which have a quality standard of -10°F, if delivered at -6°F will be dehydrated, may now have a different cooking time than that recommended on the package, a deteriorated taste and also be subject to bacterial growth. Consequently, the consignee could refuse the shipment, implement charge backs, suffer losses due to deteriorated product, litigate or find a different carrier.

With more regulations being applied to a cold supply chain looming, businesses with a cold supply chain require tools and models that are currently unavailable to assist in managing the cold supply chain's logistic practices and processes to ensure optimal outcome of such temperature sensitive goods ultimately improving bottom lines, which is especially important since most businesses who are involved in a cold supply chain run on razor thin profit margins. This thesis has been designed to help such mentioned individuals in their cold supply chain management via a statistically based proven cold supply chain model for continuous improvement.

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CHAPTER 1

INTRODUCTION

1.1 Background

"Cold chain" management, the management of a temperature sensitive supply chain, has its own particular set of logistical challenges and issues when compared to a non-temperature sensitive supply chain. Current supply chain management techniques and tools that are utilized today in industry do not take this unique set of challenges into account. This thesis will focus on how using a model that has been built upon the theories of statistical process control techniques that does take the challenges into account, when monitoring and evaluating in-transit shipment of perishable goods throughout the cold supply chain, can assist in continuously improving the cold supply chain, accomplishing the ultimate goal for every perishables retailer, delivering cheaper, better, and fast moving products, that are not only safe but top quality products to happy end customers world-wide.

The goal of this thesis is to educate individuals involved in cold supply chain management in the deficiencies of the current techniques used in industry to manage a supply chain and how a new statistically based process improvement model, which takes in account the perishable nature of cold supply chain products, can assist in the cold supply chain management and improvement process.

As a part of this thesis, the reader will be provided background information concerning the subject at hand in the introductory chapter. The introductory chapter will discuss the problem at hand, the need for the study, the impact on businesses involved in a cold supply chain, and the research objectives will be thoroughly defined. A literature search will also be included that will discuss the current methodologies that are being used in industry for managing a supply chain along with other key cold supply chain related topics and definitions relative to the thesis topic. The literature search will be followed by a methodologies chapter, which will define the statistical model that has been designed to revolutionize the industry by assisting managers in improving their cold supply chain management by implementing techniques of process improvement and statistical process control within their cold chain. The methodologies chapter will be followed by two case studies documenting not only the concepts of the methodology itself but how the model was used in industry to proactively locate problematic areas within a restaurant chains' and retailers' cold supply chain as a part of an ongoing continuous improvement of the cold supply chain program. The final chapter will discuss the results and recommendations derived from the industry case studies. It will also include a review of what has been learned thus far from using the cold supply chain statistical model, how others can benefit from what has been learned along with a definition of what next steps could be done as a continuation of this work.

Please note that this thesis will focus on the component of cold supply chain degradation that is the key contributor to cold supply chain losses only, the culprit of such losses being temperature.

With the techniques discussed in this thesis, several millions of dollars of wasted food products can be saved every year with simple changes in cold supply chain management and the process deficiencies that are discovered through statistical process control and the model that has been developed. With the cooperation of all parties involved in a cold supply chain, a win - win result for all is possible, perishables that are not only safe but top quality delivered to end consumers with maximum profits discovered for all businesses involved.

1.2 Statement of the Problem

Pre-cooked, portion-controlled, frozen, chilled and vacuum-packed foods account for more than half the food purchases we make today. Almost 50 percent of food products we consume did not exist 10 years ago and this will probably be the case again for the food industry in 10 years time (17, 21).

For this expanding market, optimizing the increasing volumes of "temperature-sensitive" material flow through the supply chain is not only needed but required due to the fact that the current state of the management of the cold supply chain is negatively affecting product quality and all financial bottom lines in the food industry. In addition, new and emerging pressures, stricter guidelines on quality control, improved methods and technologies for transporting perishable goods, plus tougher food safety and public health regulations, have compounded the need for cold supply chain management tools and models that aid in making cold supply chain improvements. The logistical handling of perishable food products and the quality of a cold supply chain has gained new attention since poor cold chain management can result in billions and billions of dollars of wasted perishable products for businesses. With more regulations being applied to a cold supply chain looming, businesses with a cold supply chain require tools and models that are currently unavailable to assist in managing the cold supply chain's logistic practices and processes to ensure optimal outcome of such temperature sensitive goods ultimately improving bottom lines, which is especially important since most businesses who are involved in a cold supply chain run on razor thin profit margins.

1.3 Need for the Study

For starters, the temperature-sensitive requirements of virtually all chilled, fresh and frozen foods cannot be underestimated. Even the smallest fluctuation in heat levels inside a food transport truck caused by insufficient refrigeration, distribution delays or improper handling will have an immediate impact on food safety, product yield and taste.

Beef patties, for example, which have a quality standard of -10°F, if delivered at -6°F will be dehydrated, may now have a different cooking time than that recommended on the package, a deteriorated taste and also be subject to bacterial growth. Consequently, the consignee could refuse the shipment, implement charge backs, suffer losses due to deteriorated product, litigate or find a different carrier.

Fresh fruits and vegetables, which once enjoyed a romantic history of being transported from the countryside in open-sided, canvas-covered trucks, are now subjected to more technology and handling standards than ever before. In many locales, temperature, humidification and ethylene control systems control the ripening process in transit so the produce reaches the supermarket fresh, ripe and ready for sale.

In the case of fast food distribution, where shipments typically consist of a product mix each with its own temperature band tolerances, the picture is similar: improper loading procedures, incomplete data collection, poor technical control of multi-temperature requirements and the result is inevitable. In the chilled and frozen food business, poor logistics upstream means poor - or no - product downstream.

The frozen food category can also be seen as an unruly candidate for many current logistics theories and practices. Efficient consumer response tends towards smaller and more frequent shipments which means more frequent stops, inconsistent handling and, for perishables, a much higher risk of wastage. Shippers often note the difficulty of maintaining proper temperature control on a multi-stop shipment when loads are consolidated.
At the loading dock, delays, which occur while receivers review shipping notices from consolidated carriers, provide another opportunity for product failure.

Delivery bay congestion, caused by more vehicles bringing in chilled and frozen product, means the enforcement by retailers of restrictive time windows. Consequently, night operations of cold storage and vehicles are increasing, creating pressure on distributors to invest in communication systems to minimize dwelling, fuel and mileage.

In the past, the supply chain for fresh, frozen and chilled food has been largely an unregulated industry, the exceptions being voluntary standards and quality control guidelines set by industry for product quality and hygiene practices.

In Europe, food distributors comply with regulations governing constructions standards of refrigerated motor carriers, public health and food safety regulations, plus road transport legislation. Since 1976, the European Union (EU) construction standards for controlled temperature bodywork of motor carriers have been monitored by the Accord Transport Perissables (ATP) authority. Body or trailer types submitted for ATP approval are subjected to a thermal temperature-holding test in which the rate of heat dissipation from a 30°C temperature inside the trailer into the ambient 10°C of the chamber is measured. Depending on its thermal performance in the ATP test, the body or trailer is assigned one of six different ATP classifications for carrier use. Additional recent legislation establishing the maximum temperatures at which chilled or frozen products must be preserved in transit are found in the European Union's Directive 93/43/EEC of June 1993. Legislation governing food storage and distribution temperatures for hygiene and public safety has yet to be harmonized within the EU. However, some individual states have implemented their own regulations dictating maximum temperatures for vehicles carrying chilled produce (9).

In the United States, the Clinton administration took a number of steps to improve food safety standards, largely at the behest of food safety experts, the Center for Disease Control and Prevention, the Food Safety and Inspection Service (FSIS) and the Food and Drug Administration (FDA). In his 1998 budget proposal, President Clinton requested $43 million to fund an industry watchdog program for increasing safety inspections, food safety research, risk assessment, training and education. As well, the FSIS and the FDA have issued legal requirements for the meat poultry and seafood industries to follow Hazard Analysis Critical Control Point (HACCP) procedures. First developed by the Pillsbury Co. for the NASA space program in 1959, the HACCP system is an assessment of potential biological, chemical and physical hazards introduced into the food by all process inputs. Though still in its infancy in the United States, and largely directed towards food manufacturers, processors and retailers, the scope of the HACCP principles may yet expand to every link in the supply chain to include transportation and distribution (23, 27).

With regulatory constraints looming on the horizon, its development and disciplines have, it would appear, a very long way to go. In fact, to many suppliers of food products, managing a cold supply chain from point of production through to the end receiver is undiscovered country that is in fact a mystery. What happens to the product when it leaves the plant? Has the temperature been lowered enough to keep it fresh and safe until the consumer buys it? Are there any weak links in the supply chain? And, who is responsible for the product once it leaves the plant anyway? Regardless of responsibility and level of control over the supply chain, the lack of effectiveness reflects on the product and all parties involved, especially the supplier who has its brand name on it and the store or restaurant it in fact has been purchased or consumed at.

Improper temperature management of a cold chain leads to shorter shelf life, deteriorated product quality, and growth of pathogenic microorganisms, which create product loss and consumer concerns. Given the critical nature of these issues, it is very important to understand, measure and continuously improve the refrigeration methodology that is required in each stage of the supply chain to ensure the interaction between each stage in fact is managed appropriately; however, currently there is a lack of visibility that allows one to review the refrigeration methodology used at each step of a cold supply chain.

1.4 Research Objectives

In order to understand a cold supply chain of this nature, one must do above and beyond what is required in managing a non-temperature sensitive supply chain. Its no longer simply about getting the right product, to the right place, at the right time which current supply chain management techniques, data collection systems and models address; its about getting the right product, to the right place, at the right time, in the right condition. Condition is the key to success in all cold supply chains. Currently the condition piece of the puzzle is lacking techniques and models used to measure cold supply chain performance. In order to take condition of product into account, one must have a supply chain model that includes the following:

- Establishment of an optimum temperature for the product. The temperature must be based on product quality parameters that provide the best quality product out turn. Currently, within industry, these optimal temperature requirements have been developed for every product in existence within in industry; however, current supply chain management techniques, data collection systems and models do not take this important piece of information in account.

- A profile of the complete cold supply chain is required on an on going basis. Examination of all aspects of the chain including refrigeration facilities, docks, transportation systems, warehouses, and end users in regards to temperature is required to ensure proper quality out-turn. Currently, temperature monitors exist in industry to accomplish profiling the complete cold supply chain; however, again no tools exist to massage the data and turn it into valuable, usable information for managers.
- Based on optimum temperatures that have been defined, a cold supply chain must be modeled, analyzed and continuously measured to ensure that the cold supply chain has adhered to standard operating procedures in regards to specified product temperatures. Proper temperature monitoring and analysis is key to proper cold supply chain management and will allow for achieving the optimum temperature that is required to get product to end customers in the right condition.

While the above-mentioned items sound fairly straight forward, temperature fluctuations throughout a cold supply chain are not well understood by most major food manufacturers, supermarkets, restaurant chains and end consumers. Also in today's retail industry, as mentioned above there is a lack of cold chain management standards for perishable food products along the cold supply chain, meaning that there is even a lack of understanding in governmental agencies across the globe. In the absence of such a standard, there is always a potential danger of food contamination resulting from frequent breaches along the links of the cold supply chain.

Hence, proper management of every link of the cold supply chain constitutes an integral part in the production and delivery of wholesome perishable food products to the consumers. Any breaches along the links of the chain would be hazardous and pose a serious threat to the health of consumers. Again, something that most every day supply chains of most major manufacturers do not have to think about, condition of their goods in regards to health.

Good cold supply chain management results in the consumer receiving a product of "fresh" quality, leading to greater satisfaction and increased demand. The cold supply chain often involves long journey times and frequent handling whether they be by sea, air or truck. This makes effective cold chain management more difficult but even more essential to ensure the product offered for final sale retains maximum freshness. Maintaining the cold supply chain is the responsibility of everyone who handles the product, from production to retail sale. A breakdown in temperature control at any stage will impact on the final quality of the product, although the effect may not be visible until several days later when it is in the hands of another party who may or may not have been responsible for the temperature breakdown. Clearly, there is a need for understanding what it takes to accomplish good cold chain management and there is a need to develop tools and models that support good cold supply chain management so that everyone can successfully accomplish the goal at hand, delivering not only safe but top quality products to end customers.

As mentioned above currently, there are no models that have been developed that are being utilized within the industry to help assist in ongoing cold supply chain management. In this thesis a model will be discussed, evaluated and proven that will revolutionize the industry's way to effectively manage and continuously improve a cold supply chain.

CHAPTER 2

LITERATURE SEARCH

2.1 Background

After reviewing numerous refrigeration, supply chain, cold chain, retailer, foodservice, supply chain, and temperature related journal articles from the World Wide Web and from the library databases at the University of Minnesota and the University of California Davis, both universities specializing in cold chain management, it has been determined that no research has been done concerning cold chain management and the usage of statistical process control models in continuously improving a cold chain's temperature management. Thus, my literature search will focus on related topics that are important to understand when applying the approach discussed within this thesis. Topics to be covered in the literature search section include the following: supply chain challenges, the forces that effect the future of supply chain management, the principles, major paths and the approaches to a traditional supply chain. Also the literature search will discuss cold chain management and how temperature management affects the cold chain and a companies bottom line who is involved in a cold supply chain.

2.2 Definition of a Supply Chain

Defined at a high level, the supply chain encompasses all value added activities involved in delivering a product to an end customer: manufacturing, logistics and transaction management. Using this definition, the supply chain must be considered to be among the most critical set of processes in any enterprise, even as they become more complex and global in nature. That complexity is evident in both the inbound and outbound segments of the supply chain (1, 3, 6).

2.3 Supply Chain Challenges

To remain competitive, industrial organizations are continually faced with challenges to reduce product development time, improve product quality, and reduce production costs and lead-times. Increasingly, these challenges cannot be effectively met by isolating change to specific organizational units, but instead depend critically on the relationships and interdependencies among different organizations. With the movement toward a global market economy, companies are increasingly moving toward specific, high value-adding manufacturing niches. This in turn, increasingly transforms the above challenges into problems of establishing and maintaining efficient material flows along product supply chains.

The ongoing competitiveness of an organization is tied to the dynamics of the supply chain in which it participates, and recognition of this fact is leading to considerable change in the way organizations interact with their supply chain partners (2, 5).

2.4 Definition of Supply Chain Management

Since its inception about 15 years ago, the field of supply chain management has become tremendously important to companies in an increasingly competitive global market. Supply chains exist in both service and manufacturing organizations, although the complexity of the chain may vary greatly from industry to industry and firm to firm. Supply chain management refers to the entire network of companies that work together to design, produce, deliver, and service products or in other words, it is a network of facilities and distribution options that perform the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. In the past, companies focused primarily on manufacturing and quality improvements within their four walls, now their efforts extend beyond those walls to encompass the entire supply chain (3).

Some doubts about supply chain management have throughout the past 10 years. Recent developments at three major US corporations provide the answers to these doubts, boldly underscoring the impact of supply chain management on modern business.

- *Dell Computer*, founded on a vision of customer-responsive order fulfillment, has seen its stock price nearly 200-fold since 1990. "We have a quick-ship plan for large customers were we can deliver a machine within 48 hours of an order" –Michael Dell (36)

- *Boeing Aircraft*, one of America's leading capital goods producers and top exporters, was forced to announce write-downs of $2.6 billion in October 1998. The reason? "It is blaming on raw material shortages, internal and supplier part shortages, and productivity inefficiencies…" (26)

- *Proctor and Gamble*, long revered for its marketing touch, also drives its supply chain hard. The company estimates it saved retail customers $65 million through logistic gains over the past 18 months. "According to P&G, the essence of its approach lies in the manufacturers and suppliers working closely together…jointly creating business plans to eliminate the source of wasteful practices across the entire supply chain." (26)

Clearly, supply chain management, good or bad, directly affects corporate performance. Most companies have realized most of these gains achieved from an internal focus, however; the opportunities that exist through cooperation and collaboration are the new frontier. (15)

In order to continue into the new frontier, existing disagreements over the future of supply chain design and deployment must be dissolved. Senior supply chain professionals express a broad range of views on their future role, despite the current widespread recognition of the field's growing importance.

2.5 Forces that Effect the Future of Supply Chain Management

There are many factors on importance when discussing supply chain management that are continuously discussed by senior supply chain professionals; however, there are six business and economic forces that will most impact the future of all supply chain management (14, 30).

1. Consumer Demands
2. Globalization
3. Competition
4. Information and Communications
5. Government Regulation
6. Environment

2.5.1 Consumer Demands

The answer to the question, "What do Customers want?" is "All of the above." Customers will expect to be able to get everything and anything in a short and timely manner and they will get it. There has been a shift in power from the supplier to the customer. Corporations today work to balance low cost with high level of service and customization with availability. The new paradigm for many products and in many segments of the marketplace will be that customers demand everything. This means instant availability of customized products, inexpensively and wrapped in a high services bundle. The bar will continue to rise inexorably on expectations of choice service, speed, and cost. These expectations are fostered by consumers' experience in a few influential areas: home computers (i.e.: Dell and Gateway 2000), clothing (i.e.: L.L. Bean, Lands' End, and J. Crew), books (i.e.: Amazon.com and Barnes & Noble), and overnight package delivery (i.e.: UPS and FedEx). In these areas products are becoming better, cheaper and available faster and faster (16, 31, 32).

Customers now expect such performance from other segments of the economy as well. In fact, the 1998 Toyota Camry and Ford Taurus are better equipped and less expensive than the 1997 models they replaced. These and other automakers are moving toward delivering vehicles within a very shot timeframe. (Volkswagen, for example, aims to deliver a made-to-order vehicle within two weeks of customer order). Cadillac already offers near-custom vehicles within 24 hours of customer order in the Florida market. The trend clearly is to offer customers what they want, when they want it, and at a price lower than competition (31, 32).

2.5.2 Globalization

Most observers expect dramatic shifts, in global demographics and economic power. Corporations based in the US and Europe discovered long ago the attractiveness of parts and products sourcing from China, Mexico, and other emerging economies. They also have been investigating in these emerging nations' markets. This trend will accelerate as these economies pick up western-style democracies throughout the world. In fact, some places of economic central planning are in the process of being discredited such as, South Korea, Thailand, Malaysia, Indonesia, and many other economies undergoing structural transformation. Even Japan is in a recession that will require structural changes similar to those forces on its neighbors. These transformations will only accelerate the long-term development of East Asia and South America (36).

Not only will businesses need to serve markets around the globe, but companies also will have to provide comparable levels of service worldwide. The communications revolution and globalization of consumer culture will not tolerate hand-me-down automobile design or excessive delivery times even in markets like China, India, or Indonesia (28, 36).

2.5.3 Competition

Tougher competition will continue to spur supply chain innovation. This competition stems from several sources: advances in industrial technology, increased globalization, tremendous improvements in information availability, capital resources, and creative business design. These forces have places traditional market leaders under attack.

As the pursuit of market share becomes no longer sufficient to ensure profitability, companies will focus on redefining their competitive space. Today, start-up companies can become almost a global phenomena overnight. This dynamic will raise the competition to a new level, redefining the game constantly in most industries (29).

2.5.4 Information and Communications

The information explosion is of important significance to supply chain leaders. New developments seem incredible as compared to those in the historical record books. Surprisingly enough, the future still holds for even more remarkable information breakthroughs. These will occur by way of the Internet and other powerful tools and techniques that will be readily available.

2.5.5 Government Regulation

Governments even though slow moving will continue to influence the shape of supply chain evolution. With the recent activities on 9/11/02, the department of defense has been to pay special attention to all goods moving in and out of the United States and between the states. As technology strengthens, the department of defense and homeland securities will begin to make demands for those moving goods to understood where, when, why, and how all items are moving throughout the country.

2.5.6 Environment

Pressures linked to the environment (i.e.: recycling, sustainable eco-efficiency, and waste minimization) will undoubtedly affect future supply chain design. For example, Volkswagen is required to take responsibility for automobile recycling (7).

2.6 Supply Chain Management's Role in the Next Century

Now that more definition has been placed in supply chain management's future, here are a few key points that will help to predict supply chain management's role in the next century:

- Emphasis will shift to the broader supply chain from the narrower logistics discipline, to derive the greatest value.
- Supply chain management will provide true competitive advantage only when new concepts, practices, performance are combined to sharply impact companies' and customers' bottom lines.

- Supply chain mangers must harness the leading external drivers of change including rising consumer demands, globalization, and information/communication.
- The future responsibilities of the supply chain manager will change, although his or her organizational level may appear to be similar to those of today's.
- If companies are to survive and prosper, their supply chains will have to be managed far more effectively than at present. The major forces will place huge burdens on supply chain managers.
- Customers will keep demanding better service, wider choices, and lower costs.
- Parts and finished goods will have to be shipped from and to any point in the world.
- Competition will intensify.
- Information technology will keep changing what is available to and what is required of managers.

To meet these increasingly demanding business requirements future supply chain will have to deliver remarkably high levels of performance. Product innovation and choice, speed and precision of delivery, global access to the latest models, environmental imperatives can only be met through far more effective supply chains. Product design or marketing brilliance alone cannot meet this challenge. Rather, companies will depend on much better designed and managed supply chains to deliver what customers want, due to global competition, while providing superior returns to shareholders (11, 12, 13).

2.7 Principles, Major Paths and Approaches to Current Supply Chain Management, Their Strengths and Weaknesses

There are several approaches currently utilized in industry for supply chain management that are being used primarily to meet these strenuous demands. The four major paths that currently allow supply chains to deliver against the new requirements include: flexible, integrated design, household replenishment, and virtual organizations paths. However, before discussing the different paths and approaches to supply chain management, it is important to keep in mind some key principles of supply chain management. Adherence to these principles will help in determining what customers want and how to coordinate the efforts across the supply chain to meet those requirements faster, cheaper, and better.

2.7.1 Principles of Supply Chain Management

Principle 1

Segment customers based on the service needs of distinct groups and adapt the supply chain to serve these segment's profitability.

Segmentation has traditionally grouped customers by industry, product, or trade channel and then taken a one-size fits all approach to serving them, averaging costs and profitability within and across segments. The typical result is that no one ever fully understands the relative value customers place on service offerings.

By segmenting customers by their particular needs, the company is equipped to develop a portfolio of services tailored to various segments. Surveys, interviews, and industry research have been the traditional tools for defining key segmentation criteria.

A company should also apply a disciplined, cross functional process to develop a menu of supply chain programs and create segment-specific service packages that combine basic services for everyone with the services from the menu that will have the greatest appeal to a particular segment. The goal is to find the degree of segmentation and variation needed to maximize profitability.

The customers' needs and preferences do not tell the whole story. The service packages must turn a profit, and many companies lack adequate financial understanding of their customers' and their own costs to gauge likely profitability. This type of knowledge is essential to correctly match accounts with service packages, which translates into revenues enhanced through some combination of increases in volume and/or price. Only while understanding their costs at the activity level and using that understanding to strengthen fiscal control can companies profitably deliver value to customers.

Most companies have a significant untapped opportunity to better align their investment in a particular customer relationship with the return that customer generates. To do so, companies must analyze the profitability of segments, plus the costs and benefits of alternate service packages to ensure a reasonable return on their investments and the most profitable allocation of resources. To strike and sustain the appropriate balance between service and profitability, most companies will need to set priorities, and sequence the development of tailored programs to capitalize on existing capabilities and maximize customer impact (18).

Principle 2

Customize the logistics network to the service requirements and profitability of customer segments.

Companies have traditionally taken an approach to logistics network design in organizing their inventory, warehouse, and transportation activities to meet a single standard. For some, the logistics network has been designed to meet the average service requirements of all customers; for others, to satisfy the toughest requirements of a single customer segment.

Neither approach can achieve superior asset utilization or accommodate the segment-specific logistics necessary for excellent supply chain management. In many industries, tailoring distribution assets to meet individual logistics requirements is a greater source of differentiation for a manufacture than the actual products, which are largely undifferentiated (13).

Principle 3

Listen to market signals and align demand planning accordingly across the supply chain, ensuring consistent forecasts and optimal resource allocation.

Forecasting has historically proceeded silo by silo, with multiple departments independently creating forecasts for the same products, all using their own assumptions, measures, and level of detail. Many consult the market place only informally, and few involve their major suppliers in the process.

Distributors should share information on an actual and fairly stable end-user demand with the manufacturer, and the manufacturer should begin managing inventory for the distributors. This coordination of manufacturing, scheduling, and inventory deployment decisions will pay off handsomely, improving fill rates, asset turns, and cost metrics for all concerned.

Such demand based planning takes time to get right. The first step is typically a pilot of a leading-edge program, such as a vendor managed inventor or jointly managed forecasting and replenishment, conducted in conjunction with a few high volume, sophisticated partners in the supply chain. The customer will then no longer send a purchase order, and the manufacturer commits inventory from its available-to-promise stock. After this pilot formalizes a planning process, infrastructure, and measures, the program expands to include other channel partners, until enough are participating to facilitate phenomenal improvement in utilization of manufacturing and logistics assets and cost performance (13, 18).

Principle 4

Differentiate product closer to the customer and speed conversion across the supply chain.

Manufacturers have traditionally based production goals on projection of the demand for finished goods and have stockpiled inventory to offset forecasting errors. These manufacturers tend to view lead times in the system as fixed, with only a finite window of time in which to convert materials into products that meet customer requirements.

While even such traditionalists can make progress in cutting through set-up reduction, cellular manufacturing, just-in-time techniques, and lean manufacturing, great potential remains in less traditional strategies such as mass customization. For example, manufacturers are striving to meet individual customer needs efficiently through strategies such as mass customization and are discovering the value of postponement.

Realizing that time really is money, many manufacturers are questioning the conventional wisdom that lead times in the supply chain are fixed. They are strengthening their ability to reach to market signals by compressing lead times along the supply chain, speeding the conversion from raw materials to finished products tailored to customer requirements. This approach enhances their flexibility to make product configuration decisions much closer to the moment demand occurs (13, 18).

Principle 5

Manage sources of supply strategically to reduce the total cost of owning materials and services.

Determined to pay as low a price as possible for materials, manufacturers have not traditionally cultivated warm relationships with suppliers. While manufacturers should place high demands on suppliers, they should also realize that partners must share the goal of reducing costs across the supply chain in order to lower prices in the marketplace and enhance margins. The logical extension of this thinking is gain-sharing arrangements to reward everyone who contributes to the greater profitability (13, 18).

Principle 6

Develop a supply chain-wide technology strategy that supports multiple levels of decision-making and give a clear view of the flow of products, services, and information.

To sustain reengineering business processes, many progressive companies have been replacing inflexible, poorly integrated systems with enterprise-wide systems. Unfortunately, many leading-edge information systems can capture reams of data but cannot easily translate it into actionable intelligence that can enhance real world operations.

Despite making huge investments in technology, few companies are acquiring a full complement of capabilities. Today's enterprise wide systems remain enterprise bound, unable to share across the supply chain the information that channel partners must have to achieve mutual success.

Ironically, the information that most companies require most urgently to enhance supply chain management resides outside of their own systems, and few companies are adequately connected to obtain the necessary information. Electronic connectivity creates opportunities to change the supply chain fundamentally from slashing transaction costs through electronic handling of orders, invoices, and payments to shrinking inventories through vendor managed inventory programs.

Many companies that have embarked on large-scale supply chain reengineering attest to the importance of information technology in sustaining the benefits beyond the first annual cycle. Those who have failed to ensure the continuous flow of information have seen costs, assets, and cycle times return to there pre-reengineering levels, which undermines the business case for broad supply chain programs (13, 18).

Principle 7

Adopt channel-spanning performance measures to gauge collective success in reaching the end-user effectively and efficiently.

Typically companies answer the question, "How are we doing?" by looking inward and applying a number of functionally oriented measures. However, excellent supply chain managers take a broader view, adopting measures that apply to ever link in the supply chain and include both service and financial metrics.

First, they measure service in terms of perfect order, the order that arrives when promised, complete, priced and billed correctly, and undamaged. The perfect order not only spans the supply chain, but also views performance from the proper perspective, that of the customer. Secondly, excellent supply chain managers determine their true profitability of service by identifying the actual costs and revenues of the activities required to serve an account, especially a key account.

To facilitate channel-spanning performance measurement, many companies are developing common report cards. These report cards keep partners working toward the same goals by building deep understanding of what each company brings to the partnership and showing how to leverage their complementary assets and skills to the alliance's greatest advantage. The willingness to ignore traditional company boundaries in pursuit of such synergies often marks the first step toward a "pay-for-performance" environment.

Companies have achieved excellence in supply chain management tend to approach implementation of the guiding principles with three concepts in mind.

- Orchestrate improvement efforts
- Remember that Rome wasn't built in a day
- Recognize the difficulty of change

By keeping these things in mind and implementing the 7 principles in supply chain management, one can make significant improvements in their supply chain management philosophies.

Now that the 7 principle steps in supply chain management have been thoroughly discussed, the four current and most widely recognized major paths that will allow future supply chains to deliver against the new requirements (flexible, integrated design, household replenishment, and virtual organization) can be discussed (13, 18).

2.7.2 Major Paths to Supply Chain Management

Flexible integrated design path

A holistic, fully integrated path to supply chain design and management will have to replace conventional, functional, silo-limited thinking. In the past, the logistics function, for example, added value through traditional operations activities: moving products to destinations within a fixed timeframe, storing them until they were needed, and rearranging them as desired by consumers. Performance metrics such as cost per unit, transit time, and order fill rates were used to fine-tune well-entrenched distribution systems. These methods were essentially drawn from industrial engineering (1, 2, 3).

Other elements of the value chain, such as procurement and manufacturing, were designed in similar fashion, as virtually stand alone functions primarily focused on day-to-day fire fighting within the confines of their own straightjacketed objectives. Large manufacturers can still be found today operating in similar fashion. Several of these functions, particularly logistics and procurement, have been perceived as corporate backwaters for years. Even among companies considered well managed, responsibility for inventory management may fall through the cracks; materials managers are measured on avoidance of line shutdowns, but not on inbound transportation cost or inventory carrying cost; and once the finished product reaches the loading dock, the plant no longer takes responsibility. Analysis of overall cycle times, or of opportunities to reduce inventory, involving coordination across departments, does not occur since responsibility is unclear, decision-support tools are lacking, and appropriate performance metrics are not in place.

Future supply chain designs will be characterized by agility, flexibility, and integration, in support of equally agile overall business designs. These designs will incorporate dynamic flow management of products, information, cash, and even ideas. The focus will be on coordination across the entire supply chain, both within a corporation and critically linking backwards to suppliers and forward to customers and end-consumers.

The ability to respond rapidly to constant changes in customer demand, network design, and sourcing will emerge as a major new performance metric. Organizational nimbleness will be key and measuring this capability will be more challenging than gauging cycle time or cost in a static environment. Constant re-optimization of supply chain flow levels will replace one-time calculations. Partnering skills will become a major differentiator of supply chain management performance. (i.e: Volkswagen calls this flexible design the "breathing organization," referring to an ability to adjust volumes throughout the supply chain as demand goes up and down.)

These agile supply chains must be focused around customer needs. A critical missing link that progressive enterprises will forge in coming years is the integration of supply chain design considerations into corporate business design, marketing, and product design. How can key supply chain variables drive down order-to-delivery cycle times, make customer delivery more convenient, enhance the ordering process, or reduce inventories? These questions will be asked as part of setting new corporate or product-line decisions, rather than as mere "operational" afterthoughts. The supply chain no longer will be viewed as a given that must be applied no matter what value proposition changes are made. New techniques are emerging to enable practical and rapid integration of supply chain variables in business decision-making represents a major avenue to help meet increasing consumer demands cost-effectively (1, 2, 3).

All of this implies that supply chain thinking will permeate the entire organization rather than exist only in one or two staff silos. Supply chain management skills must become diffused throughout the company; everyone must have an understanding of integrated demand/supply management just as all business people today are attuned to the culture of marketing. This may also be one path to the demise of the supply manager, as we know him or her. When each executive in the organization thinks about the supply chain, just as everyone is a marketer who thinks about customers, why will we need a large supply chain function?

Household Replenishment

Household replenishment, via Internet orders, with freeze-point delay represents a second major means by which supply chain management can fulfill rising consumer expectations of choice, service, and cost. By "household replenishment" we mean the automated fulfillment of consumer demand at the point of use, the home. And "freeze-point delay" simply refers to customizing product as late in the process as possible, when final demand can be more accurately determined. This technique also is known as postponement. It requires that products be "designed for logistics" so that feature professionals must be involved early in the product design cycle, working directly with marketing and product design, or at least be able to convey to the designers the benefits of freeze-point delays and other logistics variables (25, 36).

The Internet will drive a major revolution in consumer spending, with fully half of all orders being placed electronically within the next decade. This trend is under way at companies such as L.L. Bean and Amazon.com. The extension is consumption can be ordered via the Internet, with past patterns of use driving automated replenishment and home delivery. This combination suits the hectic lifestyle of many modern consumers who look to fulfill their everyday needs as conveniently as possible (8, 25, 28, 36).

The replenishment concept also will allow companies to take major costs out of the supply chain. Numerous tiers in the distribution chain can be removed. Of course, advertising will take place on the Internet, but this "virtual" activity will not trigger the physical distribution efforts that can now be seen. Product choice will be greatly expanded and delivery can be timely, even anticipating needs, based on analysis of a household's past consumption patterns.

Freeze-point delay is another critical element of the process. The goal here, too, is to maximize consumer choice while minimizing the demand-forecasting challenges driven by product proliferation. Incredible efficiencies in inventory management will result, even as the consumer enjoys a much greater range of product customization.

All of this suggests the emergence of a new class of third-party service provider: the replenishment service specialist. This comprehensive provider will receive truckload quantities of consumer goods at a large number of convenient locations nationwide ;or create them automatically, and deliver a mix of products to individual households.

Just how automatic household replenishment will work, who will provide the service, and how quickly consumers will adapt to the new path are fascinating questions that will likely be answered within the next ten years.

Virtual Organization

The third major way seen by industry leaders in supply chain management meeting future needs is through virtual organizations. These will be based on intellectual capital, brands, technology, new product development, new channel strategies, with operations activities largely outsourced. The counterpart will be the emergence of powerful will be the emergence of powerful supply chain specialists.

Nike, sells $9 billion worth of athletic shoes annually, does so without owning any factories itself. Gateway 2000 assembles product to customer-direct orders, but without building any of the equipment itself. Also, Sara Lee recently signaled a move in the same direction with its announcement that it would divest itself of 13 US spinning and weaving machines (25, 28, 36).

Monorail Inc. is an exciting example of a virtual organization. Founded in 1995 to sell PCs via the established reseller/retailer channel, Monorail has no factories, warehouses, call centers, or logistics of its own, it doesn't even invoice its customer or collect payment. Everything is outsourced to a set of strategic partners (19, 28).

2.7.3 Approaches to Supply Chain Management

The Traditional Supply Chain Approach

Traditional supply chains are efficient when it comes to delivering new products to consumers. Consider that thousands of new products each year are conceived, designed, and produced by the manufacturer, delivered to the marketplace, and made available to consumers. Most move through the supply chain reasonably efficiently and cost effectively thanks to a streamlined distribution process, sound logistics strategies, and advanced information technology.
The glaring failure in traditional supply chain management though is its inability to deliver products that the ultimate user needs in the right condition and will actually purchase. Studies indicate that about eighty percent of the time, consumers fail to buy products on the market at rates high enough to be profitable for the supply chain members. To increase the consumer acceptance rate, a major change in the process needs to occur. The objective must be to produce and supply products that not only do what they are designed to do but also out perform existing solutions. Mind to market leaders are beginning to transform this process form the old left to right paradigm into nonlinear, boundary spanning thinking and partnering.

The Integrated Supply Chain Approach

The supply chain of a manufacturing enterprise is a world wide network of suppliers, factories, warehouses, distribution centers and retailers through which raw materials are acquired, transformed and delivered to customers.

In order to optimize performance, supply chain functions must operate in a coordinated manner. But the dynamics of the enterprise and the market make this difficult: bank rates change overnight, political situations change, materials do not arrive on time, production facilities fail, workers are ill, customers change or cancel orders, etc. causing deviations from plan. In some cases, these problems cannot be “locally contained” and modifications across many functions are required.

Consequently, the supply chain management system must coordinate the revision of plans/schedules across supply chain functions. The agility, with which the supply chain is managed at a tactical and operational level in order to enable timely dissemination of information, accurate coordinate of decisions and management of actions among people and systems, is what will ultimately determine the efficient, coordinate achievement of enterprise goals (1, 2, 3).

The Demand Chain Approach

Dominance in the supply chain has shifted throughout American history. From the Revolution to the Civil War, the most influential member of the supply chain was the wholesaler, that entrepreneurial trader of the Colonial era and the early years of the nation. The wholesaler served as the connector between English products and US markets. Without these middlemen, goods did not make it to the new colonies for sale to retailers and individual consumers.

From the Civil War to World War II, manufacturers emerged as the most powerful member of the supply chain. They were in charge of what was produced and ultimately made available for consumers to buy, if the manufacturers wanted to produce one million black cars, they did regardless of now popular some other colors might have been with auto buyers.

This era gave way to a period of mega-retailers that began in the 1950s and 1960s. During this time retailers began to take more control in the supply chain because they provided a powerful connection between manufacturers and wholesalers to the elusive consumer. When Wal-Mart emerged as the retail giant, among giants, in the 1990s, it rewrote the rules on what the supply chain would produce and how goods would be sold (39).

Although Wal-Mart and its thousands of vendors and partners continue to shape how the world does business, even this superpower is being challenged for the supply chain throne. As the center of power begins another landmark sift, this simple thesis can be said, Consumers will be in charge of supply chains and will dictate how business is done in the future.. It is believed that the new environment and the corresponding sift in supply chain dominance mark the beginning of the "Century of the Consumer." Companies have recognized this shift and in turn developed the Demand Chain to adhere to the thought processes and demands of the consumer (39).

The demand chain is so named for its intense focus on the needs of consumers. A demand chain represents a circular process that flows from the mind of the consumer to the market. It encompasses all of the supply chain entities that may be involved in that process, manufacturers, distributors, retailers, etc. More importantly, consumer behavior and consumer analysis dictate the exact composition of the demand chain (1, 2, 3).

Rather than building and operating their supply chains from manufacturers to market, demand chain leaders are creating alliance with those channel partners best able to fulfill consumers' needs and wants.

The focus on the end-user is fueling a paradigm shift from supply to demand, causing companies to re-examine their roles in the supply chain. The players in today's emerging demand chains are the same as those in traditional chains. Yet, their respective roles and responsibilities have changed, as have the rules of the game itself. The responsibilities of each demand chain member are not based on the demand chain as while. The company best able to perform a role does and this does not necessarily originate from the manufacturers. They can be developed at any point and by any player in the chain, based upon consumer research and information gathered by any entity and shared with all of the partners.

The best scenario exists when every member of the demand chain whether it designs, creates, markets, sells, transports, or retails a specific product monitors the consumer market. Although not every chain member will be conducting direct consumer research, each should be given information on relevant consumer trends and product information. This knowledge makes it easier for everyone to identify product packaging improvements, marketing opportunities, or brand extensions.

Success of both the products and the channel members depends on upon full participation in the transfer of products from mind to market. Whether information is obtained from point of sale databases, focus groups quantitative surveys, or from newer methods like "shadowing" consumers and in home research, the data must be shared, analyzed, and acted upon by all channel members working as one entity. This is essential if supply chain are to be reinvented as demand chains.

Supply chain management has evolved over the years to provide strategic and competitive advantage to many companies. Demand chain management with its emphasis on delivering to the marketplace what consumer actually will buy, adds a new dimension to this concept. The demand chain approach goes beyond the physical distribution boundaries of supply chain management. Demand chains seek to unite channel members with the common goal of delighting customers and solving consumer problems by:

- Gathering and analyzing knowledge about consumers, their problems, and their unmet needs.
- Identifying partners to perform the functions needed in the demand chain.
- Moving the functions that need to be done to the channel member that can perform them most effectively and efficiently.
- Sharing with the other chain member's knowledge about consumers and customers, available technology, and logistics challenges and opportunities.
- Developing products and services that solve customers' problems.
- Developing and executing the best logistics, transportation, and distribution methods to deliver products and services to consumers in the desired format.
- Successful implementation of these activities will lead to profitable, long-term demand chain partnerships. Within these partnerships, information from and about consumers will flow freely to the channel members as will product and service information.

When channel members join together in the demand chain and share the same long-term strategic intent, they can provide consumers with more value than competitive chains. Just as importantly superior performance in the marketplace over time builds consumer loyalty and enhances the profit potential of all the partners (1, 2, 3).

Dynamic Supply Chain Approach

To survive, supply chains are going to have to work at Internet speed, which will mean turning outward and cooperating with customers and suppliers in a new way. Executives must implement changes to prepare their companies for "dynamic trade", the ability to satisfy the current demand with customized response, by creating supply chain networks that include dynamic planning, constant communication and make/move logistics.

A recent survey of Fortune 1000 companies found that customers demands are forcing firms to adopt new supply chain models to address key logistical challenges like rapidly changing customized products and shorter time to market expectations. Meeting these new demands means firms must know what they rapidly have in stock at all times. This is nearly impossible in a supply chain when over eighty percent of respondents collect some of their inventory and order data manually, and forty-eight percent update this data less than once a day (39).

In noting the importance of the external supply chain, forward-looking firms have identified the growing importance of coordinating activities between companies, across the supply chain. They recognize also that their current supply chains are simply not going to make the grade in this new world because of the traditional over-the-wall approach to filling time.

Supply chains that prosper in environment of dynamic trade will change their information flows, from the current sequential flow along predetermined path to dynamic exchanges across all supply chain participants. A dynamic trading network is a network of business units that share planning and execution information to satisfy demand uniquely with an immediate coordinated response. Instead of passing information and goods sequentially form company-to-company, dynamic supply chains share information broadly and use it to coordinate reactions across the entire supply chain.

In order to perform a dynamic supply chain, firms must communicate continuously and provide the pathways for information to flow between business units and external organizations. Dynamic trading networks require a connection management infrastructure that will enable fast, unambiguous exchanges of information on a broad range between participants.

This infrastructure will help business units to establish connections quickly and operate them efficiently, routing information to planning systems according to per-determined business rules. Once firms have established the planning infrastructure for a dynamic trading network, they must share and receive information between their partners to execute effectively. Business units will publish attribute-coded information about itself to an Internet connected server to be distributed to subscribers of that information. Subscribers will quickly interpret messages from publishers and take action based on a set of predefined rules.

The first step to creating dynamic trade network s requires firms to create component architecture because it will give the firm the flexibility to alter processes by adding or reordering components or outsource processes to partners without rewriting the system. After choosing a technology foundation, firms must build a messaging backbone and supply chain monitor. This type of technology can be supplied by companies such as I2, Manuguistics and Descartes. In order to extend the messaging capabilities outside the organization, forms must automate supplier customer communications and include security and business process management. After the foundation is set, firms should implement a constraint based planning tool for master planning on top of this integration layer. As the supply chain systems become capable, forms can move from static to dynamic available-to-promise quantities. Firms should always drive planning into execution. Given the tight time horizons of dynamic trade, companies can't rely on weekly planning exercises to run daily operations. Finally, firms must choose vendors that meet their specific needs (10).

Moving to a dynamic trading network will require firms to publish information to supply chain members. Companies can leverage their current sharing efforts with suppliers and key customers to feed improved demand and materials availability information into the supply chain architecture in the short term. As collaboration, suppliers, manufacturers, and distributors grows, companies will move beyond information sharing to allow real-time interactions with supply chain systems.

The Agile Supply Chain Approach

One of the biggest challenges facing organizations today is the need to respond to ever increasing volatility. To meet the demands of this challenge, organizations needs to achieve greater agility such that it can respond in shorter time frames both in terms of volume change and variety change. In other words, it needs to be able to quickly adjust output to match market demand and to switch rapidly from one variant to another.

To be a truly agile supply chain, the supply chain must posses a number of distinguishing characteristics. First, the agile supply chain is market sensitive, and is capable of reading and responding to real demand. Secondly, the use of information technology to share data between buyers and suppler is by creating a virtual supply chain. Electronic Data Exchange and the Internet have enabled partners in the supply chain to act upon the same data real demand, rather than be dependent upon the distorted information that arises when orders are transmitted from one step to another in an extended traditional chain.

Third, shared information between supply chain partners can only be fully leveraged through process integration, the collaborative working between buyers and suppliers, joint development, common systems and shared information. This form of cooperation in the supply chain is increasingly prevalent as companies focus on managing their core competencies and outsource all other activities. This idea of confederation-linked partners as a network provides the fourth and final key to an agile supply chain.

Today, the markets for raw materials are worldwide, requiring even the smallest businesses to operate inbound supply chains with increasing length. With improvements in communication technologies, outbound supply chains are also becoming longer, facilitated by new kinds of logistics suppliers that make it possible to service remote locations as easily as if they were right around the corner (14, 15, 16).

Information technology has developed rapidly in order to enable these extended supply chains. There is a large amount of data required to keep these processes on track and the information has to be delivered quickly from various geographically distributed locations. Complex systems are built from enterprise wide resource planning/execution, integrated warehouse management/traffic, customer relationship management and data/telecommunications systems. Data from these systems is considered the enterprise's lifeblood. It is important to consider the nature of this data.

2.7.4 Current Deficiencies in Regards to Current Supply Chain Management Methods, Paths and Approaches In Regards to a Cold Supply Chain

While the above mentioned principles, paths and approaches to supply chain management are also important and can be applied in regards to the management of a temperature sensitive perishables supply chain, there are deficiencies that exist within the philosophies if used stand-alone, that are currently used for managing the typical consumer goods supply chain. Managing a cold supply chain is much more difficult in regards to delivering a customer the product that they expect. Most cold supply chains do operate using one of the above mentioned paths and approaches to supply chain management; however, systems that gather data concerning the typical paths and approaches pay no attention or regards to the condition of the goods in respect to temperature, an integral part of the cold supply chain. When temperature sensitive products from a cold supply chain are not help within temperature specification, they diminish in value overtime.

As documented above in the supply chain management system principle, paths and approaches, traditionally they develop two kinds of information: transactional information and location oriented information. Transaction information conveys all of the financial details of the exchange of goods for currency. Order management/CRM, purchasing, shipping, point of sale systems, etc., provides information to the enterprise financial systems showing how much material was bought, sold, shipped, and then how much money was paid and received. Location information is more specific to where the actual goods themselves are: in transit (traffic), warehouse, inventory systems generate this kind of information. This data may not be sufficient, depending upon the nature of the goods being supplied. For example, in a cold supply chain, a wide variety of food products are degraded by improper exposure to temperature.

2.8 Definition of a Cold Supply Chain

Cold Supply Chain, "Cold Chain", is the term applied to a supply chain established for products that must be handled under controlled temperature conditions. The cold chain can be defined as the supply and distribution chain for products that must be kept within a specific temperature range. If there is a breakdown in the temperature management of a cold chain at any time during the process, temperature-sensitive products may loose their quality, freshness and/or integrity (4, 17, 35).

The cold chain includes all stages of perishable product movement or value-add, whether the goods are in transit, in process, in storage or on display. For enterprises that manage temperature sensitive goods, the investments in equipment and labor are considerable. An inventory of the specific assets and standard operating procedures all dedicated to the management of temperature may include refrigerated trucks, containers, cargo holds, warehousing, packaging display cases, personnel, and training. These are specific assets and labor costs deployed to manage specific products. By definition, they require specific information in order for the associated processes to be managed properly (4).

Where traditional supply chain systems provide transaction and location information, the cold chain requires additional information about the "condition" of the product. Doing business in perishable goods requires similar systems that allow goods to be bought, sold, shipped, and stored. However, it is critical that their condition also be tracked, so that the changes in value can be monitored, controlled, minimized and improved.

The cold chain is a specific, high value portion of many businesses' supply chains. Traditional supply chain management systems produce information regarding "transactions" (orders, shipments, payments) and "location" (warehousing, traffic, inventory). Perishable goods require information regarding their "condition: as they change in value while in the supply chain. It is possible to improve the quality, timeliness and granularity of traditional supply chain information with sophisticated data gathering applications (17, 35). However, product losses due to improper management of product condition can easily overshadow gains expected from that incremental investment. While transaction and location information are necessary to proper management of the cold chain, they are not sufficient. Condition information, particular relating to temperature, must be a part of the equation.

Exposure of these temperature sensitive or "perishable" goods, increase the potential for them to diminish in value. However, different categories of perishable goods can degrade at different rates. The value of food products can decrease incrementally. Considering a truckload of fresh produce that is subjected to high temperature while in transit. Product that was once fresh and valuable is less valuable at the point of delivery. This loss of value can be measured as a reduction in available selling price/grade, weight and/or shelf life.

The cold chain is a multi-billion dollar, increasingly complicated and critical segment of the worldwide supply chain (34). Companies operating in the cold chain include both over-the-road and ocean freighters, rail and airlines, third party logistics providers, mobile asset tracking companies, RFID-providers and packaging companies offering various transportation and warehousing services. Goods flowing through the cold chain include food, pharmaceuticals, cosmetics, chemicals, and a variety of industrial raw materials. In the last decade, cold chain monitoring has grown rapidly due to the explosion of perishable products, the extension of distribution routes throughout the world, regulatory pressure, technological advances, and increased public scrutiny and consumer expectation about the quality and efficacy of its food and drugs.

2.9 Proper Temperature Management is Key to Good Cold Supply Chain Management for Businesses to Remain Profitable

Proper temperature management, the portion of the cold supply chain that is not addressed by typical supply chain models, during the life of perishable products is critical to ensure maximum freshness and shelf life. Proper temperature management of a cold chain helps companies save money, reduce loss, comply with regulatory requirements and provide the highest quality products to their customers .As imagined, the stakes in food cold chain are high. The loss of a trailer of food due to improper temperature management can be measured in the hundreds of thousands of dollars. Because of the financial pressures and increasing regulatory demand for better record keeping resulting from the Bioterrorism Act, suppliers and logistics service providers need systems that allow for the documentation and analysis of temperature data with regards to food products while in transit. More than half of all the fresh produce grown and sold in the US is lost between the field and the plate. In fact, inventory shrink amongst perishable products has been estimated at 5% to 10%. For a very large US grocer, that could be $100 million to $200 million in perishable product shrink. About

50% of that typically can be attributed to poor cold chain management, resulting in spoilage or products in condition too poor to stock on store shelves (33).

2.10 Definition of Shrink

Shrink and/or loss is an ongoing concern for purveyors of consumable goods, whether its theft in the broad world of retail or spoilage in the world of perishable products. For sellers of produce or perishable goods, it doesn't matter whether the goods actually spoil and go bad or if they simply lose their key quality attributes, like look, smell and taste. The end result is the same, the product cant be sold, should not be sold and the retailer in turn looses money (37, 38).

In general, losses due to shrink in perishables categories occur for one of the following reasons:

1. Theft
2. Physical damage to the product
3. Code date expiration
4. Spoilage (This can include products that are still within the code date but must be discarded from inventory due to improper temperature handling which results in quality degradation.)

The last two factors, code date expiration and spoilage due to temperature abuse, are the primarily causes of shrink in the perishables industry. Fortunately, one can do a great deal to manage the issue of spoilage due to ineffective cold chain management. In fact, one can increase the useable life of many products. The key lies within aggressive cold chain improvement programs.

Typically, shrink in the fresh cut industry ranges from 10 to 20 percent but varies widely stock keeping unit (SKU) to SKU. For example, shrink for a high volume SKU, such as a one-pound garden salad may be 2 to 3 percent while for slower moving gourmet produce items it may be as high as 50 percent (37, 38).

2.11 Current Traditional Approaches to Attack Cold Supply Chain Management Problems and Their Weaknesses

2.11.1 Reducing Inventory Approach

Traditionally, retailers concerned about perishable shrink attack the problem by manipulating inventory levels downward. By dropping stock levels and increasing inventory turns for target SKUs the retailer reduces the risk that the product will pass code or degrade below acceptable quality levels prior to sale. However, this often proves to be too blunt a tool for attacking shrink because it is almost inevitably leads to an increase in out of stocks. It also becomes much more difficult to maintain the variety in key categories that consumers expect. Lower volume SKUs are, of course, extremely vulnerable to efforts to reduce inventory levels. Therefore, it becomes difficult to continue carrying such products (20).

With this dynamic in mind, it is understandable that those charged with keeping eyes on supermarket financial performance can be a bit skeptical about initiatives to substantially cut shrink. Their position is that the perishable shrink number and the out of stock number sit on each end of a seesaw. If a retailer aims to bring one of these key metrics down, the other has to go up, and vice versa. It becomes a sort of shell game where an undesirable financial metric is shifted from one place to another and back again.

However, initiatives to control perishables shrink don't have to result in increased out of stocks. There is a different approach that attacks the spoilage issue head on, by better managing temperature and cold chain processes, retailers and their supplier partners can reduce spoilage or quality losses without having to manipulate inventory levels and risk out of stocks (20).

2.12 Proactive Approach to Cold Supply Chain Management Through On-going Cold Chain Analysis

Traditionally, cold chain management operates at two levels: the transaction level, where you are dealing with individual shipments and trying to react to things in real time, and the more complex level, where you are managing the global supply chain and need a dashboard of temperature data that gives you feedback in terms of how the company and its partners are doing in regards to adherence to temperature specifications for product lines offered. Strategically, companies need a way to look at their supply chain in aggregate in order to determine how the company and its partners are doing against its standard operating procedures. The concept of cold chain begins with temperature monitoring, a process that most retailers understand and embrace.

However, cold chain management goes beyond the collection of temperature data on a single truck trip, the procedure that is most often used in industry, simply collecting data, but it involved identifying where break downs in the entire cold chain occur, so that process improvements can be made, often at a modest cost, to achieve significant financial benefits.

The cold chain for fresh produce for example involves a group of fairly standard processes. It starts with harvesting and cooling, can include transport to plant, continues on to processing and packaging, then shipment to customer, on to intermediate warehousing, then transport to supermarkets or restaurants, and finally to store level storage, handling and merchandising.

Moving a single case of product from production through to the supermarket shelf or restaurant kitchen may involve more than a hundred individuals, dozens of pieces of refrigeration equipment, several different vendors and multiple facilities. The path to reduced product shrink and enhanced freshness requires managing each of the key processes.

The nuts and bolts work of measuring and improving each of these key processes is where retailers and their supplier partners must focus their effort. Cold Chain Management remains an industry wide challenge despite the fact that reliable mechanical refrigeration is readily available and has been used widely in food distribution for over 40 years (24). In general, the problem is not the refrigeration systems themselves, it is in the process of managing the cold chain – how we move products through the various refrigeration systems and how we operate and maintain those refrigeration systems and of course how we adhere to standard operating procedures. The chapter will discuss a new statistically based model that will approach cold chain management in regards to its temperature sensitive element in a manner which will allow for improved visibility within a cold supply chain, leading to improved cold chain management that faces problems and brings them to light to find resolution and solving problems head on in a proactive manner.

If improved cold chain performance were depend solely on the capital-intensive process of replacing or upgrading refrigeration systems, meaningful improvement would be largely out of reach. But, in fact, when the key handling segments are intensively measured and analyzed, the corrective actions often turn out to involve much more manageable and cost effective solutions, adjustments to procedures, loading patterns, product flows, storage procedures, just to name a few.

Cold chain analysis using a statistically based model can help retailers identify breakdowns in the distribution system; it pinpoints what process (not just which equipment) is involved and what happens in different distribution segments. This "process mapping" information goes beyond just transportation and looks at events such as what happens at product hand off points. For example, it's useful to examine the process that occurs when trucks arrive at distribution centers. Proper temperature control on a 1,000 mile truck trip can be undone if the process of unloading the trailer and moving product in to proper storage conditions is mismanaged. Other improvements come by more closely managing vendor performance.

In the world of food retailing, there are fewer and fewer ways to produce more profit out of already tight margins. Reducing shrink is one of those ways, and making those improvements through non-traditional means, such as cold chain management offers retailers new avenues to improve financial performance and also achieve a competitive edge based on an enhanced reputation for perishable product freshness and quality. Potential shrink reductions when applying these techniques are estimated to be as much as 30 to 50 percent for key categories and SKUs. This savings not only provides direct financial and competitive benefits to participating retailers, it enhances the financial performance and relevance of the fresh cut industry and other food related industries as a whole (38).

In its current state, the cold chain is approached in a transactional manner, a series of discrete un-related shipment transactions. When one of the transactional processes break down, an expert is brought in to correct the issue. However, as time goes by, typically the processes begin to fail again, resulting in a vicious cycle, see the cycle below in figure 1 (20).

Following the traditional approach to fixing issues in regards to cold chain management leads to data that is difficult to interpret that does not help managers make decisions, often intensifies finger pointing to parties who may be responsible for the issues and it does not focus on continual improvement.

The good news is that the cold chain is not a series of discrete un-related shipment transactions, but a process or pipeline that can be subject to statistical process control to ensure that all temperature related bottlenecks have been discovered and eliminated from the process.

With the appropriate tools and models utilized and methodologies applied, cold chain analysis techniques now turns what was a vicious cycle into a continuous improvement effort that can be monitored, measured and sustained overtime.

The proactive approach of cold chain management, includes continual monitoring and analysis based on the findings. It involves looking for cold chain problems since significant dollar losses are involved and typically the problems can be fixed, improving quality, customer satisfaction, and at the same time protecting brand equity. Cold chain problems are usually discovered through customer complaints, audits of the cold chain or product quality. The typical approach to

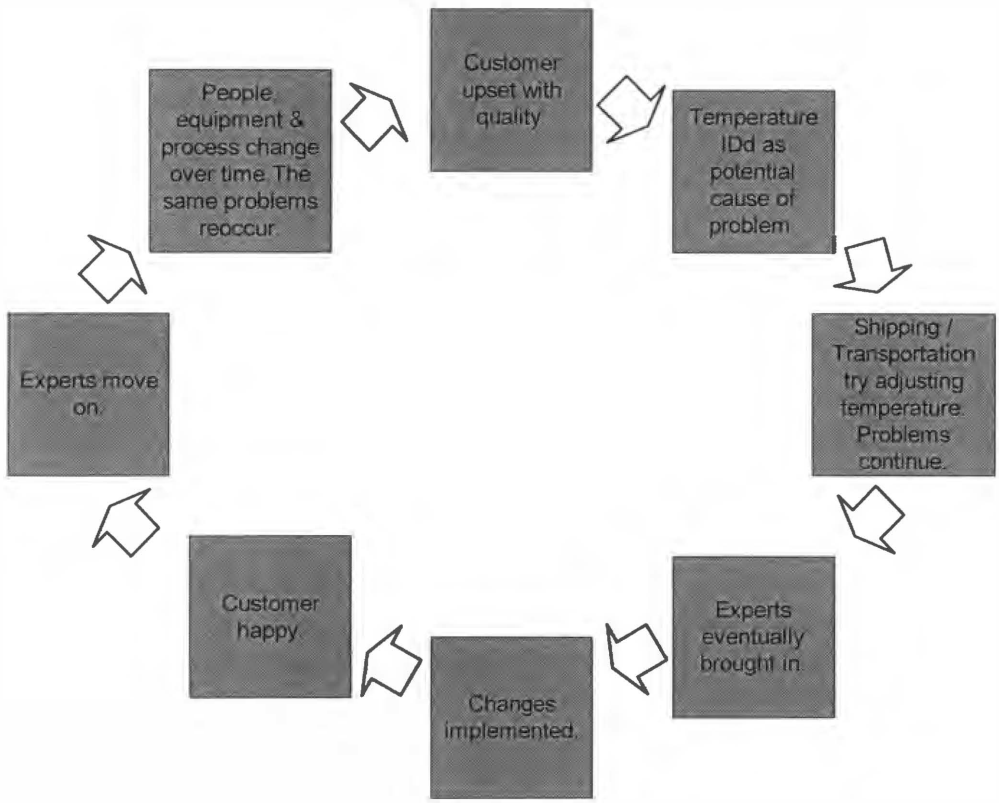


Figure 1. Traditional vicious cycle of cold chain management

identifying such customer complaints during audits of the cold chain or product quality are usually hit or miss, very expensive and very reactive instead of proactive. Cold chain analysis is methodical, more effective than traditional reactive approaches, fixes problems and continually improves the process and typically results in reduced costs and improved quality. Cold chain analysis is about collecting the right data, conducting the proper analysis, communicating the results and taking the right action on an ongoing basis.

2.13 Definition of the Data Collection Process

Collecting temperature data concerning one or more aspects of a cold chain and performing statistical analysis on the collected data to facilitate the identification of anomalies or inefficiencies in the process, and for communicating the results of such statistical analysis to those responsible for the cold chain so that remedial measures may be taken, if appropriate is a win - win for all participants in a cold chain.

There are temperature monitors available in industry that are designed to collect this type of data. However, simply collecting temperature data in regards to shipments of goods will not provide only part of the information required to fix temperature related problems within cold chains. Most suppliers of major retailers ship thousands and thousands of shipments each year to their customers with temperature monitors contained with their product.

Data repository systems and a model are needed in order to fully understand how logistics partners are performing. The model would need to be able to handle and massage temperature data and by combining the temperature data with important pieces of supply chain oriented logistics information within the model, such as which carriers and suppliers are responsible for the load, would allow for complete measurement, monitoring, and improvement of a cold chain, if necessary.

More specifically, there is a need to utilize statistical methods within the model to grade supply chain partners, techniques such as statistical process control allowing for analysis of the data with ease in regards to performance of cold chain partners, so that companies can get a global view of a complex supply chain and then they can start looking at the trends within the data and focus on the areas, which need the most improvement.

2.14 Definition of Statistical Process Control

Statistical process control, otherwise known as SPC, is an important tool in this required model. SPC is a method of monitoring a process, like a cold chain, during its operation in order to control the quality of the products while they are being produced, shipped, or in storage, rather than relying on inspection to find problems after the fact. It involves gathering information about the product, or the process itself, on a regular basis so that the action to improve the process can occur on a regular basis. This is done in order to identify special causes of variation and other non-normal conditions, thus providing critical information to help managers bringing the process under statistical control and reduce variation (40).

The concept of process variability forms the heart of statistical process control. For example, if a basketball player shot free throws in practice, and the player shot 100 free throws every day, the player would not get exactly the same number of baskets each day. Some days the player would get 84 of 100, some days 67 of 100, some days 77 of 100, and so on. All processes have this kind of variation or variability.

This process variation can be partitioned into two components. Natural process variation, frequently called random variation, is the naturally occurring fluctuation or variation inherent in all processes (40). In the case of the basketball player, this variation would fluctuate around the player's long-run percentage of free throws made. Assignable (or special cause) variation is typically caused by some problem or extraordinary occurrence in the system. In the case of the basketball player, a hand injury might cause the player to miss a larger than usual number of free throws on a particular day.

Of all the tools for analyzing data, the control chart is one of the most useful. It helps the user understand whether variations from point to point are due to random variation or due to an assignable cause. Control charts are used to determine whether your process is operating in statistical control. Until it is, any improvement efforts are, at best, mere process tampering. Basically, a control chart is a run chart that includes statistically generated upper and lower control limits. The purpose of a control chart is to detect any unwanted changes in your process. Abnormal points or certain patterns in the graph will signal these changes (40).

Extensive research by statisticians shows that by establishing upper and lower limits at three times the standard deviation of the process (plus and minus, respectively), 99.73% of the random variation would fall within these limits. When a point falls outside the control limits or when certain patterns occur in the data it is usually due to an assignable cause. A process is said, therefore, to be in "statistical control" when the process measurements vary randomly within the control limits; that is, the variation present in the process is consistent and predictable over time. The upper and lower control limits are not the same as tolerance or specification limits. Control limits are a function of the way your process actually performs over time. Specification, or tolerance, limits are a function of what we want a process to do and may not necessarily have any direct relationship to the actual performance of the process (40).

Figure 2 shows a diagram of a control chart. All control charts have three basic components:

- Performance data plotted over time.
- A centerline (CL), the mathematical average of all the samples plotted.
- Upper and lower statistical control limits (UCL & LCL) that define the constraints of common cause variations.

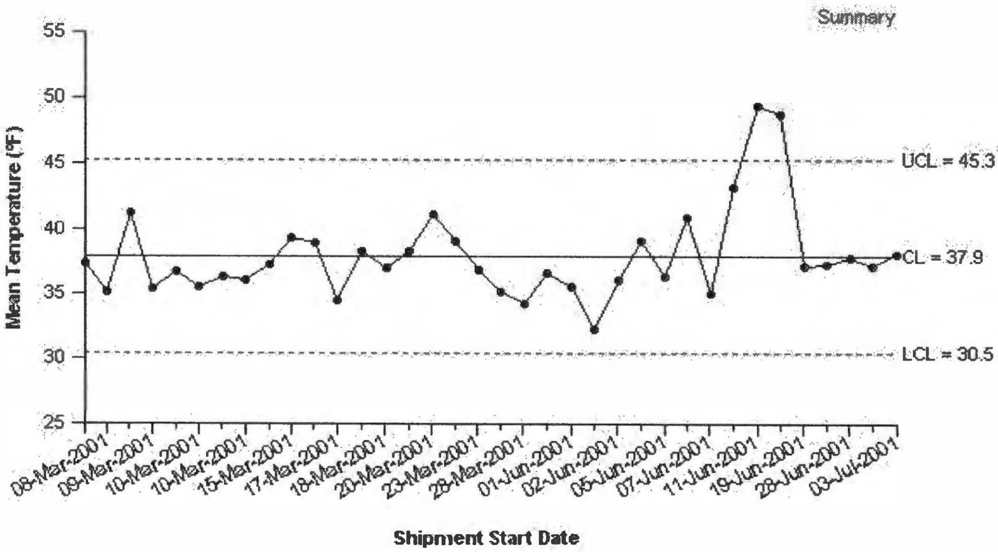


Figure 2. Diagram of a control chart

Control limits are used in conjunction with Control Charts to help interpret process data. Control limits reflect the expected variation in your process. Results that fall outside of these limits, UCL (upper control limit) and LCL (lower control limit) can be considered out of control points and may suggest that some cause has acted on your process resulting in that data to fall outside of those limits. If the data fluctuates within the limits, it is the result of common causes within the process (flaws inherent in the process), and can only be affected if the system is improved or changed. If the data falls outside of the limits, it is the result of special causes. The process is said to be "out of control" if one or more points falls outside the control limits (40).

The point of making control charts is to look at variation, seeking to determine what is the driver behind the variation and what changes in the process can be made to reduce this variation that is seen. Variation due to assignable causes on a control can be spotted using several tests:

- 1 data point falling outside the control limits
- 6 or more points in a row steadily increasing or decreasing
- 8 or more points in a row on one side of the centerline
- 14 or more points alternating up and down

2.15 The Integration of Temperature Monitoring and SPC

By implementing the usage of temperature data loggers and combining the temperature data logged with logistics information concerning the shipments, a tool such as SPC integrated with the appropriate cold chain model will allow for trends within the data to automatically be discovered.

CHAPTER 3

METHODOLOGY

3.1 Statistically Based Cold Chain Model

The cold chain is simply a process. It has definitive inputs and expected outputs. It uses specific assets and standard operating procedures. Personnel are trained to execute those standard operating procedures. Cold chain processes must be managed or outputs will not meet expectations. Product quality, shelf life/shrink, product safety/efficacy, brand image, and costs for all participating parties can be affected.

The goal of this model and its methodology allows for continuous improvement of a cold chain. It is a simple truth that what you don't measure you certainly can't manage. The model follows the following Deming's methodology and techniques, those which are key to every six sigma program:

- Design data gathering process.
- Collect data.
- Analyze.
- Prioritize opportunities.
- Plan improvements.
- Execute.
- Repeat.

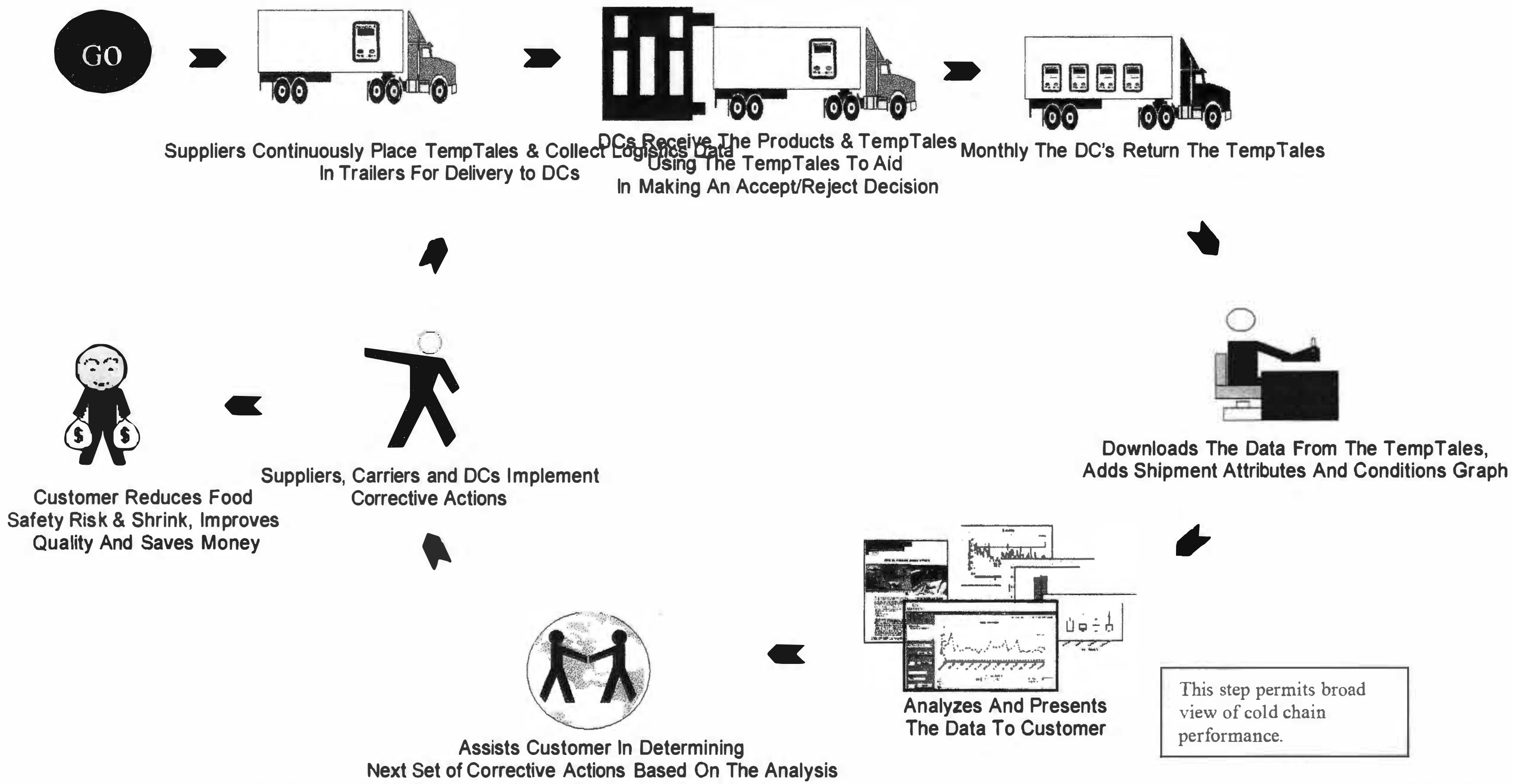
Implementing the statistically based cold chain monitoring system model requires the following specific steps when using the above methodology:

1. Data Gathering Process: Placing temperature monitors in in-transit shipments of goods used to log temperature data during the trip on an ongoing basis.
2. Collect Data: Collecting logistics information concerning all supply chain partners, such as the following:
    a. Shipment Supplier
    b. Shipment Origin (City/State)
    c. Shipment Distributor
    d. Shipment Distributor's Location (City/State)
    e. Shipment Carrier
    f. Shipment Receiver (Consignee/Buyer)

g. Shipment Product

3. Collect Temperature Information: Downloading temperature monitors' data into a centralized repository along with entering logistics information.
4. Analyze Data: Analyze the data using statistical process control charts to view key temperature summary statistics data that has been aggregated by supply chain partners such as mean/average temperature of the shipment, minimum temperature of the shipment, maximum temperature of the shipment, time product spent above specification temperature and time product spent below specification temperature, to highlight positive and negative trends within the data in regards to which suppliers, distributors, carriers and product lines require improvements due to deviations from the cold chain standard operating procedures.
5. Prioritize Opportunities: Identify trends and opportunities for improvement in regards to deviation from the product's ideal temperature specification range and standard operating procedures within the data.
6. Plan Improvements and Execute: Plan and performing necessary corrective actions based on data by working with supply chain party that is responsible for the issues at hand.
7. Repeat: Continue to monitor the system and analyze data on an ongoing basis to ensure integrity of the cold chain in regards to the condition/temperature of the goods. Repeat Step 1 of model.

See figure 3 below for a diagram, which documents the steps in the methodology visually. The details of the methodology, is best described and represented in figure 3, a proactive approach to cold chain management, and in the case studies that follow in chapter 4. The best opportunity to understand the methodology in action can be found by reading chapter 4, case studies, in which all 7 steps have been integrated into the process that was utilized when performing 2 case studies. The 2 case studies can not only be used as a proof of concept for using a statistical process control based cold chain model to discover potential temperature related cold chain problems and improvement solutions but it also describes the methodology utilized in detail to proactively locate and continuously improve temperature related issues within ones cold chain. The 2 case studies will provide the background information necessary to understand the issue at hand, the objectives and goals of the actual studies, the monitoring and analysis process utilized, which follow the methodology presented in figure 3, along with discussing the results and recommendations of the case study itself. In order to understand the methodology in action, one should focus on reading and applying the steps outlined in the case study in one's cold chain.



Ongoing cycle of monitoring, analyzing and corrective actions ensures continuous improvement of cold chain.

Figure 3. Proactive approach to cold chain management

CHAPTER 4

CASE STUDIES

4.1 Introduction to Case Studies

A total of 2 case studies will be discussed as proof of concept for using a statistical process control based cold chain model to discover potential temperature related cold chain problems and improvement solutions. The participants of the case studies that will be discussed are as follows:

- A top 25 burger quick serve restaurant chain (QSR) which has a total of 608 restaurants located primarily in the southwestern portion of the United States is the participant discussed in case study 1. The QSR's sales totaled $702.40 million in 2003, representing a 7.1% increase in sales from 2002 to 2003 (38).

- A top 40 supermarket chain which has a total of 62 supermarkets located throughout the United States will be the participant discussed in case study 2. The supermarket chains sales totaled $2.7 billion in 2002 (38).

Please note that case study 1 will focus on the discovering temperature data and the necessary improvements about the restaurant chains liquid eggs, hamburger patties and diced onion cold chain only. Case study 2 will focus on the supermarket's cut fruit and bagged salads cold chain only.

In the next sections, a summary of both case studies will be discussed including the test design process, data collection and the data analysis process. Results and recommendations based on data found will also be discussed in detail.

4.2 Case Study 1

4.2.1 Summary – Quick Overview

<u>Background</u>

The case study, performed for the QSR chain described above, is described in detail below. The cases study was designed to gather pertinent temperature and logistics data required to determine what factors and participants within the cold chain are in fact affecting the quality of the products studied.

The case study focused on gathering actual time and temperature data for cases of liquid eggs, beef patties, and diced onions during distribution from supplier to various restaurants. The comprehensive assessment provides the QSR chain an objective view of the cold chain from point of manufacture to point of use.

Objective

The objective of the case study was as follows:

To identify and prioritize problems in the cold chain during shipments of diced onions, beef patties, and liquid eggs from the supplier to restaurants so that resources can be efficiently applied to continuously improve the temperature management of diced onions, beef patties, and liquid eggs.

Goals

Improve product quality, minimize customer complaints and reduce costs.

4.2.2 The Monitoring and Analysis Process

A temperature monitor, a yellow instruction sheet and pre-addressed, postage-paid return mailer were placed inside boxes of liquid eggs, beef patties, and diced onions destined for the restaurants prior to shipment from the suppliers.

150 temperature monitors along with instructions and return mailers were placed in cases of product as they were packed at 3 participating supplier locations. The three participating suppliers are as follows:

- Supplier 1 in Dallas, TX: Placement of the 150 monitors in cases of diced onions took place from December 2-December 13 2003.
- Supplier 2 in San Antonio, TX: Placement of the 150 monitors in cases of beef patties took place from December 4-December 18, 2003.
- Supplier 3 in Gaylord, MN: Placement of the 150 monitors in cases of liquid eggs took place on January 28, 2004 and February 4, 2004.

The products were then distributed normally through a DC located in San Antonio, TX. The temperature monitors were started upon loading and recorded temperatures as the product traveled throughout the distribution process. When opening boxes of product, restaurant employees discovered a bright yellow sheet that instructed them to locate the temperature monitor and return mailer immediately as they unpacked the boxes of product. The return mailer provided a space for the employee to fill in their store number, store location and the date and time the case was opened. The instruction sheet also instructed them to stop the temperature monitor to indicate the end of the trip. The temperature monitors were then returned for downloading and analysis.

The analysis is presented using control charts of summary statistics for the shipments as well as the individual time-temperature graphs. The analysis approach allows the reader to see:

- Variation in time and temperature from shipment to shipment over the period of the study
- Temperatures to which the individual shipments were exposed to during distribution

Note that the time indicated on the time-temperature graphs is Eastern Time.

4.2.3 Results

The results of the temperature data can be viewed below. The key statistics are:

- Mean Temperature
- Time > Spec
- Time < Spec (beef patties and liquid eggs only)

<u>Results Overview</u>

Diced onions were observed to be consistently warm upon shipment and during storage at the restaurant. The ideal temperature for diced onions is 32°F. Diced onion shipments should be 31°F-41°F. The average temperature during diced onion distribution was 39.0°F. Diced onions were exposed to an average of 20.7 hours over 41°F during distribution.

Hamburger patties were frequently exposed to freezing temperatures during transport from the DC to the restaurant. The ideal temperature for beef patties is 29°F. Beef patty shipments should be 28°F-38°F. The average temperature during beef patty distribution was 30.8°F. While the beef patties were exposed to an average of 2.2 hours over 38°F during distribution; the hamburger patties spent on average 5.7 hours below 28°F.

Liquid eggs were frequently exposed to freezing temperatures during transportation and were exposed to temperatures above 41°F during transportation from the supplier to the DC and also while being held at the restaurant. The ideal temperature for liquid eggs is 33°F. Liquid eggs shipments should be 32°F-41°F. The average temperature during liquid eggs distribution was 36.6°F. Liquid eggs were exposed to an average of 21.4 hours over 41°F during distribution and were exposed to an average of 12.0 hours below 32°F.

While temperatures were quite good for many shipments and portions of shipments, opportunity for improvement exists during distribution and at the restaurant level. Several spikes in temperature were observed frequently during the transfer of product to the dc and to the restaurant. Also, temperatures were found to be higher at the restaurant level when compared to temperatures found at the supplier and dc locations. The process, results and recommendations of the study will be discussed in detail in the sections below.

Analysis By Products

Diced Onion Results:

The ideal temperature for diced onions is 32°F (Ideal.) Diced onion shipments should be 31°F (LSL= lower specification limit for onions) - 41°F (USL=upper specification limit for onions.) The mean temperatures the diced onions were exposed to were typically within these specification limits (see figure 4 below); however, they were often at the high end of this range.

Documented on figure 4 below, the current process is falling between the control limits of 34.9°F and 43.19°F, warmer than the ideal and specified temperatures for onions. In fact, 0% of the shipment experienced a mean temperature of 32°F, the ideal temperature of diced onions. Seven of the shipments monitored, representing 8.5% of the total shipments, had mean temperatures above 41°F.

While the mean temperatures of the diced onions were typically within specification, the graph depicting Time Above 41°F (see figure 5 below) shows that most of the cases of product spent time at temperatures above spec.

As illustrated in the Time Above 41°F graph represented in figure 5 below, 88.0% of the shipments spent time above the specified maximum temperature. On average, the shipments spent a total of 20.7 hours above the upper specified limit. Eighteen shipments spent over 2 days above 41°F while 8 shipments spent over 3 days above 41°F. The Time Above 41°F control chart indicates that there are opportunities for improvement in temperature management.

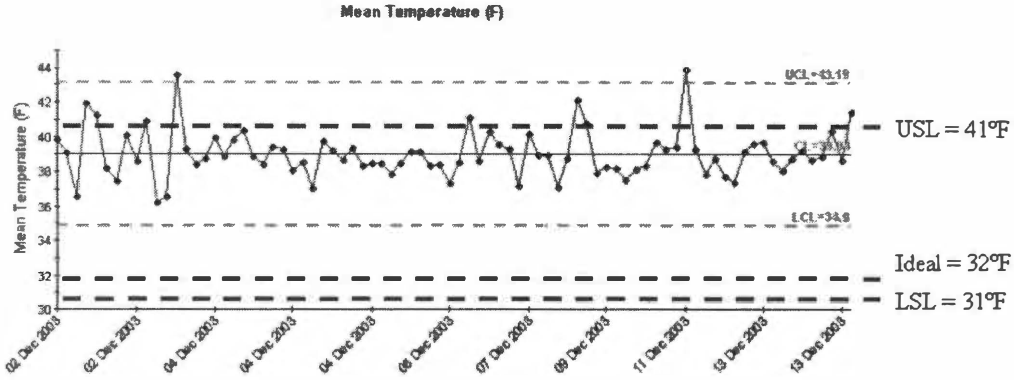


Figure 4. Diced onions-mean temperature control chart

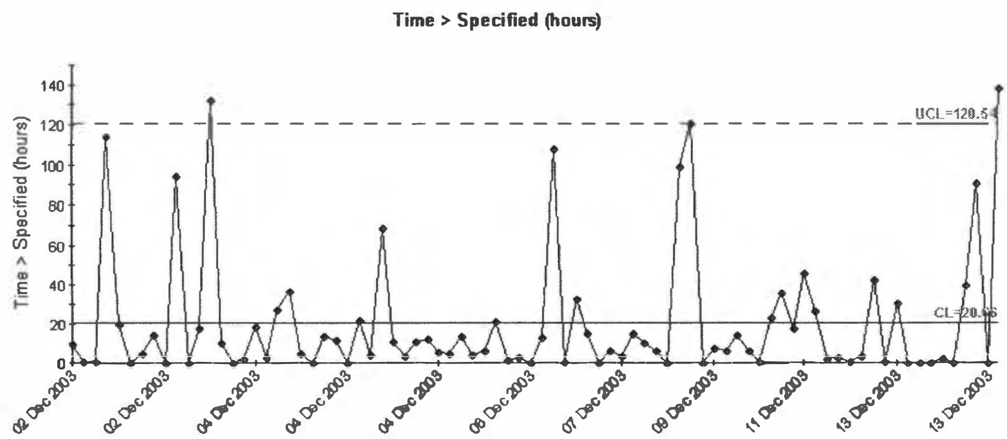


Figure 5. Diced onions-time below specification control chart

The diced onions were typically within specification when leaving the supplier's facility in Dallas TX; however, the temperature of the product tends to be on the higher end of the specification range. The shipments, which experienced significant amounts of time above specification, tend to get warmer during transportation and then they are held even warmer while at the restaurant level.

Examples documenting this observation can be found below in on the time and temperature graphs, figures 6 and 7. Higher temperatures are observed at transfer points and primarily at the restaurant locations. Note that exposure to the higher temperatures will be more severe for product facing the outside of the pallet and less severe for product located toward the center of the pallet.

Beef Patty Results:

The ideal temperature for beef patties is 29°F (Ideal.) Beef patty shipments should be 28°F (LSL= lower specification limit for beef patties) - 38°F (USL= upper specification limit for beef patties.) The mean temperatures the beef patties were exposed to were typically within specification; however, they were typically within the middle of this range.

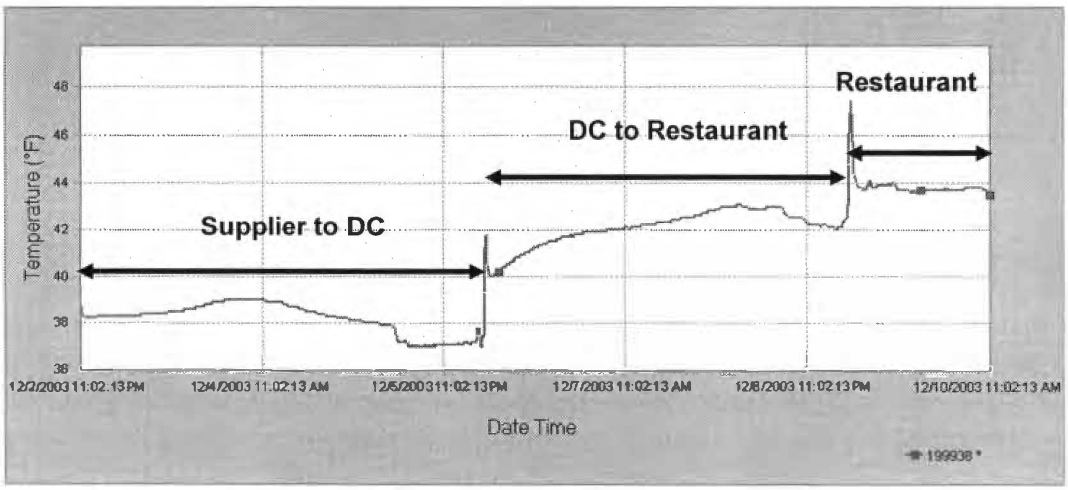


Figure 6. Diced onions-trip graph example 1

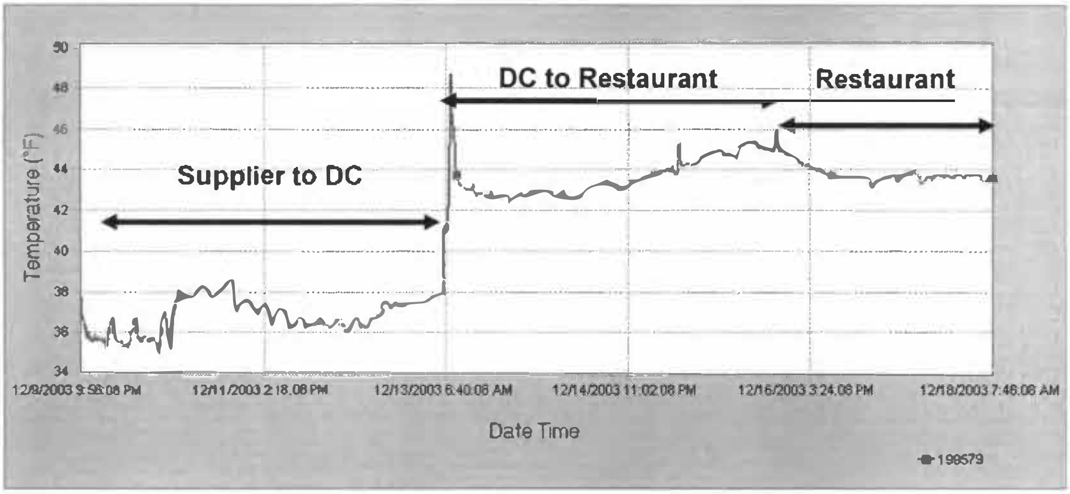


Figure 7. Diced onions-trip graph example 2

Documented in figure 8, the current process is falling between the control limits of 24.56°F and 36.99°F, indicating that product is typically within the spec temperatures. In fact, 0% of the shipments monitored had mean temperatures above 41°F; however, 7.5% of the shipments experienced mean temperatures below 28°F.

Like the mean temperature graph, the graph depicting Time Above 38°F (see figure 9 below) shows that most of the cases of product performed within specification. In fact, 5 of the shipments spent over 5 hours above the specified maximum temperature. Consistent increases in temperature while in transit and at the restaurant are the causes of the out of spec temperatures. However, the graph depicting Time Below 28°F (see figure 10 below) shows that several cases of product spent significant time below specification. In fact, on average a shipment spent 5.7 hours below 28°F. Twenty shipments (25% of the total shipments monitored) spent over 10 hours below 28°F while 2 shipments spent over a day below 28°F. The Time Below 28°F control chart indicates that there are opportunities for improvement in temperature management.

The beef patties were typically within specification when leaving the supplier's facility in San Antonio TX. The shipments, which experienced significant amounts of time below specification, tend to get cooler while in transit from the distribution center to the restaurants. Examples documenting this observation can be found below on the time and temperature graphs in figures 11 and 12. Higher temperatures are observed at transfer points and lower temperatures are observed at the distribution center.

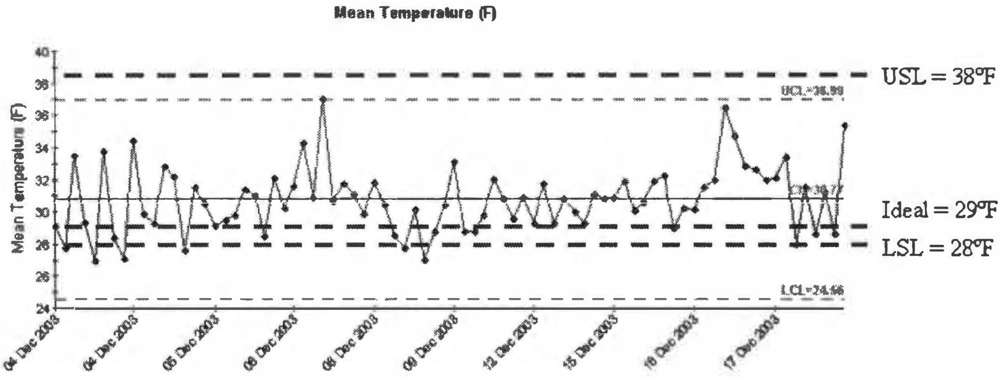


Figure 8. Beef patties-mean temperature control chart

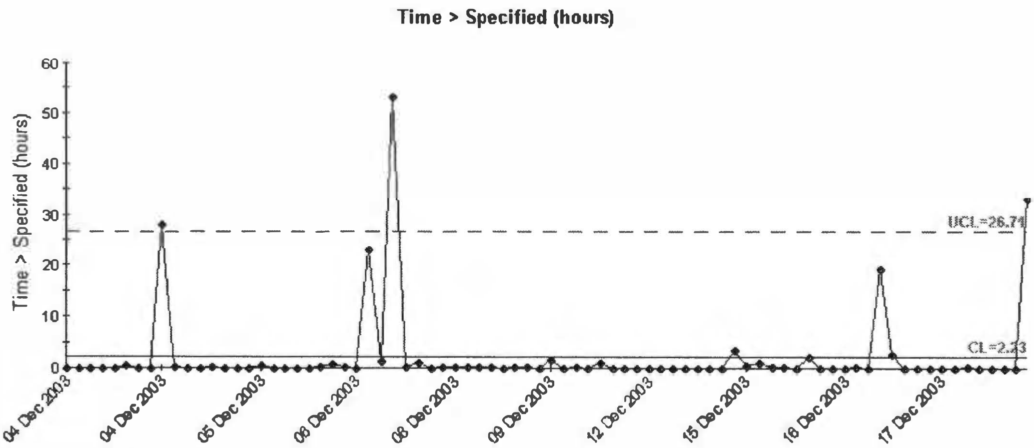


Figure 9. Beef patties-time above specification control chart

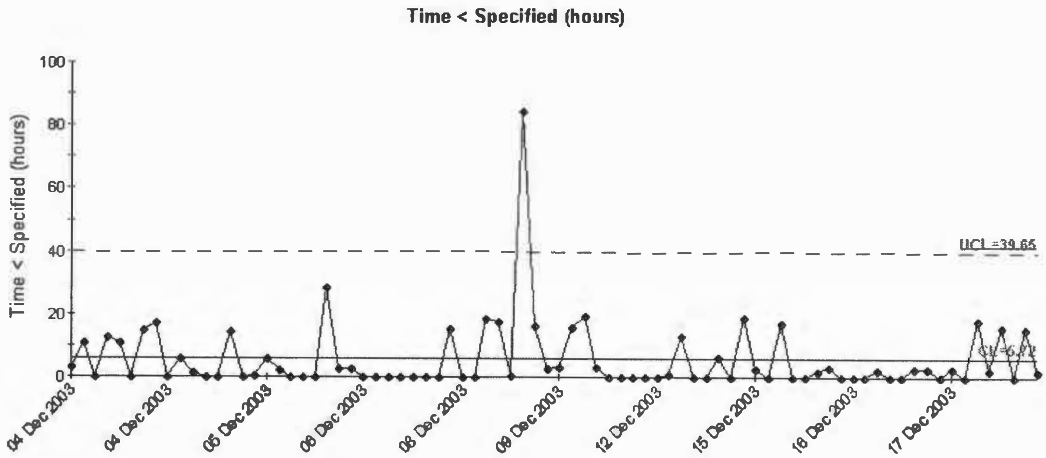


Figure 10. Beef patties-time below specification control chart

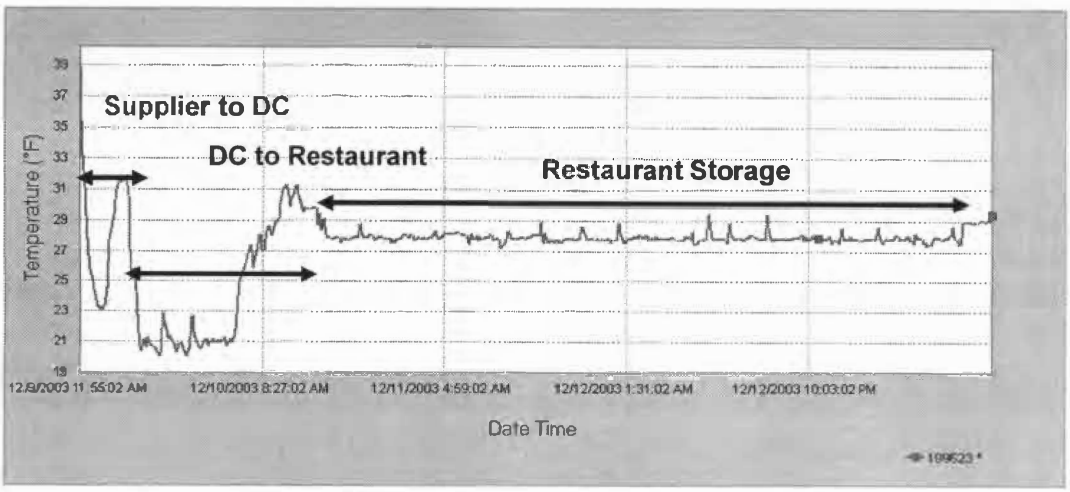


Figure 11. Beef patties-trip graph example 1

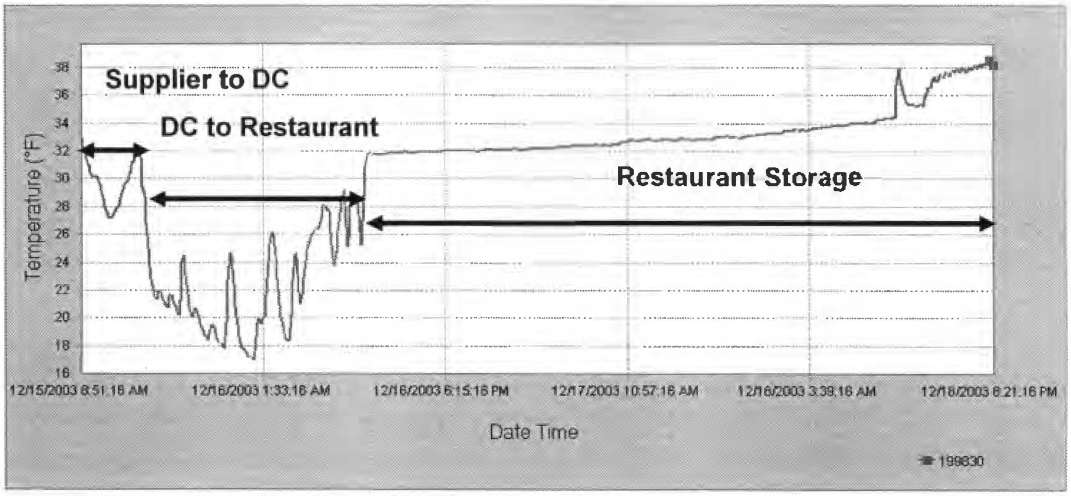


Figure 12. Beef patties-trip graph example 2

Liquid Eggs Results:

The ideal temperature for liquid eggs is 33°F (Ideal.) Liquid eggs shipments should be 32°F (LSL= lower specification limit for liquid eggs) - 41°F (USL= upper specification limit for liquid eggs.) The mean temperatures the liquid eggs were exposed to were within specification; however, they were typically within the middle of this range. Documented in figure 13 below, the current process is falling between the control limits of 33.4°F and 39.7°F, indicating that product is typically within the spec temperatures. In fact, 0% of the shipments monitored had mean temperatures above 41°F.

Unlike the mean temperature graph, the graph depicting Time Above 41°F (see graph in figure 14 below) shows that most of the cases of product spent time above specification. In fact, 18 of the 68 shipments monitored (representing 26.5% of the total shipments monitored) spent over 30 hours above the specified maximum temperature. Warmer temperatures while being held at the supplier location, during transportation from the supplier to the distribution center and during storage at the restaurant itself are the causes of the out of spec temperatures.

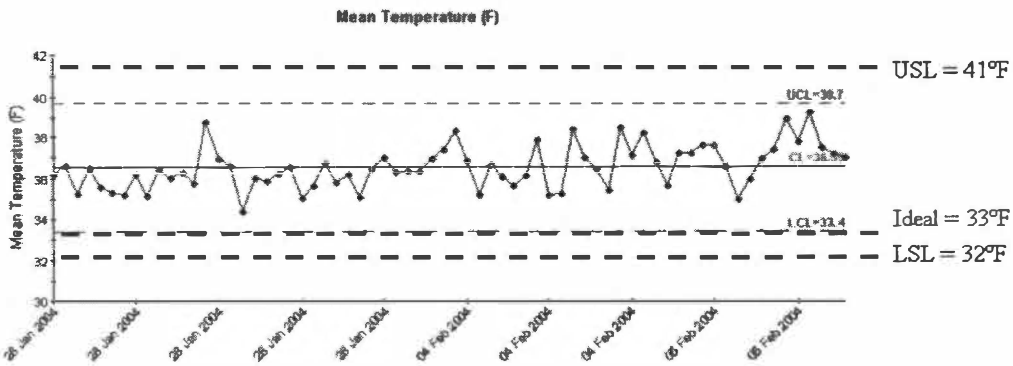


Figure 13. Liquid eggs-mean temperature control chart

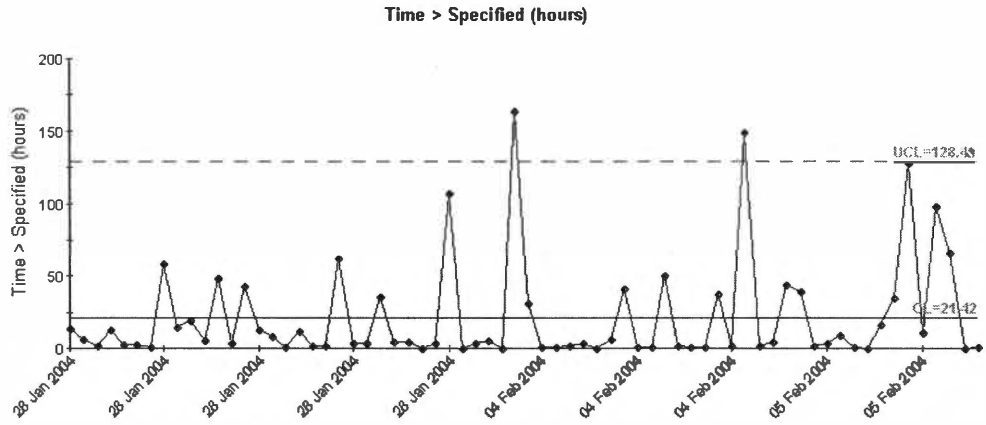


Figure 14. Liquid eggs-time above specification control chart

The graph depicting Time Below 32°F (see figure 15 below) shows that several cases of product spent significant time below specification. In fact, on average a shipment spent 12.03 hours below 32°F. Forty-two shipments (61.7% of the total shipments monitored) spent over 10 hours below 32°F while 12 shipments spent over 20 hours below 32°F. The Time Below 32°F control chart indicates that there are opportunities for improvement in temperature management.

The shipments, which experienced significant amounts of time below specification, tend to experience these cooler temperatures while being delivered to the restaurants. In fact, some cases experience temperatures as cold as 1°F. Examples documenting this observation can be found below on the time and temperature graphs in figures 16, 17, and 18. This pattern can be observed in numerous shipments.

4.2.4 Recommendations

The following are the recommendations that were given to the QSR chain.

1. Investigate the cause of the spikes in temperature observed at transfer point to the distribution center and the restaurants.

The most common cause for this type of temperature problem is leaving pallets of product in under-refrigerated dock areas for extended periods of time after unloading or during staging for loading.

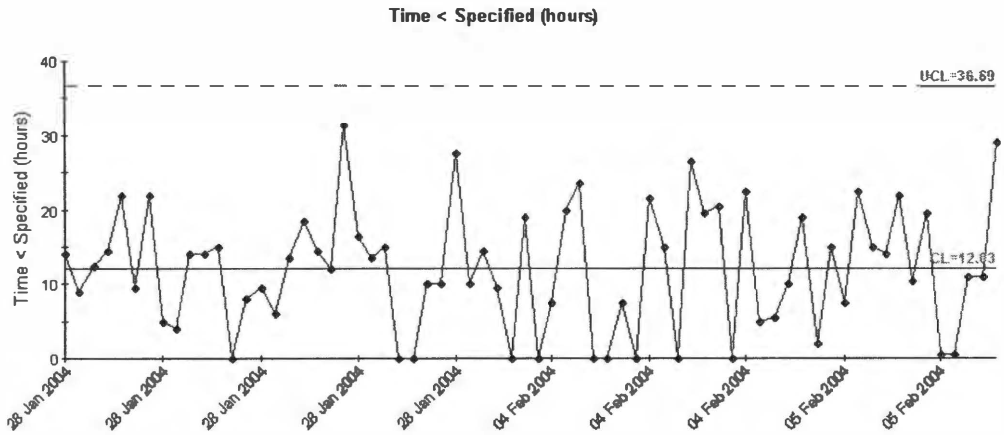


Figure 15. Liquid eggs-time below specification control chart

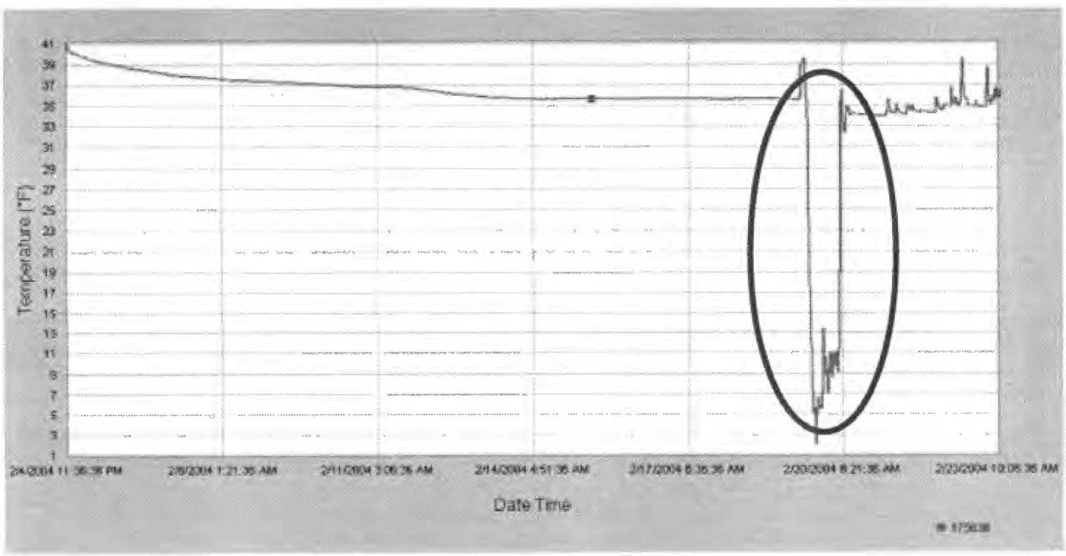


Figure 16. Liquid eggs-trip graph example 1

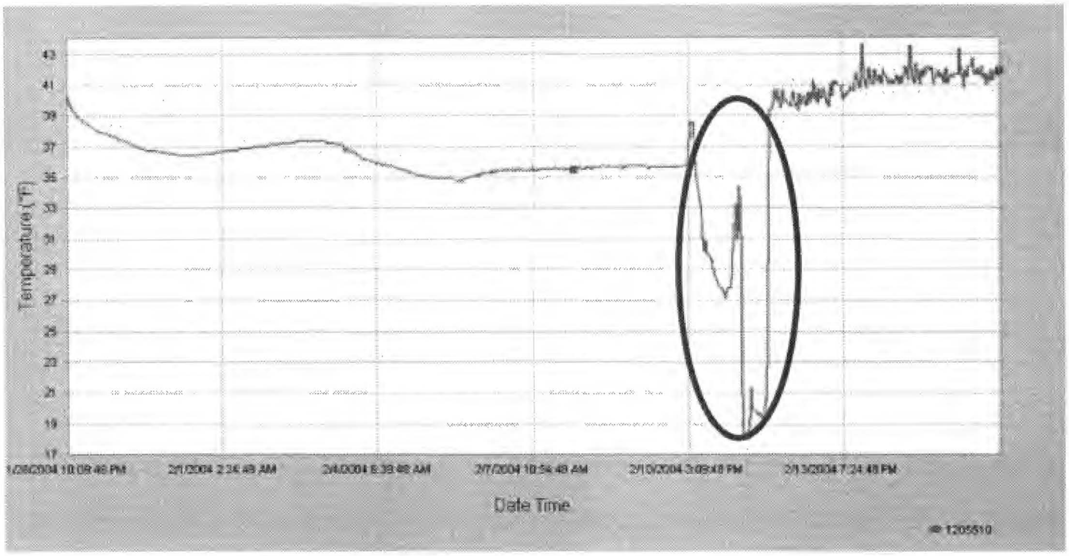


Figure 17. Liquid eggs-trip graph example 2

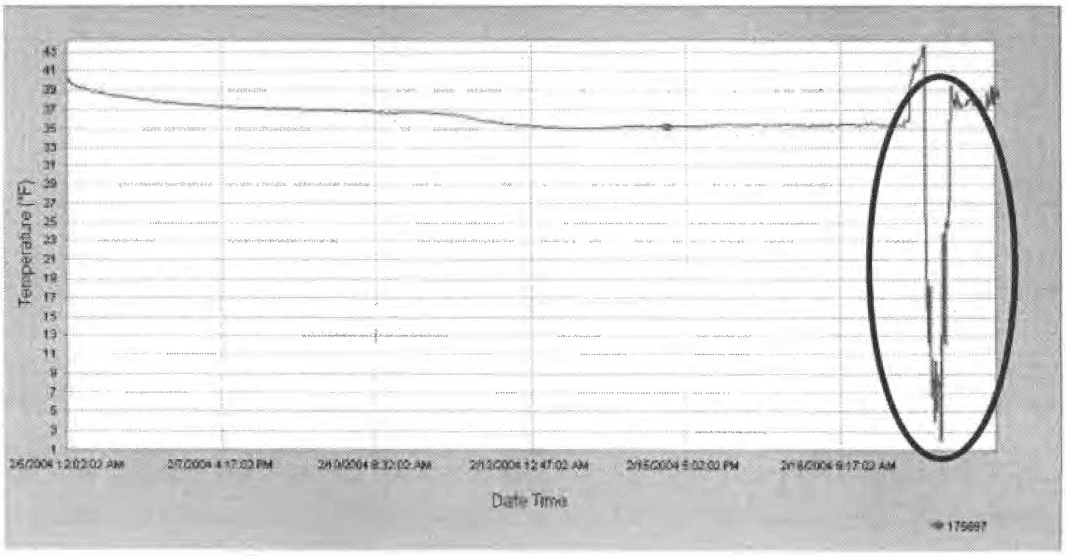


Figure 18. Liquid eggs-trip graph example 3

2. Investigate the cause of the above spec temperatures observed at the restaurants. Key areas for investigation:

    a. Verify proper set points for the restaurant refrigeration systems.
    b. Verify that proper procedures are followed for closing doors.
    c. Verify that the proper product handling procedures are being followed.

3. Investigate the cause of the higher than ideal temperatures found at supplier locations (diced onion supplier and liquid eggs supplier) and during transportation to the dc (diced onions carrier and liquid eggs carrier). Based on findings, determine if this set temperatures of the refrigeration systems utilized at the supplier locations and during transportation should be lowered based on the current supplier and in-transit temperatures found during this analysis.

4. Investigate the cause of the lower than ideal temperatures (liquid eggs and beef patties) found during transportation to the restaurants.

5. Continue to monitor on going basis to ensure the integrity of the cold chain. Perform another audit and ongoing monitoring after improvement has been made to verify and ensure changes made have created a positive outcome in temperature management.

4.3 Case Study 2

4.3.1 Summary – Quick Overview

Background

This case study presents the results of a Plant-to-Shelf Cold Chain Audit performed for the supermarket chain discussed above. The audit was designed to gather time and temperature data for cases of fresh produce during distribution from suppliers through to the retail stores. This audit provides an objective view of the cold chain from the supplier to the moment of stocking at the retail store.

Objective

Identify and prioritize problems in the cold chain during shipments from the supplier to the retail stores so that resources can be efficiently applied to improve the temperature management of perishable products.

Goals

Improve product quality, minimize customer complaints and reduce costs.

4.3.2 Monitoring and Analysis Process

During 11/30/04 to 12/30/04, temperature monitors were placed in shipments of product as they were packed at each of the participating supplier locations. 200 monitors were placed at each location. The participating suppliers were as follows:

- Fresh cut fruit supplier 1:
  - Dallas TX location
  - Grand Rapids MI location

- Fresh cut salads supplier 2:
  - Geneva, IL location
  - Morrow, GA location
  - Salinas, CA location

- Fresh cut salads supplier 3
  - Yuma, AZ location

Temperature monitors were placed inside trailers of product destined for the supermarket retail stores prior to shipment from the suppliers. The temperature monitors were started upon loading and recorded temperatures as the product traveled throughout the distribution process.

When opening boxes of product, retail store employees discovered a bright yellow sheet that instructed them to locate the temperature monitor and return mailer immediately as they unpacked the boxes of product. The return mailer provided a space for the employee to fill in their store number, store location and the date and time the case was opened. The instruction sheet also instructed them to stop the temperature monitor to indicate the end of the trip. The temperature monitors were then returned for downloading and analysis.
The analysis is presented uses box plots and control charts of summary statistics for the shipments as well as the individual time-temperature graphs. The approach is designed to allows the reader to see:

- Variation in time and temperature from shipment to shipment over the period of the study

- Temperatures to which the individual shipments were exposed to during distribution

Note that the time indicated on the time-temperature graphs is Eastern Time.

4.3.3 Results

While temperatures were quite good for many cases of product, opportunity for improvement exists in each of the major segments of the cold chain. The key issues were as follows:

- Fresh Cut Salads: Above spec temperatures in the supplier to DC segment
- Below spec temperatures during transportation from the DC to the retail store
- Above spec temperatures during storage at retail

Table 1 contains recommended temperature specifications for the products analyzed. Table 2 contains mean values for key temperature statistics by product. Table 3 contains mean values for key temperature statistics by supplier.

Table 1: Temperature specifications

Product	Ideal (°F)	Min (°F)	Max (°F)	Min (°F)
Fresh cut fruit	32	31	41	32
Fresh cut salad	32	31	41	32

Table 2: Temperature statistics by product

Product	# of Temp Monitors	Mean (°F)	Min (°F)	Max (°F)	Time > Spec (h)	Time < Spec (h)	Trip Length (d)
Fresh cut fruit	165	37.7	34.4	43.5	4.5	0.3	3.1
Fresh cut salads	521	37.5	34	45.1	7.6	1.1	6

Table3: Key supplier results statistics

Supplier	Location	# of Temp Monitors	Mean (°F)	Min (°F)	Max (°F)	Time > Spec (h	Time < Spec (h)	Trip Length (d)
Supplier 1	Dallas TX	61	37.9	34.2	45.2	3.4	0.6	2.6
	Grand Rapids MI	104	37.6	34.6	42.5	5.2	0.1	3.4
Supplier 2	Geneva IL	152	38.4	34.9	45	9.3	0	4.4
	Morrow GA	112	37.5	33.7	47.3	8	2.6	3.7
	Salinas CA	138	36.6	32.8	44.4	3.9	2.2	6.9
Supplier 3	Yuma AZ	119	37.4	34.3	44.2	9.4	0	9.3

This study was designed to provide an unbroken view of the entire cold chain from point of production to point of sale; however, below you will see a rough evaluation of the performance of the cold chain broken down into three segments: supplier to distribution center, distribution center to retail store, and retail store The trips where temperatures below 31°F or above 41°F were recorded were evaluated to determine where these events occurred.

For the fresh produce shipments, 35 temperature monitors recorded temperatures below 31°F and 491 temperature monitors recorded temperatures above 41°F. The 35 temperature monitors where temperatures below 31°F were recorded and the top 100 temperature monitors that spent the most time above 41°F were evaluated to determine where the out of spec events occurred. This was a subjective process, but it provides a compelling view of the issues. See table 4 below.

Mean Temperature

Only 6 shipments, representing 0.1% of the total shipments monitored, had a mean temperature above the specification limit of 41°F and only 1 shipment had a mean temperature below the specification limit of 31°F. See Figure 19 below. Although the shipments monitored had mean temperatures within the specification limits, opportunity for improvement still exists in the cold chain.

Table 4: Fresh produce temperature events

Fresh Produce			
Event Type	Supplier to DC	DC to Retail Store	Retail Store
Occurrence of Below 31°F Events	5.70%	71.40%	22.90%
Occurrence of Above 41°F Events	13.00%	33.00%	54.00%

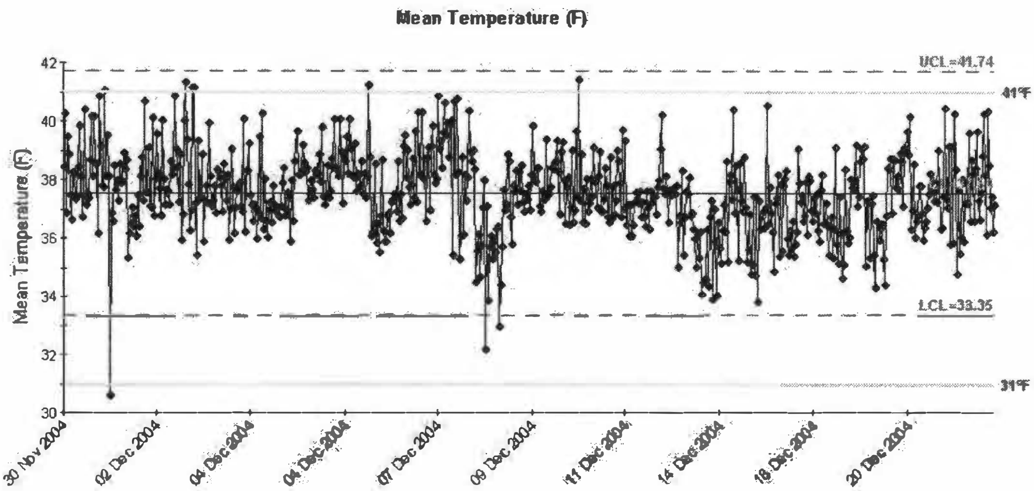


Figure 19. All products-mean temperature control chart

<u>Time Below 31°F</u>

Figure 20 below highlights the amount of time each shipment spent below 31°F. A total of 35 shipments, representing 5% of the shipments monitored, spent time below 31°F.

<u>Sources of Below 31°F Events</u>

The Below 31°F events occurred mostly during transportation from the distribution center to the retail store, primarily from the Ft. Worth TX distribution center. See examples in figures 21 through 25 below. This pattern can also be observed in numerous shipments.

The below 31°F events also occurred frequently during storage at the retail store. See examples in figures 26 and 27 below.

The Below 31°F events also occurred infrequently during transportation from supplier to the DC. See example in figure 28 below.

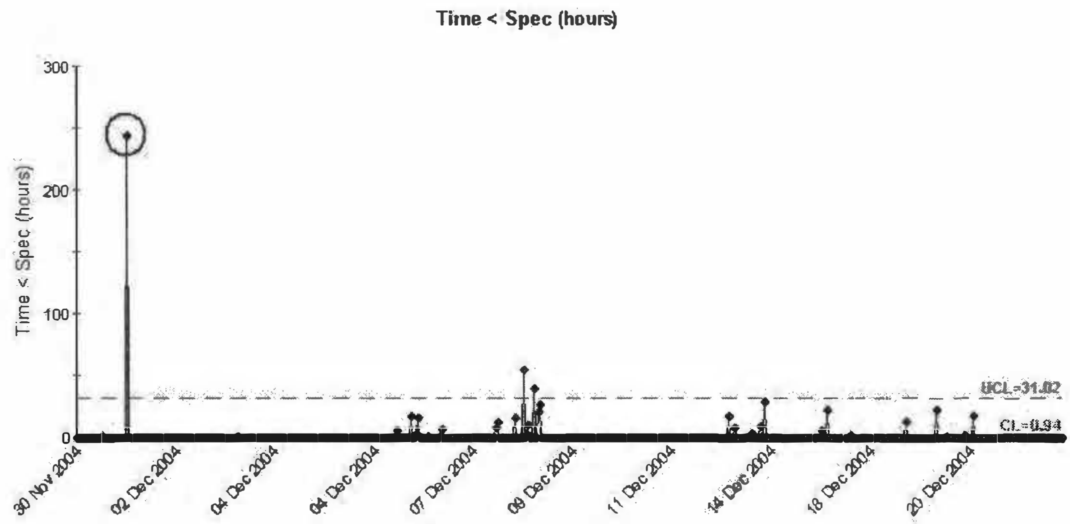


Figure 20. All products-time below specification control chart

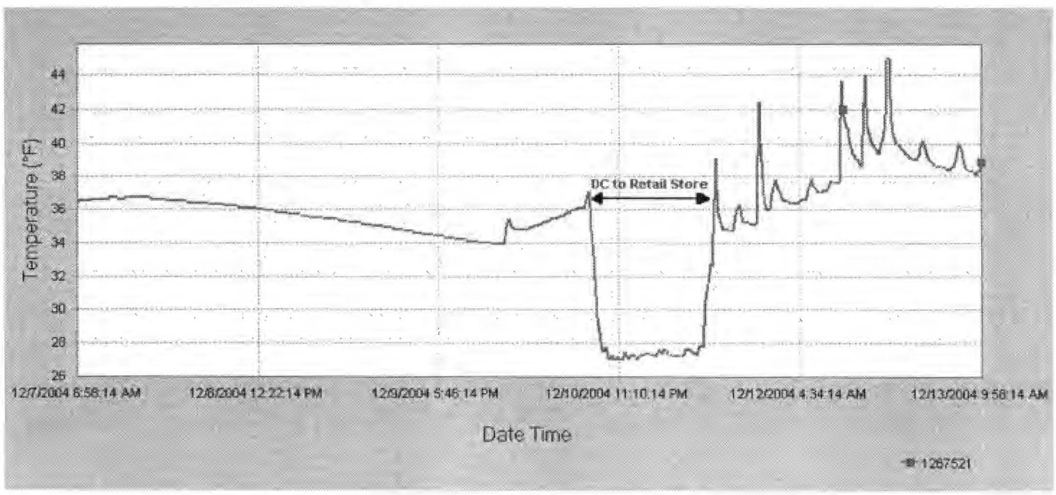


Figure 21. Fresh cut salads trip graph example 1-Supplier 2 (Salinas CA location)-Ft. Worth TX DC-Littleton CO store 1776

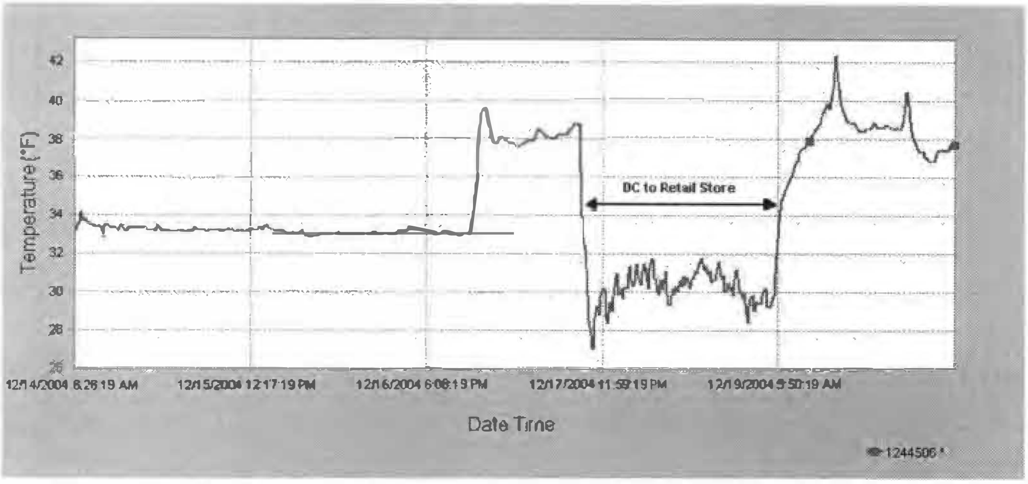


Figure 22. Fresh cut salads trip graph example 2-Supplier 2 (Salinas CA location)-Ft. Worth TX DC-Midvale UT store 1751

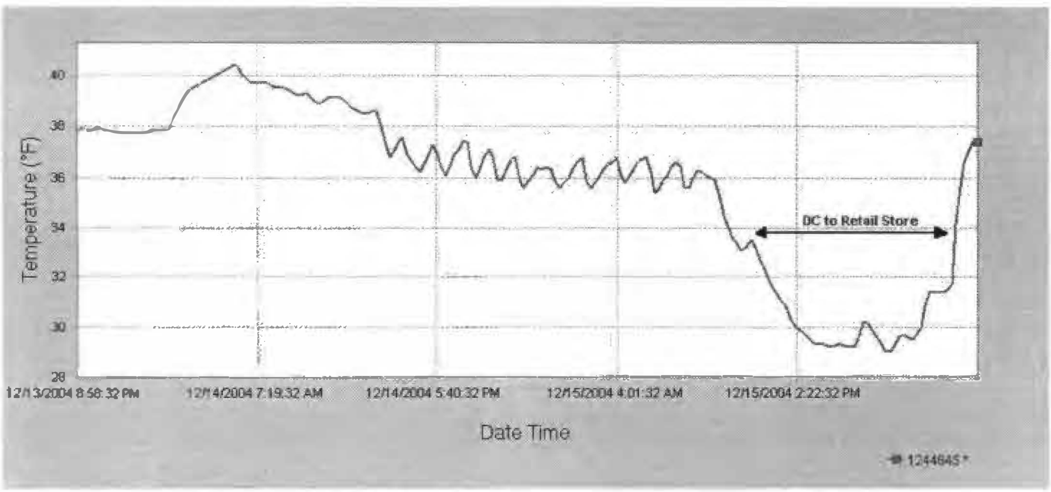


Figure 23. Fresh cut salads trip graph example 3-Supplier 2 (Morrow GA location)-Anniston AL DC-Mooresville NC store 1505

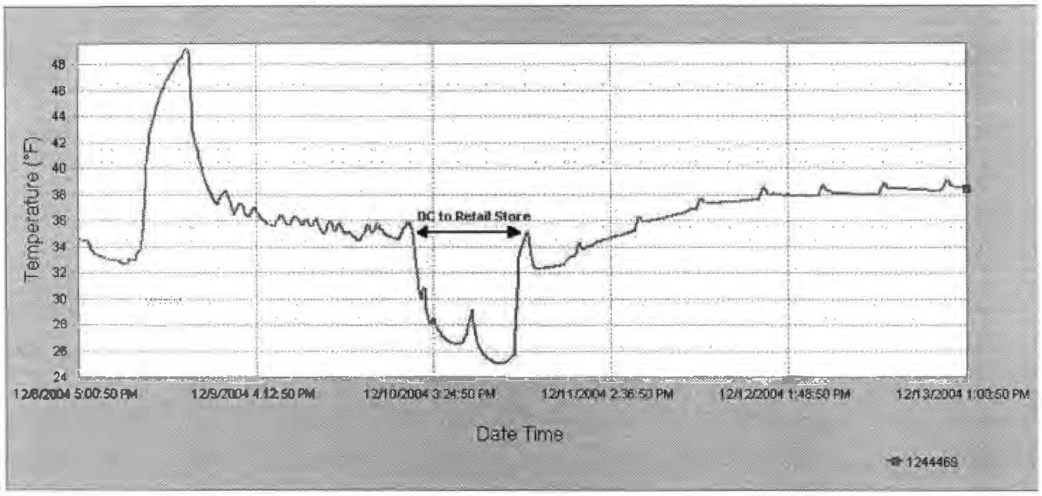


Figure 24. Fresh cut salads trip graph example 4-Supplier 2 (Morrow GA location)-Anniston AL DC-Durham NC store 1872

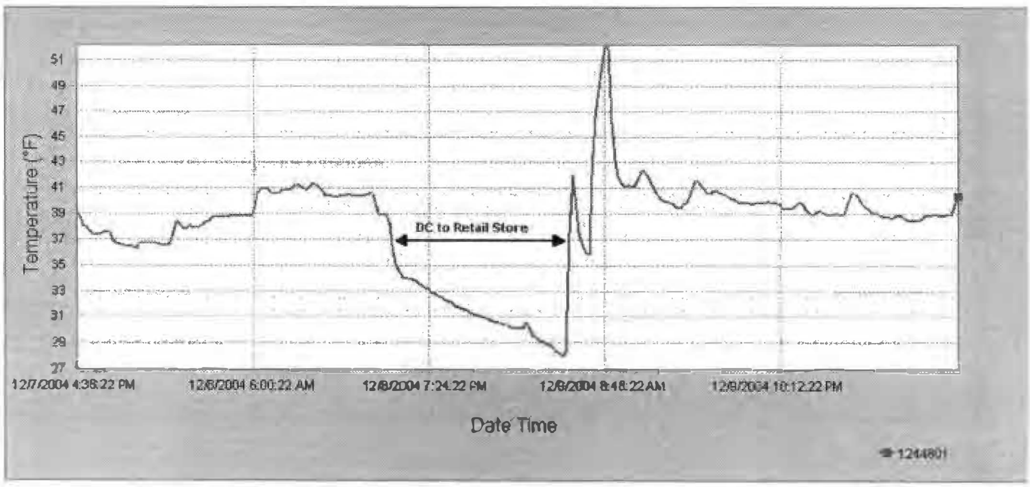


Figure 25. Fresh cut fruit trip graph example 5-Supplier 1 (Grand Rapids MI location)-Champaign IL DC-Warrenville IL store 1903

Figure 26. Fresh cut salads trip graph example 6-Supplier 2 (Salinas CA location)-Ft Worth TX DC-Layton UT store 1755

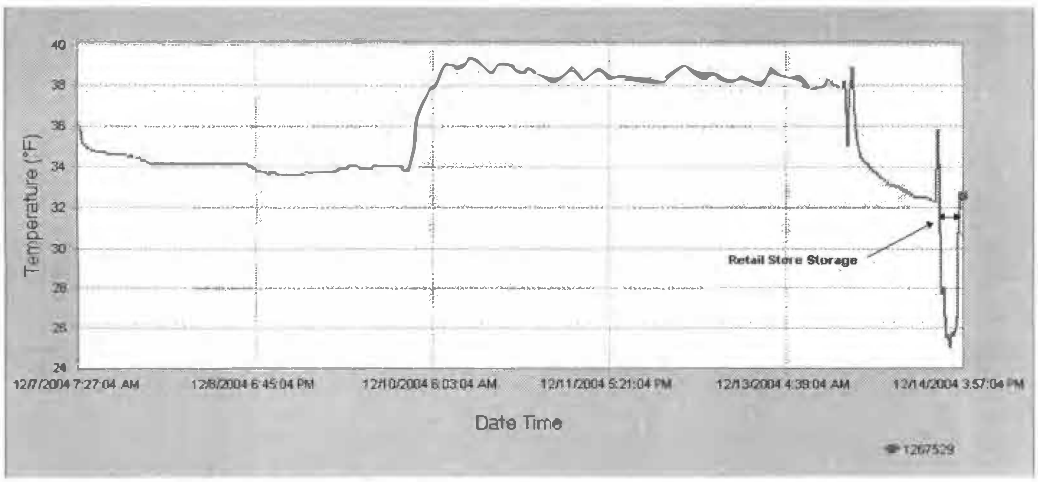


Figure 27. Fresh cut salads trip graph example 6-Supplier 2 (Salinas CA location)-Ft Worth TX DC-Superior CO store 1769

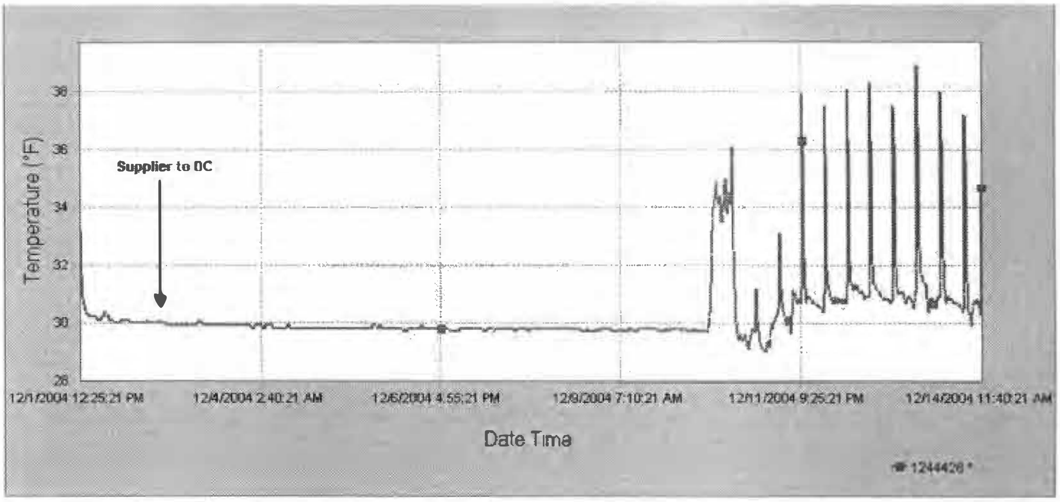


Figure 28. Fresh cut salads trip graph example 7-Supplier 2 (Morrow GA location)-Anniston AL DC-McDonough GA store 1461

Time Above 41°F

Figure 29 documents the time each shipment spent above 41°F. On average, each shipment spent 6.9 hours above 41°F. 499 shipments, representing 72.7% of the shipments monitored, spent time above 41°F and 212 shipments, representing 30.9% of the shipments monitored, spent at least 5 hours above 41°F.

Sources of Above 41°F Events

Several cases of product experienced temperatures higher than that which is expected. Examples can be found in graphs below. This pattern can be observed in numerous shipments. Above 41°F events occurred mostly during storage at the retail stores, but also occurred during transfer points and during transportation from supplier to the distribution centers.

Many of the Above 41°F Events are occurring at the stores. Examples documenting this observation can be found on figures 30, 31 and 32.

The Above 41°F Events also occurred during transfer points in the distribution process. When above 41°F Events occurred during transfer points, they tended to be in short spikes or a series of short spikes. Examples documenting this observation can be found on figures 33, 34, and 35 below.

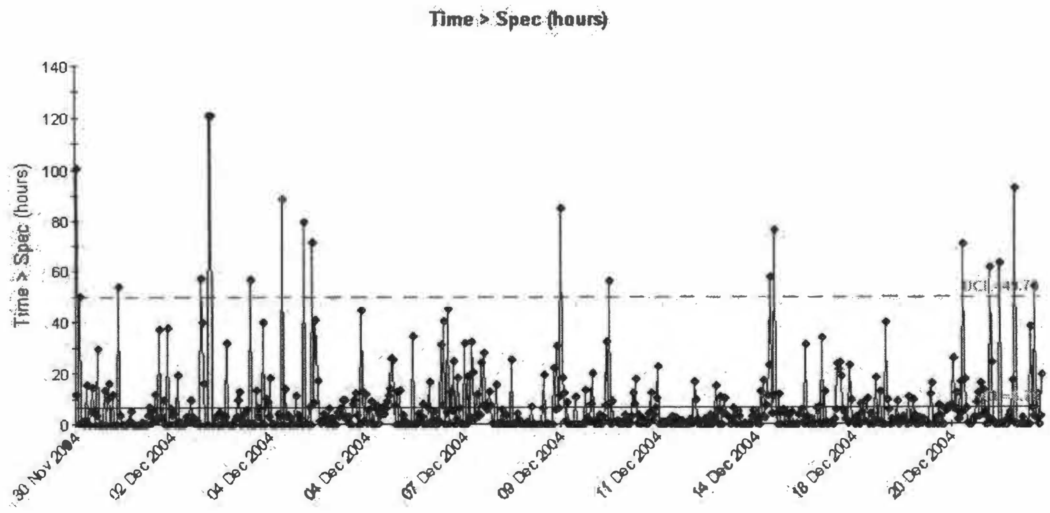


Figure 29. All products-time above specification control chart

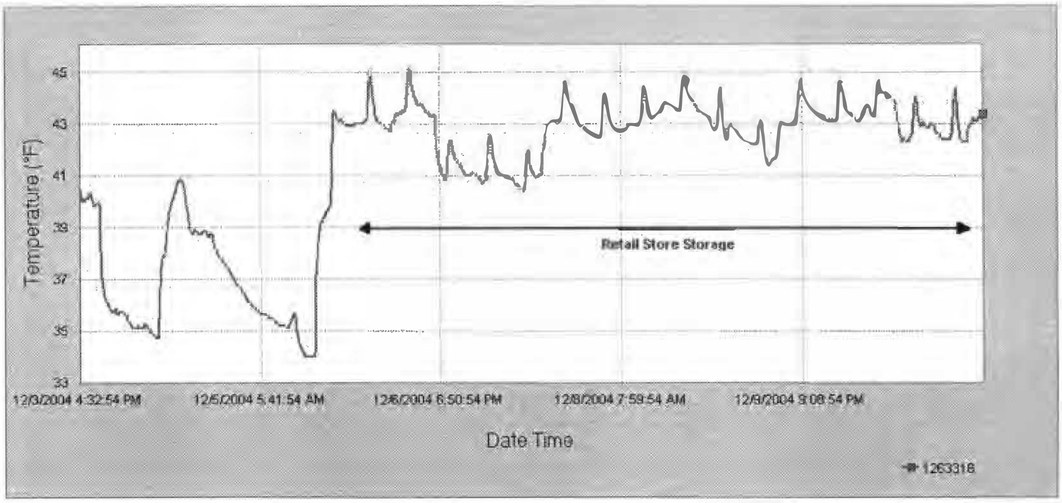


Figure 30. Fresh cut salads trip graph example 8-Supplier 2 (Geneva IL location)-Hopkins MN DC-Shoreview MN store 619

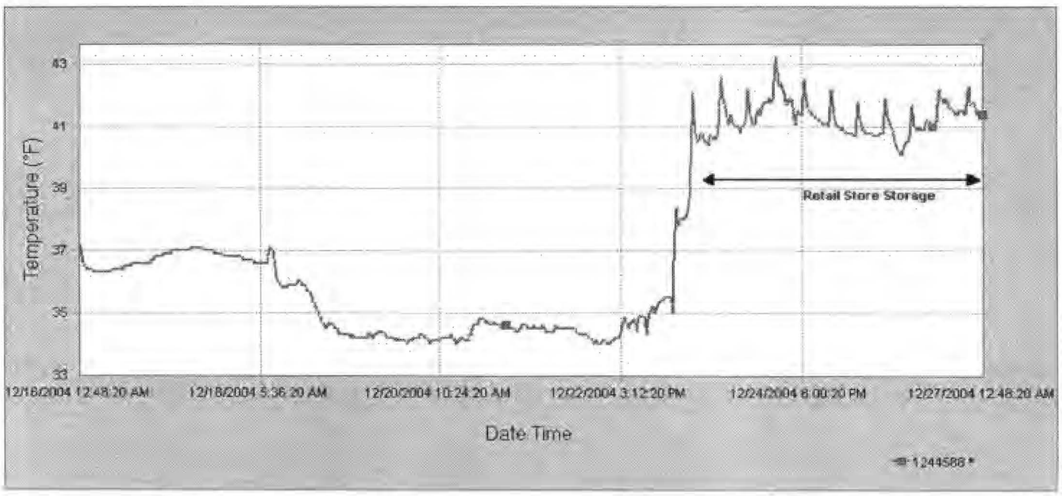


Figure 31. Fresh cut salads trip graph example 9-Supplier 3 (Yuma AZ location)-Hopkins MN DC-Chaska MN store 1352

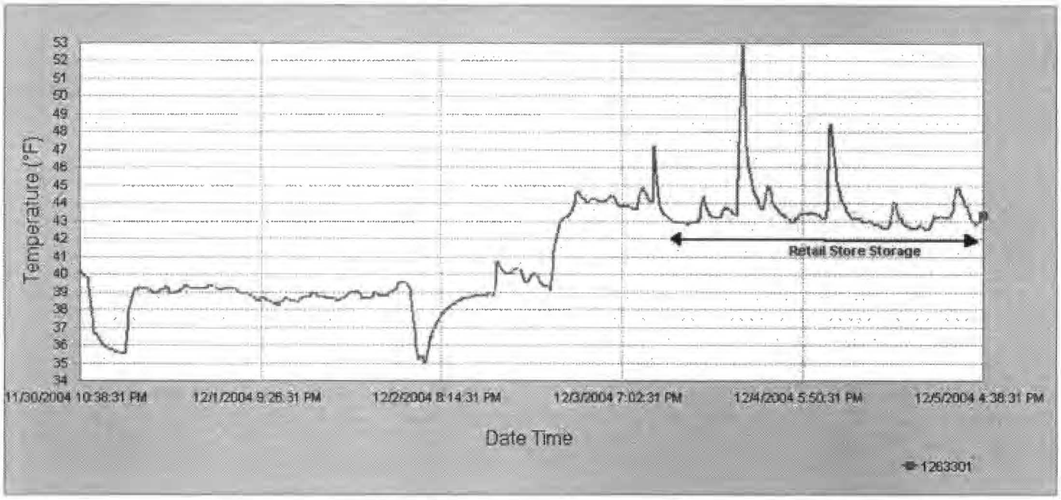


Figure 32. Fresh cut salads trip graph example 10-Supplier 2 (Geneva IL location)-Champaign IL DC-Lees Summit MO store 1392

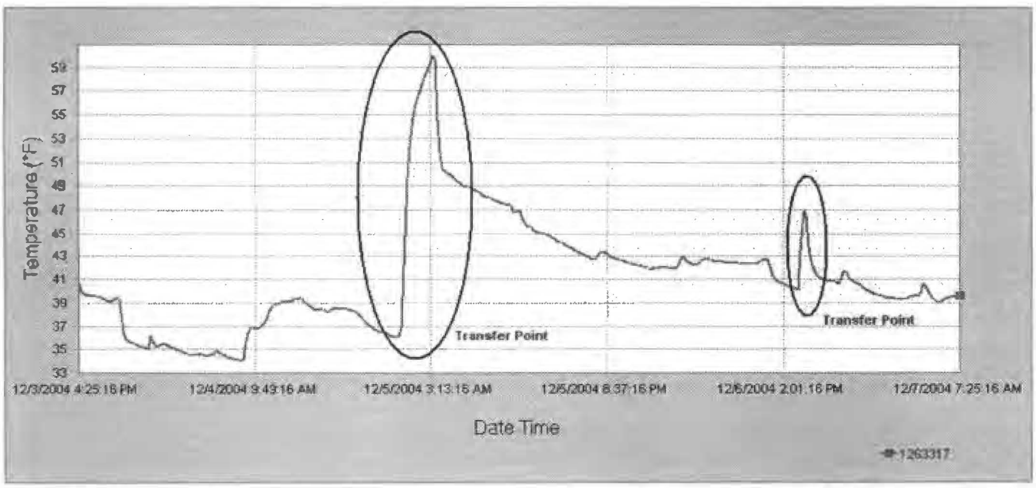


Figure 33. Fresh cut salads trip graph example 11-Supplier 2 (Geneva IL location)-Hopkins MN DC-Lakeville MN store 1484

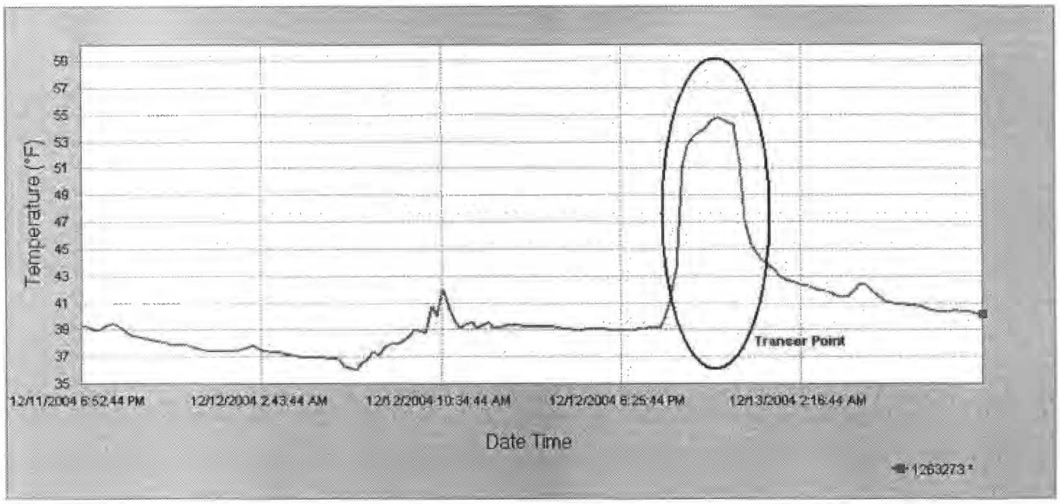


Figure 34. Fresh cut fruit trip graph example 12-Supplier 1 (Dallas TX location)-Anniston AL DC-San Antonio TX store 1354

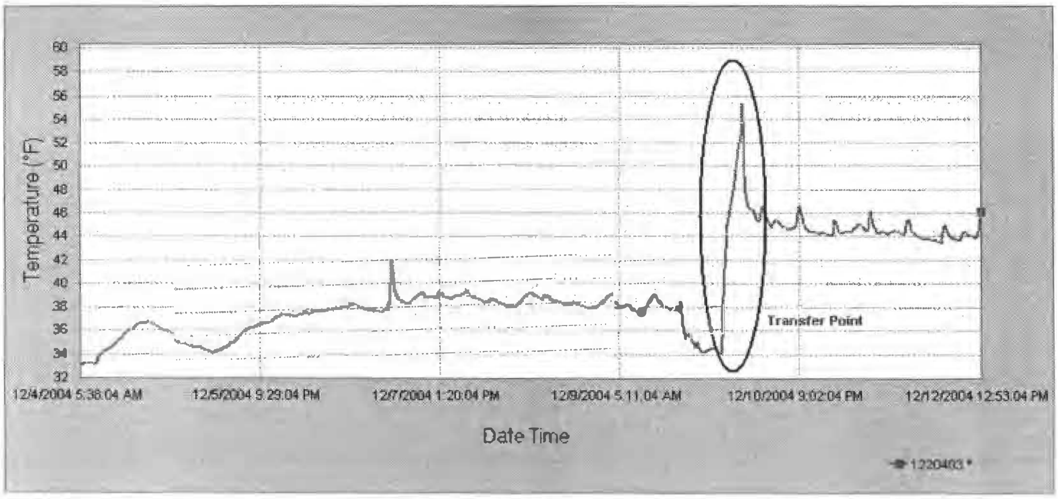


Figure 35. Fresh cut salads trip graph example 13-Supplier 2 (Salinas CA location)-Ft Worth TX DC-Euless TX store 1368

The Above 41°F events also occurred during transportation from supplier to distribution center, primarily shipments from Supplier 3, Yuma AZ and Supplier 2, Geneva IL. See examples in figures 36 through 41 below.

4.3.4 Recommendations

The following are the recommendations that were given to the retail chain.

1. Investigate SOPs used by suppliers (primarily Supplier 3 in Yuma AZ and Supplier 2 in Geneva IL), to ensure they are cooling product properly and loading trailers properly. The more time your products are subjected to temperatures above ideal, the faster their shelf life and quality deteriorate. See example below:

   For fresh cut salads:
   1 hour at 35°F = 1 hour of potential shelf life.
   1 hour at 40°F = 1.2 hours of potential shelf life.
   1 hour at 45°F = 1.5 hours of potential shelf life.
   1 hour at 50°F = 3 hours of potential shelf life.
   1 hour at 55°F = 10.5 hours of potential shelf life.
   1 hour at 60°F = 21 hours of potential shelf life.

2. Verify that carriers are following proper procedures. Verify the following:

   - Check product temperature prior to loading. Document temperatures from multiple pallets on the manifest.
   - Use correct reefer set point. Document the set point temperature on the manifest.
   - Set reefers on continuous mode. (vs. fuel saving, cycle, start-stop)
   - Pre-cool trailers. Document the trailer walls temperature on the manifest.

3. Investigate the standard operating procedures followed by the distribution centers (primarily Ft. Worth TX), to ensure that your products are being held in spec during transportation. The ideal temperatures are 32°F for fresh produce and 28°F for fresh meat. This will ensure maximum freshness and maximum shelf life of your products.

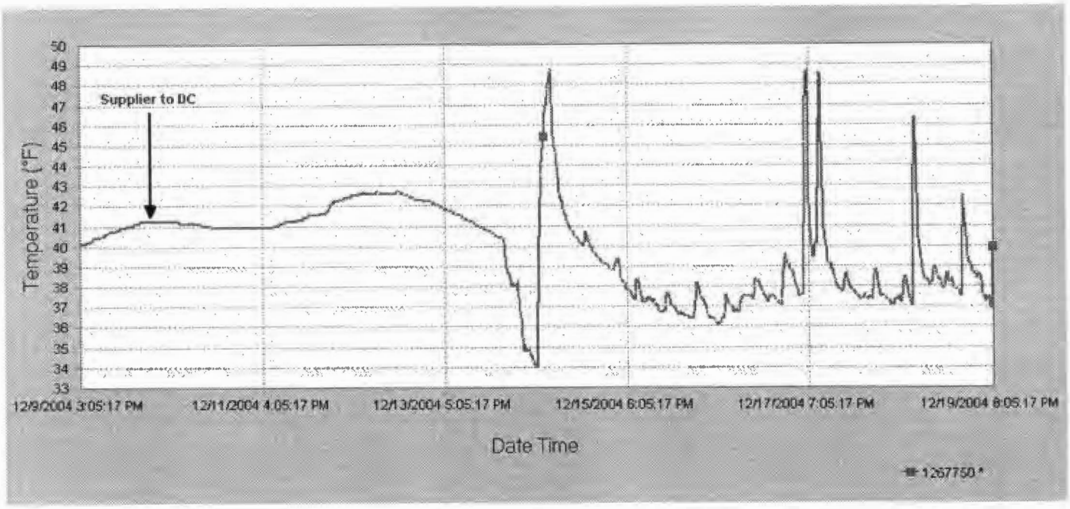


Figure 36. Fresh cut salads trip graph example 14-Supplier 3 (Yuma AZ location)-Anniston AL DC-Huntsville AL store 1367

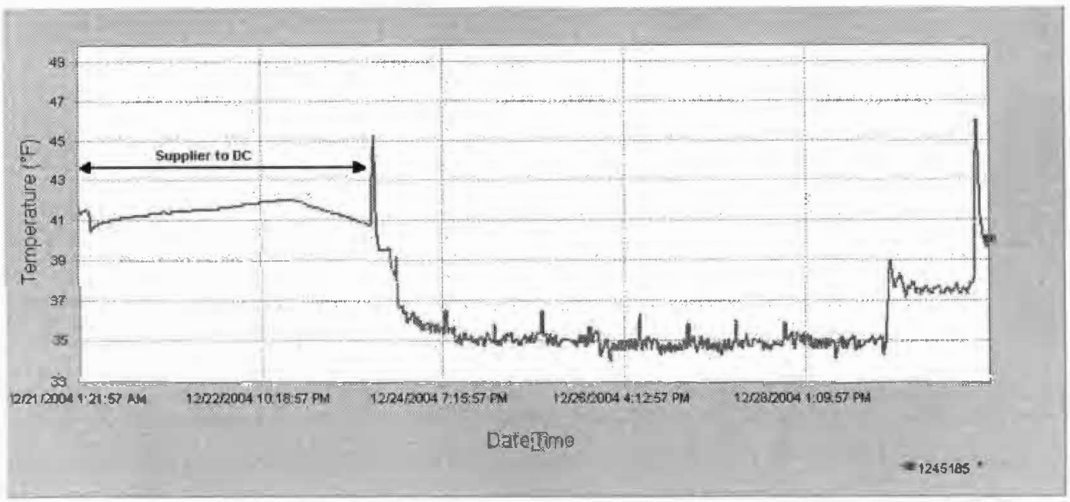


Figure 37. Fresh cut salads trip graph example 15-Supplier 3 (Yuma AZ location)-Anniston AL DC-West Palm Beach FL store 1935

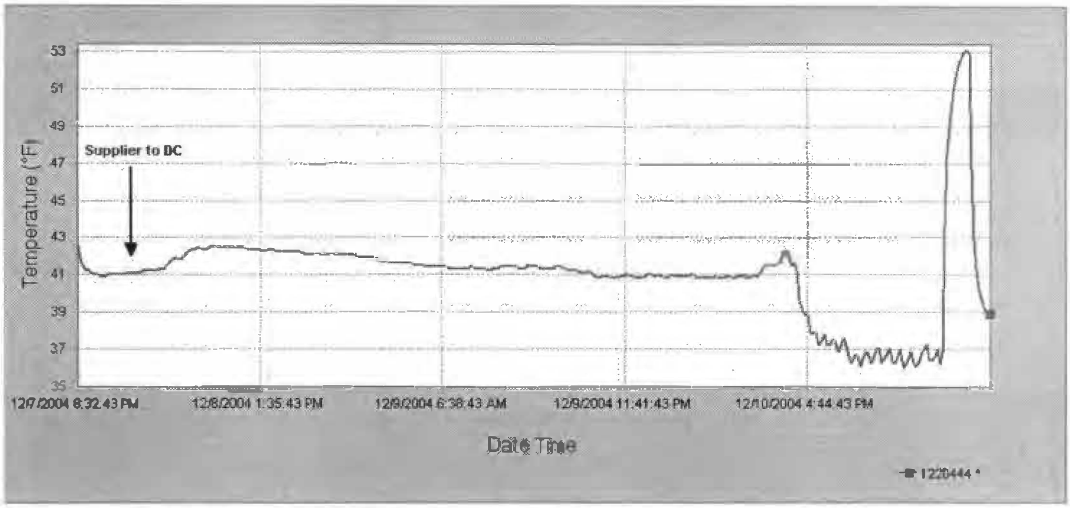


Figure 38. Fresh cut salads trip graph example 16-Supplier 2 (Geneva IL location)-Champaign IL DC-Mishawaka IL store 1445

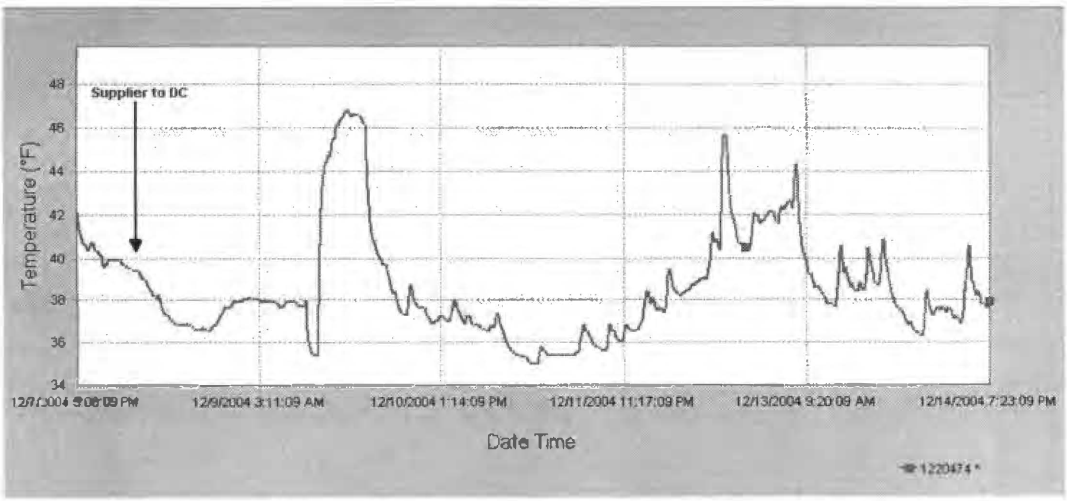


Figure 39. Fresh cut salads trip graph example 17-Supplier 2 (Geneva IL location)-Champaign IL DC-Papillion NE store 532

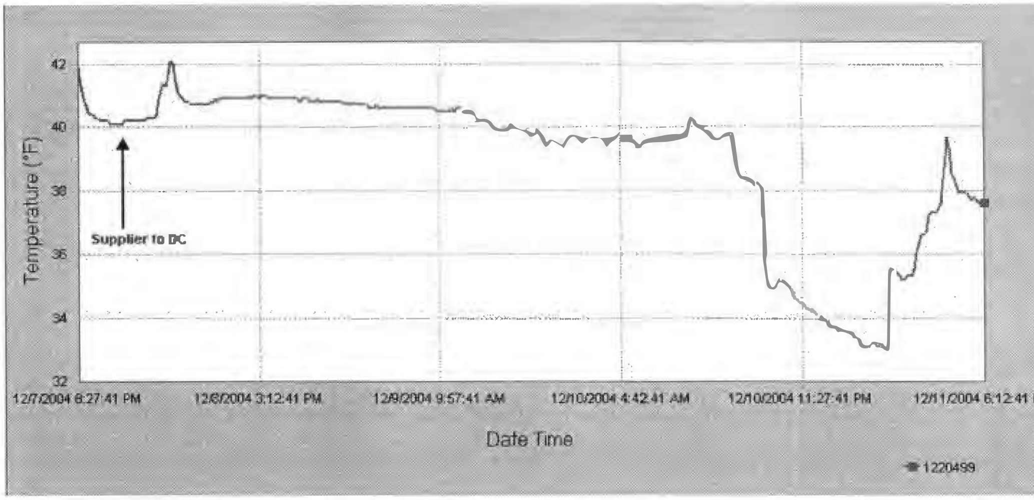


Figure 40. Fresh cut salads trip graph example 17-Supplier 2 (Geneva IL location)-Champaign IL DC-Lafayette IN store 1762

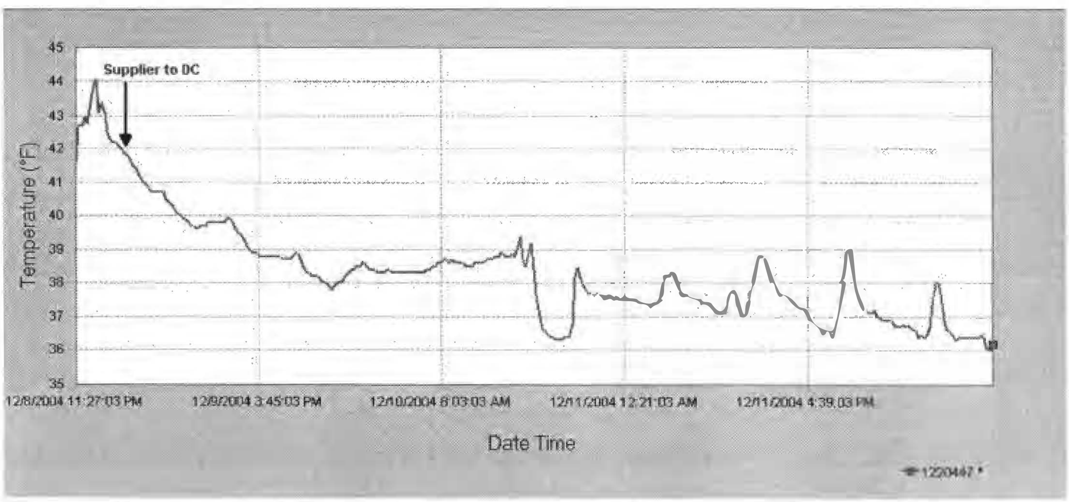


Figure 41. Fresh cut fruit trip graph example 18-Supplier 1 (Dallas TX location)-Anniston AL DC-Watuga TX store 1765

4. Proper airflow is critical to ensure proper product temperature. Whenever possible, use a centerline pallet loading pattern to ensure proper airflow between the trailer walls and the product.

5. Investigate the cause of the above spec temperatures observed at the retail stores. Verify the following:

    - Use proper walk-in cooler set points.
    - Close walk-in doors after entering or exiting.
    - Move product into the cooler as soon as possible after receipt.
    - Avoid placing highly perishable produce items near evaporator coils or near door.
    - Verify that strip curtains are installed, in good condition and are being used properly.
    - Rotate product properly.

6. Investigate the cause of the spikes in temperature observed at the transfer points. The most common cause for this type of temperature problem is leaving pallets on under-refrigerated dock areas for extended periods of time after unloading or during staging for loading.

7. Monitor all shipments from supplier to DC with temperature monitors. Incorporate cold chain improvement techniques to provide analysis of data aggregated from large numbers of trips thereby enabling evaluation of performance of suppliers and carriers.

CHAPTER 5

CONCLUSIONS

5.1 Cold Chain Management Benefits and Lessons Learned from the Usage of Model

As seen in the cases study chapter, cold chain analysis provides many benefits to the customer. They are as follows:

- Provides information that allows managers to take action to continuously improve their cold chain.
- Provides useful information for managers is a wide range of functional areas from Sales and Marketing to Transportation to Quality Assurance.
- Provides useful information for managers throughout the organization from the most senior level to line supervisors.
- Improves product quality through the ability to better manage temperature.
- Eliminates the need to deal with large amounts of data. Data is transformed through the use of statistical process control into easily usable information.
- Facilitates communication regarding temperature issues internally with suppliers and with customers.
- Allows for better, more well informed, capital purchase decisions related to cold chain management.
- Assists in determining personnel training needs.
- Serves as a basis for the development of standard operating procedures relating to cold chain management.
- Allows for identifying issues in the cold chain before they become problems, helping companies prevent problems rather than simply reacting to them after they happen.
- Makes decision making more streamlined and easier to accomplish. Temperature data is no longer just temperature data, its powerful information managers can use to take action upon.
- Allows for companies to maintain the highest standards in their distribution process and clearly track the temperature of the products all the way through to the end customer.
- Demonstrates control of a cold chain.
- Improves speed and integrity on decisions about questionable shipments.
- Increases visibility into processes and suppliers that manage a company's cold chain.

- Identifies trends and facilitates operational improvements.

The cold chain encompasses all the critical steps and processes that food and other perishable products must undergo in order to maintain their quality. Like any chain, the cold chain is only as strong as its weakest link. Major limitations experienced by the cold chain include poor temperature management due to either the lack of, or limitations in, refrigeration, handling, storage, and humidity control. Investment in cold chain infrastructure and tools that help one continuously improve the cold chain ultimately leads to a reduction in the level of losses and quality degradation in perishable products, with overall net positive economic returns (22, 34).

Deficiencies in cold chain management whether due to limitations in refrigeration, can lead to losses in profits as well as in the products themselves. Overcoming such deficiencies necessitates improvements in methodologies, operations and handling along the chain. Often the level of investment required in overcoming such deficiencies is minimal in comparison to the level of losses sustained over time (22, 34).

In fact, a University of California study determined that a one-hour delay in cooling strawberries after harvest resulted in a 10 percent loss due to decay during marketing. The resulting economic loss exceeded the increased cost of expedited handling of the strawberries by more frequent deliveries of harvested fruit to the cooling facility and initiation of forced-air cooling. Similarly, a University of Georgia study showed that poor temperature management of lettuce resulted in a net income loss of US$172.50 per truck-load of 900 cartons. Also, another study completed by the University of California determined that excess weight loss coupled with color deterioration resulting from delays between harvest and cooling, improper refrigeration temperature control during the shipping of table grapes resulted in a 15 percent loss in the value of that commodity. Resultant monetary losses were greater than the cost of improved management of temperature of the grapes with perforated plastic liners in the boxes and by minimizing delays prior to cooling with humidified, forced air (22, 24).

Better cold chain management coupled with cold chain analysis using the model discussed in this thesis is key to the success of the food industry which all run on razor thin margins. As seen in the case studies chapter, inexpensive improvement in cold chain management can reduce product losses and quality losses significantly. Poor cold chain management leads to poor brand equity. Quality and freshness of products is key to generating repeat sales and temperature from point of production to shelf plays a key role in the quality and freshness of products. The performance of a cold chain is measurable at each step in the cold chain. Issues in a cold chain must be discovered, measured, prioritized, and managed. Cold chain analysis through this statistically based model unlocks the hidden profits and brings the deficiencies to the forefront and dollars into pockets. Cold chain analysis helps prioritize temperature issues so that managers can address the challenges efficiently. As scene in the two cases studies, process improvements are usually the solutions identified. Process improvements usually focus on the following areas:

- Cooling equipment operation
- Storage cooler management
- Reefer trailer management
- Loading/Unloading practices
- SOP development and accuracy

This model helps prioritize temperature issues so that managers can address cold chain challenges efficiently. Typically process improvements are the solution.

The model involves monitoring, analyzing and improving a cold chain:

- Capturing data from throughout the cold chain according to specific methodology
- Applying analysis techniques that turn data into information that can be used by managers
- Assist in implementing recommendations for improvements

With the techniques and model discussed in this thesis, several millions of dollars of wasted food products can be saved every year with simple changes in processes that are discovered through statistical process control. With the typical supply chain management methodologies, temperature is not taken in account. With the cooperation of all parties involved in a supply chain and temperature data being known, a win - win result would not be possible for all, perishables would potentially not be safe and poor quality product could be delivered to customers putting a businesses brand equity on the line.

Using the statistical based cold chain model when improving cold chain management discussed in this thesis can create a win – win situation for all parties resulting in thicker bottom lines and safe products and excellent product quality with brand names of its providers remaining in tact for the future.

5.2 Potential Work to Follow

The recommended next steps as a continuation of this thesis would be to utilize the technologies of radio frequency and automation to automatically gather the data required from temperature monitors that are utilized in a cold chain. The system could automatically accept the data from temperature monitors and add pieces of important logistics information as a piece of advance shipping information from logistics system that currently exist to aid in controlling inventory management.

By applying rules in regards to temperature specifications in respect to acceptance or rejecting of the product to the collected data, a business could automatically be alerted when the cold chain process is deviating and one could implement the process improvements in real time resulting in less product loss and even more visibility into the cold chain.

The final recommended next step would be to incorporate shelf life modeling of product lines in regards to how the temperature management affected the shelf life of the product into the model. Then, companies could revolutionize their current inventory control systems to base inventory turns on the shelf life of goods. They could move from using the current first in first out (FIFO) procedure that is utilized within the food industry to basing inventory turns on the actual life (shelf life) of the perishable good. Those goods which had been most temperature abused could be moved through the system faster than those goods that have extended life based on minimal temperature abuse.

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VITA

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Amanda is currently working for Sensitech Inc. in Beverly, MA as the Operations Manager of their professional services division, providing her food and pharmaceutical customer's techniques and services to improve their overall cold chain management.