Economic Value of Selected NOAA Products within the Railroad Sector

A Report to NOAA's National Climatic Data Center

NOAA Satellite and Information Services

National Environmental Satellite, Data, and Information Service

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Executive Summary

Environmental data serve numerous functions within consumer, governmental, educational and industry applications. As part of the National Oceanic and Atmospheric Administration's (NOAA) continuing efforts to improve the data products and information services it provides, the agency periodically evaluates the manner in which its products and services are used and the economic value the products and services provides to its customers. This evaluation enhances the agency's understanding of its customers and assists the development of improved data and information services. This project extends the processes and methodologies employed in a previous engagement for NOAA by Centrec Consulting Group, LLC (2003) for the electricity and natural gas sector of the energy industry. This effort evaluates and provides economic estimates for utilization of NOAA services in the railroad sector of the freight transportation industry.

Three basic concepts form the economic foundation of this analysis:

1. National Climatic Data Center (NCDC) information products are generally considered public goods that are non-rival and non-exclusionary.
2. The cost of producing the first unit of information products is relatively high whereas subsequent units are very low cost to reproduce. In these instances, it is likely that a market structure characterized by dominance of one firm will emerge.
3. Emergence of a dominant firm market structure tends to lower consumer benefits due to monopolistic pricing behavior relative to competitive market pricing.

While there are several sectors within the freight transportation industry including air, water, truck and railroad, this study focused on one sector due to the complex use of NOAA data and information. Criteria used to determine which sector of the freight transportation industry was to be analyzed were:

1. Manner in which historical weather and climate data are used by and are relevant to the sector;
2. Frequency of purchases of NCDC products by individual companies; and
3. Concentration of purchases of NCDC products by the sector, based on approximate sector participants.

Based on the above criteria, it was determined that the railroad sector was the most appropriate to analyze. Once the scope was determined, the NOAA products used by the railroad sector were researched and summarized, and railroad employee customers were interviewed to learn how historical weather data and NOAA products are used in the railroad sector. Lastly, the economic value that the NOAA products provide to the railroad sector was calculated.

The railroad sector heavily utilized the NOAA's e-Government avenue for ordering and obtaining products online, with only 9% ordered by telephone. The most frequently purchased products were maintained at NOAA's National Climatic Data Center (NCDC). These products were derived from weather observations from NOAA's Cooperative Observer (COOP) and Automated Surface Observation System (ASOS) network. Products ordered from these networks included COOP Data, Local Climatological Data, and Surface Weather Observations. The five Class I Railroad Companies purchased an average of 4.4 NCDC products annually.

The surveyed Railroad Companies use NCDC products principally for three purposes: (1) validation of historical weather conditions for legal claims and other legal proceedings; (2) analysis of extreme weather-induced events to understand the weather conditions that contributed to or caused an event; and (3) validation of decision rules for decision support systems (DSS).

To evaluate and provide economic estimates for a specific application of NCDC services, the "Alternative Cost Approach" was employed to determine economic value. The goal of the Alternative Cost Approach is to document the value of NCDC's activities by assessing the costs the Railroad Companies pay to obtain weather information from NCDC versus an estimate of the costs required for the Railroad Companies to perform those functions on their own. To estimate the economic value, a cost-benefit ratio (cost estimate of establishing and operating a system that would provide the Railroad Companies with the same information divided by the average NCDC product acquisition costs). This ratio measures the economic benefit of utilizing NCDC products to the Railroad Companies. The computed cost-benefit ratio was then extended to a sector level based upon the relative revenue share of the Class I freight railroad market that the Railroad Companies comprise.

The annual average cost for the five Class I railroads to obtain the weather-related products from NCDC is $825 per year while the approximate cost to NCDC to ingest, calibrate, validate and archive the data is $2.17 million. The calculated cost-benefit ratio is 13,139.8, implying that for every $1 each of the Railroad Companies spend in acquiring data, they receive a potential benefit of not having to spend $13,139.80 to acquire the data on their own. When extended to the entire Class I freight railroad sector, the potential benefits are approximately $11.5 million.

This study generated specific recommendations for additional analysis:

1. An additional study could focus on the products and services provided by commercial weather or consulting services that utilize NCDC products. These third parties would be entities that purchase the historical data and either re-package the data or use the data in products and with services they offer to their customers.
2. In addition to the products and consulting services offered by commercial weather services, an industry providing weather risk management tools has emerged. These services provide products such as weather insurance and weather derivatives, options, collars, or swaps. A supplemental study could be conducted that would investigate the manner in which the companies offering these weather risk management tools are utilizing historical weather data.
3. Further research on additional industries or sectors would provide a deeper understanding of the way in which the products are used and provide NCDC personnel with ideas for improved products and services. Examples of additional industries or sectors that could be studied include:
    a. Agriculture, including agribusiness
    b. Insurance industry
    c. Airline sector of the transportation industry
    d. Energy distributors for crude oil, heating oil, and propane
    e. Construction
    f. Recreation – resorts, theme parks

Introduction

Environmental data serve numerous functions within consumer, governmental, educational and industry applications. As part of the National Oceanic and Atmospheric Administration's (NOAA) continuing efforts to improve the data products and information services it provides, the agency periodically evaluates the manner in which its products and services are used and the economic value the products and services provide to its customers. By quantifying that economic value, NOAA is better positioned to:

- Apply scarce resources to the most relevant and popular products
- Conduct more tangible data product development
- Identify those products providing the most economic value for data users
- Understand actual operating and planning applications of data
- Enhance existing data products
- Improve service to existing customers

In a previous project conducted for NOAA by Centrec Consulting Group, LLC (2003), the economic value of NOAA information and data services to an energy company and the electricity and natural gas sector of the energy industry were analyzed. The study, "Investigating the Economic Value of Selected NESDIS Products", found that the selected NOAA products from the National Climatic Data Center (NCDC) yielded potential benefits of slightly more than $65 million to the electricity and natural gas sector of the energy industry. A recommendation resulting from the study was to expand the investigation of the economic value of NCDC products in other industries. This expanded work would enhance the agency's understanding of its customers and assist the development of improved data and information services.

This project extends the processes and methodologies employed in the previous engagement, and focuses on the manner in which NCDC products and services are utilized in the railroad sector of the freight transportation industry.

Project Objectives

The purpose of this project is to provide economic analysis and information useful to NOAA regarding the types of data used and applications of data by NOAA's customers. This will provide NOAA leaders with information useful in demonstrating to others the value of NOAA resources and infrastructure. The project evaluates and provides economic estimates for utilization of NOAA services in one area – the freight transportation industry.

Activities Conducted Within Project

This study quantifies the benefits obtained from freight transportation companies relying on NOAA data from NCDC for decision-making as part of their ongoing operating activities (i.e., used for daily or frequent planning, budgeting, reporting, etc.). According to the Bureau of Economic Analysis, a division of the Department of Commerce, the transportation industry, as broadly defined, contributed over $338 billion to Gross Domestic Product in 2004, which is about 3% of the total U.S. economy. This project focuses on the railroad component of the freight transportation industry.

Three activities were conducted to meet the objectives of this project for NOAA products and data available from NCDC:

1. NCDC products utilized by the railroad sector were researched and summarized.
2. An understanding of how NCDC products and historical weather data are utilized in the long-haul freight railroad sector was obtained.
3. An estimate of the economic value that the NCDC products provide to the railroad sector was calculated.

The first activity consisted of researching the Customer Order Management Processing System (COMPS) to determine which products were ordered and how often they had been ordered by railroad companies. Additional queries about product usage were conducted during the interviews. Product costs were obtained from NCDC personnel, and the product information was summarized.

To gain insight as to how the railroad sector uses historical weather data, NCDC customers who worked with long-haul freight railroads and commercial weather service companies were interviewed. They were asked in what manner the historical data are used and how they have utilized the NCDC products. In addition, an understanding of the use of decision support systems was obtained through these interviews, a supplemental interview with a researcher who works in this area, and general research.

To evaluate and provide economic estimates for a specific application of NCDC services, the "Alternative Cost Approach" was employed to determine economic value. This approach is a derivative of the opportunity cost concept, one of the most basic concepts in economics. A typical definition of opportunity cost is "the cost associated with opportunities that are foregone when a firm's resources are not put to their highest-value use." In this context, highest value refers to the lowest cost means of acquiring high quality and essential information. By using the lowest cost data resource, firms forego the need to expend the additional resources required in obtaining the needed data from an alternative source.

The following section outlines the basic economic concepts that provide the theoretical foundation for the assumptions made for the economic valuation. The remaining sections review the methodology employed for this study, discuss the findings, and provide a summary and recommendations.

Relevant Economic Concepts

Industry participants obtain NCDC data to assist them in decision-making processes for numerous reasons, including the data's uniqueness, accessibility, and cost-effectiveness. Understanding the economic value that decision-making processes bring to the economy and to society guide policy makers, government and the public at large as to the most appropriate role NCDC and its products and services play. This economic analysis is based on three important concepts from basic economics and from the field of information economics[1].

The key conclusions from the three basic concepts are:

- NCDC information products are generally considered public goods. Public goods are not traded in the market place, even though NCDC charges minimal fees to recover some costs. In addition, public goods are characterized as non-rival (more than one person can "consume" the good) and non-exclusionary (no person can be excluded from consuming the good) in nature, as opposed to private goods. Private markets have difficulty in arriving at optimal quantities and prices for goods with these characteristics. Market failures, which often result when products with such characteristics are offered as private sector goods, cause inefficiencies to accrue to the users of those goods.
- The cost of producing the first unit of information products is extremely high whereas subsequent units are very low cost to reproduce. In these instances, it is likely that a market structure characterized by dominance of one firm will emerge. The costs associated with ingesting, archiving, quality control, data set development, and making available its data resources are captured in Fixed Costs. The Marginal Costs represent the very low costs of data reproduction. NCDC's pricing policy of providing data with minimal charges is consistent with the relatively low reproduction costs associated with information products.
- Emergence of a dominant firm market structure tends to lower consumer benefits due to monopolistic pricing behavior relative to competitive market pricing. Public sector provision of this information, such as through NCDC, offsets the "natural" tendency for a dominant firm market structure to emerge.

These concepts provide general guidance as to the market dynamics that result as information-based goods and services, such as those provided by NCDC, are produced and delivered. In particular, these dynamics underscore the benefits of public sector provision of these goods and services.

The remainder of this section describes the concepts and procedures employed to derive the findings just described.

Key Economic Characteristics of NCDC Data Systems

The most commonly understood aspects of economic analysis relate to private goods traded in the market place. Common examples include purchasing food in a grocery store or consumer electronic items in a retail store. The information that NCDC makes available for its users is fundamentally different from these common examples in terms of, at least, three key

[1] This section is adapted from "Investigating the Economic Value of Selected NESDIS Products".

characteristics. First, the information that NCDC provides is not traded in the market place (although charges to recover some reproduction costs are made).

A second key characteristic of NCDC information is that such information is in the form of public rather than private goods. A public good is characterized as being both non-rival and non-exclusionary in nature. These features are described later in this discussion.

The production and marketing of information has blossomed as an important economic undertaking over the last decade. Although the collapse of the "Internet bubble" has cooled speculator interest in information marketing, this issue is important in the evolving knowledge economy. Thus, a third distinguishing characteristic of NESDIS information relates to the likely market structure impacts that are associated with the production and sale of information in the marketplace. These arise from the cost structure typical for information and information systems and also will be described in this section.

Information as a Public Good

Most goods are rival in consumption. When one person purchases a can of vegetables, that can of vegetables is no longer available for others to consume. Public goods, in contrast are characterized as being non-rival in consumption *(Pindyck and Rubinfeld)*. When a public good is consumed by one individual, it is still available to be consumed by others. For example, multiple ships can benefit from the services of a single lighthouse.

Typically the provider of a good or service can restrict the use of that good or service. If a customer doesn't purchase the good or service, that customer can't enjoy the associated benefits of consumption. Providers of public goods, however, cannot prevent certain people from consuming the good. The information that NCDC provides, therefore, fits the definition of being a non-exclusive good, the second dimension of a public good. National defense is the classic example of a non-exclusive good. In addition, if a local government unit expends resources to control an agricultural pest, the benefits of doing so are available to all farmers in the area.

Most goods exist on a spectrum (or range) across the non-rival and non-exclusive characteristics. They are neither completely non-rival nor rival in consumption, nor are they completely excludable or non-excludable. For example, because NCDC charges a minimal fee to recover a portion of the reproduction costs of some information, those information items have some of the elements of being exclusive goods. However, those charges are small relative to total costs. Further, once one customer has specific information items, it is virtually impossible to restrict that user from making the information available to others. (As with all data and information produced by the Federal Government, NCDC information is not copyrighted.).

As the name indicates, it was traditionally expected that public goods would be provided by public entities rather than by firms in the private sector. With advances in technology, the capability for private sector firms to provide formerly public goods has increased. Some technologies now allow providers to exclude customers more effectively from what were formerly non-exclusionary goods. Therefore, the boundary line between the public and private good categories has become less distinct. The classic arguments for public sector provision of non-rival and non-exclusive goods include *(Savas)*:

- Positive Externalities—When a public good is provided, those who did not pay for it still enjoy its benefits. An example is clean air—when a factory spends money to produce less pollution, everyone benefits from the cleaner air.

- Low contracting costs—Because there is usually only one supplier of a public good, the government, costs to build and negotiate a contract are low.
- Less vulnerable to strikes, slowdowns—Since the government is the supplier of the public good, strikes and slowdowns occur less often.
- Economies of scale easily achieved—The benefits of scale economies are more likely to be achieved because there usually is one supplier, the government.
- Private firms do not become too powerful in the political sphere—The threat of monopolistic power emerges with private goods, which possibly can exert influence into political dealings.

Conversely, the disadvantages of public sector provision include *(Savas)*:

- Free-rider problem—Because of positive externalities, individuals can benefit from a public good without contributing to funding the costs required to bring the good into existence.
- Low levels of voluntary contributions—Individuals may see the presence of free-riders and conclude that the public good is underfunded, and therefore not worth contributing resources to public goods.

Although the basic rules of economics have not changed *(Shapiro and Varian)*, new technologies and changing market forces have caused many to call for reexamination of the best means to provide goods and services traditionally provided by the public sector. Such reexamination often is useful to inform public sector decision-makers and the public, even if it does not lead to total or even partial privatization of activities. The advantages of public sector provision of services which are non-rival and non-exclusionary in nature need to be recognized and quantified for effective analysis and decision-making to occur.

Cost Structures of Information Systems

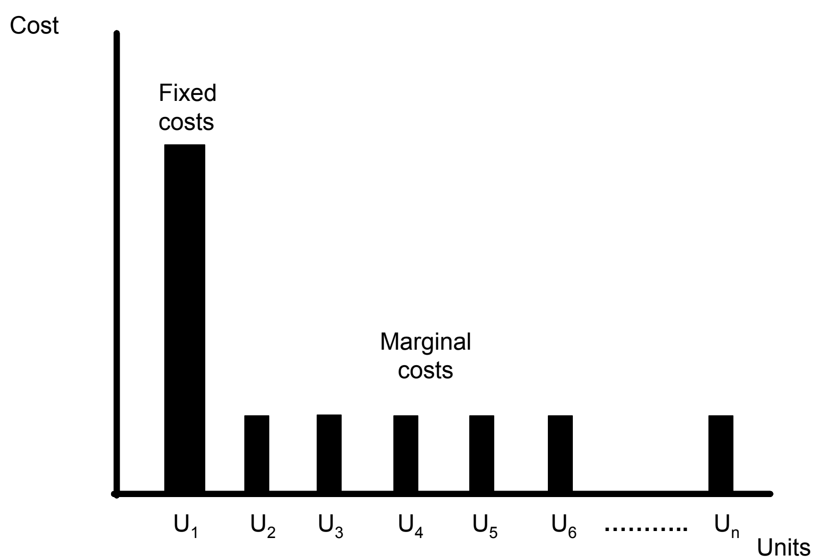

Figure 1. Typical Cost Structure of Producing Information

As the role of knowledge and information has grown in the modern economy, the attention devoted to understanding information production and marketing has grown. As a valued good, information is costly to produce. (In this discussion, the term "information" is defined very broadly—essentially anything that can be digitized as a stream of electronic bits.) "Information is costly to produce but cheap to reproduce." (Shapiro and Varian, p. 3) This is a key distinguishing feature of information as an economic good. Figure 1 illustrates this notion. A very high cost is associated with producing the first unit of information (U_1) and is depicted by the relatively tall cost bar shown for U_1 in Figure 1. The relatively low costs associated with reproduction are indicated by the low bars associated with units U_2 to U_n in Figure 1.

Relative to NCDC, the cost levels indicated by the bar U_1 are representative of the entire set of costs associated with ingesting, archiving, quality control, data set development, and making available its data resources. The much lower bars for additional units ($U_2 \ldots U_n$) represent the low costs of data reproduction. The benefits of these low costs are then experienced by users of NCDC information in terms of the low charges associated with accessing NCDC information.

Anyone who has downloaded a file over the Internet or paid a dime to copy a page of a legal document that originally cost thousands of dollars to produce has experienced the cost dynamics depicted in Figure 1. These dynamics exist for making a single copy of that document but they extend across the decisions of investing in and maintaining entire information systems. Such systems tend to have relatively large investment costs while the variable costs of operating the system tend to be relatively small. Often, however, users can experience substantial switching costs when moving from one information system to an alternative system. For example, consumers who wanted to enjoy an enhanced musical experience by using CDs instead of tapes found each CD to be relatively inexpensive per unit of music stored on the device. However, the user had to expend a more substantial amount of funds to purchase the new device needed to play CDs.

Because of this cost structure, providers of information strive to create lock-in effects to encourage their customers to procure all the information in a category from that provider. The likely market structure to result in this setting is that of the dominant firm. The initial firm to provide effectively the information resource in question will strive to keep competitors out of this market. Firms contemplating entry into the market anticipate that the existing firm will vigorously discipline the market through various means to create lock-in, including temporarily lowering prices in those areas where the entering firm is competing. Because of the relatively high initial system costs, entering firms are discouraged from investing to enter, further establishing the dominant firm market structure. The implications of that structure for customers and society are described in the following section.

Welfare Effects of Alternative Market Structures

The preceding section discussed that the dominant firm model is the most likely market structure to result from the cost dynamics of providing information. Much is known regarding the consumer welfare effects associated with different market structures. This section provides a brief overview of those implications, paying particular attention to the specific NCDC setting as a provider of historical weather and climate information. A number of these economic concepts is also employed in the analysis of NCDC information described later in the text.

Figure 2 provides the classic depiction of the long run price and quantity equilibrium in a perfectly competitive market *(Pindyck and Rubinfeld)*. Price is graphed along the vertical axis and quantity along the horizontal axis. The line marked D represents the market demand curve. This curve has a downward slope indicating that if only a small quantity is available, the unit price will be high. Conversely, if an abundant quantity is available, the per unit price will be low. The upward sloping curve (S) represents the industry supply curve. This market supply curve originates from the marginal cost curves of individual firms in the industry.

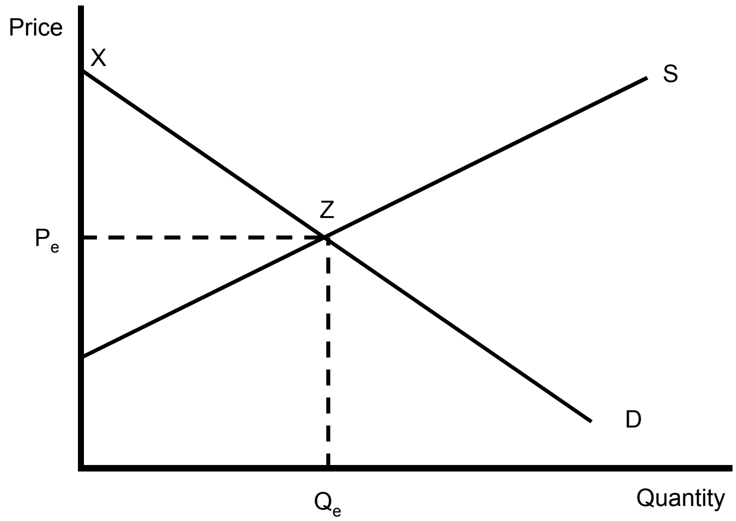

Figure 2. Long-run Competitive Equilibrium

The market is said to be in equilibrium at the price and quantity levels where the demand and supply curves intersect. In Figure 2, equilibrium would occur at points P_e and Q_e. In a perfectly competitive market, each unit sold in the market receives the same price, P_e. The downward sloping demand curve indicates that some consumers would have paid more than that price, if less of the product had been available. The result is that many consumers in the market are able to purchase the product at a price which is lower than what they would have been willing to pay, if forced to, for the product. This notion is called consumer surplus. In the setting described in Figure 2, the amount of consumer surplus is given by the area enclosed in the triangle formed by the points P_e, Z, and X.

The *Shapiro and Varian* based analysis in the preceding section noted that the dominant market structure is likely to occur in a market where the product is characterized by the cost dynamics of information systems. In a dominant market, one firm's product holds the preponderance of the market. Further, that firm has sufficient market power to constrain the market price effectively to a level that the firm finds most profitable. A market with a single, monopolist firm represents the extreme case of a dominant firm market structure.

Figure 3 depicts the equilibrium price and quantity in a market where a monopoly exists *(Pindyck and Rubinfeld)*. The demand and supply curves in Figure 3 are identical to those in Figure 2. In the competitive setting shown in Figure 2, each unit was sold at the same price, P_e. In

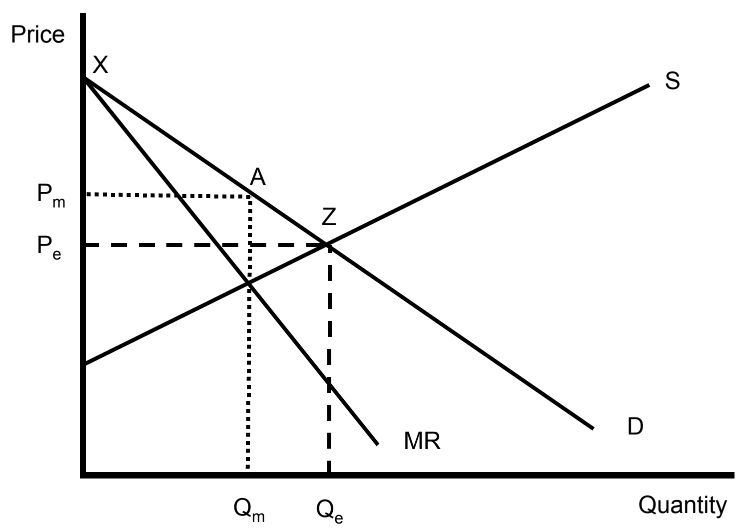

Figure 3. Long-run Monopolistic Behavior

Figure 3, a second downward sloping line is shown to the left of line D. This line is labeled MR for marginal revenue. The concept of marginal revenue refers to the additional revenue a firm receives by providing one more unit of a product. In a perfectly competitive market, as depicted in Figure 2, the marginal revenue is equal to P_e for all units provided. In a market with a monopolist, however, the monopolist could sell just one unit at a very high price. Although the price would be at its maximum, firm profits might not be. To sell the second unit, the firm has to lower the market price that will be charged on both units sold. Therefore, the marginal revenue for the second unit has to reflect the reduction in price associated with unit 1. The MR line reflects this notion for each of the unit levels of Figure 3.

Profit maximization for a monopolist occurs when the marginal revenue line intersects the supply curve. (As in Figure 2, the supply curve also is the marginal cost curve.) In Figure 3, this equilibrium point occurs at Q_m. At that quantity, the monopolist can charge the price P_m. Note that the quantity available in the market is lower and the price charged is higher in the case of a monopoly than was the case in perfect competition (Figure 2). Consumer well-being, therefore, is lower in the case of a monopoly. In geometric terms, consumer surplus is reduced by the four-sided area defined by the points P_e, Z, A, and P_m.

With advanced information technology, it is becoming increasingly possible to provide the market with different versions of essentially the same information product. For example, many firms and individuals are interested in the price movements that occur during each day's trading on stock and futures exchanges. Some individuals desire to know price information the moment it occurs, while others are satisfied to know those movements 10, 20 or 30 minutes after the trade occurs. The firm that provides these price quotes can charge differing prices to those customers who receive "real-time" information versus those who are satisfied with receiving the information after some time delay.

A monopolist providing information products/services would be interested in the "versioning concept". That firm would attempt to provide a different version of the product that corresponded with the demand curve facing the firm. Optimally, for the monopolist, a specific version could be provided to those customers who were willing to pay relatively high prices if only a few units of the product were available to the market. Other versions, which do not satisfy the needs of the highest paying group, would be offered to customers willing to pay less for the product. This setting is referred to as perfect price discrimination. The term "perfect" reflects the view of the monopolist firm as the firm's welfare is at a high level and consumer surplus is minimal.

Although the dominant firm market structure is a typical result of the cost dynamics of information and information systems, competition has been intense in many software and information technology markets in the past few years. Rapid technological change often is the factor that mitigates the monopoly price and quantity effects of the dominant firm structure. While the dominant firm may have power within a specific market niche, that power may not provide excess returns if the entire product market is supplanted by offerings in new product markets. Further, the potential for technological change disciplines the dominant firm from extracting excessive profits from consumers. Excessive profits will attract competition from firms with potential new technologies that can lead to new product markets being developed.

A conceptual analysis of the probable market structure if the private sector provided the information now supplied by NCDC has been presented. Two reasons why the dominant firm market structure could be expected have been outlined. First, the cost structure of information systems tends to encourage "winner take all" outcomes because users desire one standard and the relatively high initial investment costs can act to reduce the attractiveness of markets to potential new entrants. Second, because the information resources provided are both non-rival and non-exclusionary in nature, firms will be hesitant to make investments unless they have a major share of the market. As previously outlined, the dominant firm market structure, when extended to the monopolist setting, results in reduced consumer well-being.

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Methodology

Determining Project Scope

As with the previous analysis, this study's objective is to capture the economic importance of providing climate and historical weather data to an industry that plays an important economic role in the U.S. economy and is significantly affected by weather and climate events. Transportation plays a vital role in the U.S. economy. Without freight transportation fulfilling its role, businesses would not have access to their raw products for manufacturing, and consumers would not be able to obtain the goods they have chosen to purchase. In addition, weather and climate significantly impact the freight transportation industry through their influence on operations (ability to deliver goods and services in the time frame promised to customers) and infrastructure (engineering and construction of runways, railroads, roads, and associated modes of transportation boats, airplanes, etc.).

While there are several sectors within the freight transportation industry, including air, water, truck and railroad, this study focused on one sector due to the complex use of NOAA data and information. Criteria used to select the sector of the freight transportation industry analyzed were:

1. Manner in which historical weather and climate data are used by or are relevant to the sector;
2. Frequency of purchases of NCDC products by individual companies; and
3. Concentration of purchases of NCDC products by the sector, based on approximate sector participants.

Discussions with various NCDC customers classified as transportation users and NCDC personnel provided an overview of the manner in which historical weather and climate data are used by the various sectors of the freight transportation industry.

The frequency of product purchases per company implies the relevance of weather and climate data to the individual companies. It was assumed that the more frequently NCDC products are purchased, the more relevant historical weather and climate data are to the company and sector.

In addition to frequency of NCDC product purchases by company, concentration of purchases by freight transportation sector was evaluated. A simple evaluation of the number of products purchased at the sector level does not accurately reflect the importance of weather and climate data to that particular sector. If a sector has hundreds or thousands of participants with each participant generating orders, the total number of orders across the sector could be large, while the average number of products per company could be low. A low average of orders per company would imply that NCDC products are used infrequently by each company. On the other hand, a sector might be very concentrated (for example, ten participants). These companies might order a smaller aggregate quantity of NCDC products than the other sector, but the resulting orders per company might be much higher, indicating that NCDC products are frequently used by that sector.

Purchases of NCDC products compiled in the COMPS database were reviewed for concentration and frequency of purchases by company and by transportation sector. Of the different transportation sectors, the freight railroad sector purchased NCDC products by company with the highest degree of frequency. Due to the manner in which the railroad sector utilizes historical weather and climate data (described in a later section of this report) and the degree to which it has purchased NCDC products, the freight railroad sector was selected for this analysis.

As described in the following section, the freight railroad sector consists of long-haul, regional, local linehaul, and switching and terminal carrier rail companies. The long-haul component of the sector primarily consists of seven Class I railroads that contributed 87.3% of the freight railroad revenues in the U.S in 2003. Review of the COMPS database revealed that five of the seven Class I railroads had purchased NCDC products from 2000 through 2004, and they contributed 94.4% of the Class I railroad revenues in 2003. Representatives from each of these five Class I railroads were willing to participate in the study. Therefore, a survey of the five Class I railroads was conducted to measure the economic value of historical weather and climate data to the long-haul freight railroad sector. They are henceforth referred to as the Railroad Companies.

Alternative Cost Approach to Understanding Value

In "Investigating the Economic Value of Selected NESDIS Products", Centrec employed a quantitative methodology called the "Alternative Cost Approach to Understanding Value" to analyze the economic value of NCDC products to the energy industry. The same methodology is implemented in this analysis.

The goal of the Alternative Cost Approach is to document the value of NCDC's activities by assessing the costs the Railroad Companies pay to obtain climate information from NCDC versus an estimate of the costs required for the Railroad Companies to perform those functions on their own. In general terms, there are five steps in this process:

1. Identify and categorize significant uses of NCDC data within the Railroad Companies.
2. Estimate the typical annual data acquisition costs for the information currently received from NCDC.
3. Develop, in consultation with NCDC staff, a general estimate of the costs of establishing and operating a system which would provide the Railroad Companies the same information. This cost estimate is considered to be a "benefit" to the Railroad Companies.
4. Calculate a cost-benefit ratio (the benefit estimate from Step 3 divided by the cost identified in Step 2). This ratio measures the economic benefit of utilizing NCDC products to the Railroad Companies.
5. Extend the computed cost-benefit ratio to a sector level based upon the relative revenue share of the Class I freight railroad market that the Railroad Companies comprise.

The Alternative Cost Approach employed here is a derivative of the opportunity cost concept, a basic concept in economics. A typical definition of opportunity cost is, "the cost associated with opportunities that are foregone when a firm's resources are not put to their highest-value use" *(Pindyck and Rubinfeld, p. 204)*. In this context, highest value refers to the lowest cost means of acquiring high quality and essential information. By using the lowest cost data resource, firms forego the need to expend additional resources to acquire the needed data from alternative sources.

Findings

Industry Overview

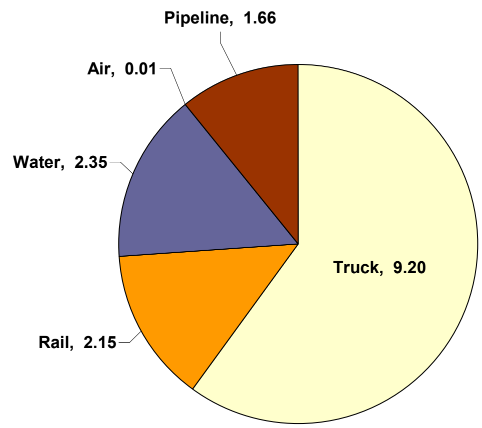
To gain perspective as to railroad's role in the freight transportation industry and the economic significance of the freight railroad sector, a brief overview of the freight transportation industry and the freight railroad sector is provided.

Freight Transportation Industry

The United States transportation system is the largest, most highly developed in the world with total value of freight shipments in 2002 of approximately $11 trillion. The freight transportation sector serves approximately 7 million businesses around the nation and employs nearly 4.4 million people directly involved in freight transportation.

The freight transportation industry is comprised of five major modes: trucking, railroad, water, air, and pipeline. All five of these modes have a valuable role in the U.S. freight system.

As shown in Figure 4, trucks were the largest mode of transportation in terms of tons shipped in 2002, moving 9.2 billion tons of goods and merchandise across the country.[2] America's waterways were the second largest mode of freight transportation, moving 2.35 billion tons of products and bulk commodities. Even though rail freight was third with 2.15 billion tons shipped, it has a much higher percentage of the ton-miles shipped, moving product over approximately 1.5 trillion ton-miles in 2002 (the same amount as trucks).[3] Railroad's high share of ton-miles reflects the heavier weight and the longer length of haul of products moved by rail. For example, grain and coal travel an average of 450 miles per ton shipped, whereas the majority of freight shipments move less than 250 miles. The total tons of product shipped by all five modes in 2002 were approximately 15 billion.

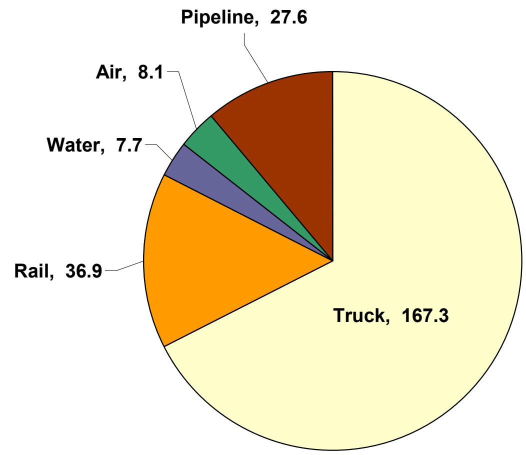


Source: US Department of Transportation
Bureau of Transportation Statistics

Figure 4. Tons Shipped By Mode, 2002 (Billions)

[2] 2002 is the most recent year that data for all five modes is available for comparison between tons shipped and revenue.
[3] Ton-miles measure the shipment weight multiplied by the distance traveled by the shipment.

Trucks were also the largest mode of transportation in terms of revenue in 2002, with over $167 billion in operating revenue (Figure 5). This equates to over $18 of revenue for every ton shipped in 2002. Rail was second with almost $37 billion in revenue (approximately $17 of revenue per ton shipped) and pipeline was third with almost $28 billion. Water and air freight had similar revenues in 2002. In 2002, total freight transportation revenues were approximately $248 billion. Rail freight's lower revenue per ton shipped reflects the large quantities of lower value-per-ton products such as coal, ores, and grains that are shipped by rail.



Source: US Department of Transportation
Bureau of Transportation Statistics

Figure 5. Revenue By Mode, 2002 (Billion $)

Freight Railroad Sector

Freight railroads are an important component in the global competitiveness of the United States. They serve nearly every sector of the U.S. economy and form an integrated network of more than 170,000 route miles (Table 1). According to the Association of American Railroads (AAR), U.S. freight railroads move 42% of intercity U.S. freight (measured in ton-miles).

In 2003, there were a total of 549 railroads operating in the U.S., two of which were subsidiaries of Canadian railroads. Total freight revenue in 2003 was $38.27 billion with over 1.2 million freight cars in service. A little over 174,000 people are employed by the U.S. rail freight industry.

Table 1. U.S. Railroad Statistics

	2002	2003
Number of Railroads	552	549
Operating Statistics		
Miles of Road Operated in the U.S.	170,348	170,192
Freight Cars in Service, U.S. Railroad Owned*	608,341	591,643
Freight Cars in Service, All U.S. Owners*	1,299,670	1,278,980
Employment		
Number of Employees	177,060	174,062
Average Wages	$58,421	$60,618 P
Average Compensation Including Benefits	$80,319	$84,009 P
Total wages (billion)	$10.34	$10.55
Total wages, including benefits		$15
Traffic		
Carloads Originated (million)	32.43	33.28
Tons Originated (billion)	2.15	2.16
Ton-miles (trillion)	1.56	1.61
Financial		
Freight Revenue (billion)	$36.90	$38.27

* U.S. owned only, excludes Canadian-owned railroads operating in the U.S.
P=Preliminary
Source: Association of American Railroads (AAR)

The vast majority of rail miles in the U.S. is owned by the railroads themselves and, because of this, major capital expenditures are required. These expenditures are in the form of construction and maintenance of rail track and hundreds of millions of dollars more in property taxes. Since 1980, Class I railroads have spent about 44% of revenue (more than $320 billion) on capital expenditures and maintenance related to infrastructure and equipment in order to help meet the freight transportation requirements of the U.S.

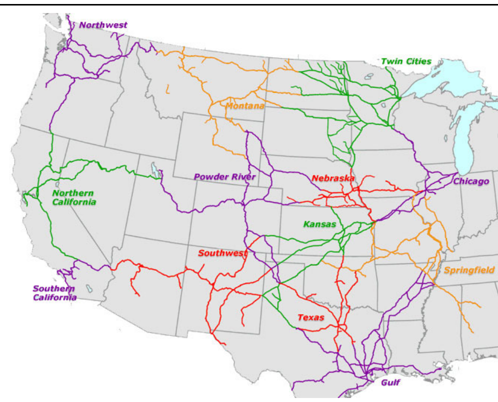
Profile of U.S. Freight Railroads

Of the 549 common carrier U.S. freight railroads in 2003, seven are classified as Class I railroads, 32 are regional railroads, 304 are local linehaul carriers, and 206 are switching and terminal carriers.

Class I railroads are defined here as railroads earning adjusted annual operating revenues for three consecutive years of $250 million or more. Class I carriers generally have a presence in multiple states and focus mostly on the longer distance loads with a higher concentration of schedules. The seven Class I railroads are Burlington Northern and Santa Fe (BNSF), CSX Transportation (CSXT), Grand Trunk Corporation (GTC), Kansas City Southern (KCSI), Norfolk Southern (NS), Soo Line (SOO), and Union Pacific (UP). A brief description of each of the seven Class I railroads along with their system map is presented in Table 2.

Table 2. Class I Railroad Profiles[4]

Burlington Northern and Santa Fe (BNSF)	Operates one of the largest railroad networks in North America, with 33,000 route miles covering 28 states and two Canadian provinces. BNSF is the largest grain-hauling railroad in the U.S. and transports sufficient coal to produce approximately 10% of the electricity in the U.S. BNSF earned over 24% of U.S. freight revenue in 2003.



[4] The system rail maps accompanying the company descriptions are publicly accessed maps that reflect rail company operations. These maps may or may not accurately reflect the rail lines the companies own and/or to which they have running rights. The reader should contact the individual companies if an accurate understanding of ownership and running rights of the tracks is desired.

CSX Transportation (CSXT)	Operates the largest rail network in the eastern United States with over 23,000 route miles and $6.4 billion in freight revenue in 2003. The parent company, CSX Corporation, also operates a transcontinental intermodal transportation service and world terminals in the Far East, Europe, Latin America, and Australia.	
Grand Trunk Corporation (GTC)	The U.S. operations of Canadian National (CN) which includes the former Grand Trunk Western (GTW), Illinois Central (IC), and Wisconsin Central (WC). Freight revenue was almost $1.5 billion in 2003. The parent company, Canadian National, operates the largest rail network in Canada covering eight Canadian provinces and 16 U.S. states.	
Kansas City Southern (KCSI)	Combined North American rail network of approximately 3,000 miles of rail lines that link markets in the United States and Mexico. KCSI serves customers in the central and south central regions of the U.S. KCSI does not have any commodity group that exceeds 25% of its total carloads and had revenue in 2003 of $540 million.	

Norfolk Southern (NS)	Carries raw materials, intermediate products, and finished goods on over 21,300 route miles in 22 states primarily in the Southeast, East and Midwest. Coal, coke and iron ore are the largest commodity groups. NS had revenue of almost $6.3 billion in 2003 or approximately 16% of the total U.S. rail company revenues.	
Soo Line (SOO)	Soo Line Railroad Co. is wholly owned by Canadian Pacific Railway (CPR) and does rail business under the CPR name. It is headquartered in Minneapolis, MN. Freight revenue in 2003 was $560 million. CPR owns Soo Line track in the US (the red lines in the figure to the right) and has running rights on the lines with pink dots.	
Union Pacific (UP)	The nation's largest hauler of chemicals with a system that serves 23 states, linking every major West Coast and Gulf Coast port. It is one of the largest Class I railroad company with almost 29% of all freight revenue in 2003. UP's largest customer is APL Limited, one of the largest container transportation companies in the world.	

BNSF and Union Pacific operate primarily in the western part of the U.S. while Norfolk Southern and CSXT trains are concentrated in the eastern half of the country. The Midwest has access to multiple railroads - Kansas City Southern operates in the lower middle part of the country while the U.S. operations of Canadian National (Grand Trunk) reaches into the U.S. primarily along the Mississippi River corridor. The Soo Line (CPR) operates on rails throughout the upper Midwest and Northeast. These railroads are vulnerable to many types of severe weather conditions due to the geographic expanse in which they operate.

The seven Class I railroads range in size from just over $500 million to almost $11 billion in freight revenue and from 22 million to almost 500 million tons originated. As shown in Table 3, Class I carriers operated over 120,000 miles of road and originated almost 1.8 billion tons of shipments in 2003. Total assets for all Class I carriers are approximately $100 billion, with 2003 freight revenue at over $35 billion.

Table 3. 2003 Financial Summary of Class I Railroads

	BNSF	CSXT	GTC	KCSI	NS	SOO	UP	Total Class I
Plant and Equipment								
Miles of road operated	32,266	22,841	6,493	3,084	21,520	3,258	32,831	122,293
Miles of road owned	24,674	19,181	6,016	2,888	16,964	1,687	27,388	98,798
Freight cars in service*	99,815	105,601	n/a	15,001	110,341	n/a	136,305	467,063
Locomotives in service	5,338	3,426	649	479	3,335	355	7,192	20,774
Financial (billion)								
Total assets	$28.12	$15.19	$8.11	$2.07	$13.69	$1.34	$32.06	$100.57
Total liabilities	13.50	9.66	5.48	1.29	9.33	0.86	19.31	59.42
Net stockholder's equity	14.62	5.53	2.63	0.78	4.36	0.48	12.75	41.15
Freight revenue	9.28	6.40	1.46	0.54	6.24	0.56	10.94	35.41
Operating expenses	7.74	6.28	1.29	0.52	5.61	0.51	9.48	31.44
Net railway operating income	1.06	0.37	0.22	0.05	0.90	0.05	1.42	4.08
Net income	0.96	0.14	0.08	0.02	0.32	0.06	1.11	2.69
Road and equipment expenditures	1.83	0.93	0.27	0.08	0.64	0.06	2.04	5.86
Return on Shareholders' Equity	6.81%	2.58%	3.13%	2.54%	6.95%	10.95%	8.98%	6.65%
Traffic								
Carloads originated (million)	7.66	6.47	1.18	0.40	5.12	0.36	7.69	28.87
Tons originated (million)	461	392	91	29	306	22	497	1,799
Ton-miles (billion)	506	234	52	21	183	23	533	1,551
Employment								
Total wages	$2.40	$1.85	$0.45	$0.15	$1.62	$0.15	$2.96	$9.58
Employees	36,604	31,740	6,214	2,648	28,488	2,656	46,302	154,652

*Total freight cars in service excludes Canadian railroads

Sources: AAR, Surface Transportation Board (STB)

A railroad is classified as a regional railroad if it has at least 350 route miles or revenue between $40 million and the Class I level. In 2003, the 32 regional railroads had freight revenue of approximately $1.35 billion (average of $42 million). Regional railroads normally control 400 to 650 miles of road and provide services across a few states. Most regional railroads have less than 500 employees.

Local linehaul carriers typically perform service over a short distance with operations of less than 350 miles and revenues below $40 million per year. In 2003, the 304 local linehaul carriers generated freight revenue of $910 million. A majority of the local linehaul carriers provide service to one state and manage fewer than 50 miles of road.

Switching and terminal (S&T) carriers mainly provide collection and transfer services within a specific zone for linehaul carriers. In a few situations, S&T carriers guide traffic along linehaul railroads. The average S&T carrier generates $2.9 million in freight revenue. In 2003, the 206 S&T carriers generated a total of $600 million in freight revenue.

When comparing the values presented in Table 3 and the financial numbers provided for the regional and short-line carriers, it is evident that the freight railroad industry is highly consolidated. In total, Class I carriers make up only 1% of the number of U.S. freight railroads, but account for almost 93% of its freight revenue (Table 4). BNSF and UP combined accounted for over 52% of the total freight revenue. Similarly, Class I railroads employ 89% of the railroad workforce and generate over 96% of the ton-miles. Interestingly, of all the market share statistics available, the miles of road operated had the lowest market share for Class I railroads, with 72% of the industry mileage.

Table 4. 2003 U.S. Market Shares of Class I Railroads

	BNSF	CSXT	GTC	KCSI	NS	SOO	UP	Total Class I
Plant and Equipment								
Miles of road operated	19.0%	13.4%	3.8%	1.8%	12.6%	1.9%	19.3%	71.9%
Financial (billion)								
Freight revenue	24.2%	16.7%	3.8%	1.4%	16.3%	1.5%	28.6%	92.5%
Traffic								
Carloads originated (million)	23.0%	19.4%	3.5%	1.2%	15.4%	1.1%	23.1%	86.7%
Tons originated (million)	21.3%	18.1%	4.2%	1.3%	14.2%	1.0%	23.0%	83.3%
Ton-miles (billion)	31.5%	14.5%	3.2%	1.3%	11.4%	1.4%	33.1%	96.4%
Employment								
Total wages	22.7%	17.5%	4.2%	1.4%	15.4%	1.4%	28.1%	90.8%
Employees	21.0%	18.2%	3.6%	1.5%	16.4%	1.5%	26.6%	88.8%

Sources: AAR, Surface Transportation Board (STB)

Class I Freight Traffic

Coal is the most carried product by Class I rail, accounting for almost 44% of the tons originated in 2003 as shown in Table 5 (and 21% of revenue). Coal is an important energy source, accounting for half of U.S. electricity production, and Class I railroads handle around 70% of the coal freight.

Table 5. Class I Railroad Freight, 2003

	Tons Originated	
Commodity Group	Million	Percent of Total
Coal	784.0	43.6%
Chemicals and Products	163.0	9.1%
Farm products	141.3	7.9%
Minerals	132.6	7.4%
Miscellaneous*	103.9	5.8%
Food products	102.1	5.7%
Metals	55.2	3.1%
Stone and Clay	51.0	2.8%
Petro and Coke	48.0	2.7%
Lumber	47.5	2.6%
Waste and Scrap	41.5	2.3%
Pulp and Paper	38.5	2.1%
Vehicles and Equipment	34.3	1.9%
Metallic Ores	32.7	1.8%
All Other	23.4	1.3%
Total	1,799	100%

* Miscellaneous is mostly intermodal traffic.
Source: AAR

Another major commodity carried by rail is chemicals, with 1.9 million carloads originated by railroads. This includes substantial amounts of industrial chemicals and fertilizers. A total of 163 million tons of chemicals and products are shipped by Class I rail.

Railroads are also vital in the transport of agricultural products, originating around 141 million tons and 1.5 million carloads of agricultural products each year.

Other commodities include non-metallic minerals such as sand and crushed stone, food products such as beer and flour; steel and metals; and lumber and paper products. Another important segment of rail shipments are vehicles and equipment. Approximately 70% of motor vehicles built are moved by rail.

Railroad Regulation

The freight railroad sector was one of the most highly regulated industries in the U.S. until the passage of the Staggers Act in 1980. Freight railroads had to deal with strong competition from other modes of freight traffic, but the existing regulation did not allow them to earn sufficient revenues and compete successfully. Prior to the Staggers Act, regulation prevented railroads from obtaining the pricing flexibility they needed to compete with other modes of freight transportation and barred carriers from restructuring their systems (i.e., canceling unused freight lines). The conditions of rail track were also deteriorating, with more than 47,000 route-miles operating at reduced speeds by 1976.

The fundamental ideas of the Staggers Act were to put rail management back in charge and allow competitive rail rates to be established through market demand. The principles of the Staggers Act provided the rail industry the flexibility it needed to adjust rates and service in ways that better met the needs of their customers. The Staggers Act also legalized shipper contracts, which helps railroads to better manage their assets. The railroads and shippers can negotiate arrangements for rates and level of service. According to the Surface Transportation Board (STB), at least 55% of all traffic moves under contract.

The Staggers Act, however, did not completely deregulate the industry. According to the Federal Rail Administration, the STB did keep the authority to set maximum rates or other necessary action if a railroad came to be in a dominant position. The Staggers Act limits the authority of the STB to regulate only rates in places where competition is not completely effective. The STB estimated that only 16% of traffic was still regulated by the mid-1990s.

Since passage of the Staggers Act, the economic performance of the rail industry has improved considerably, rail rates have gone down, and rail safety has improved. For example, inflation adjusted freight rates have declined approximately 1.5% a year since 1980, compared to a 3% increase each year from 1975-1980, and return on equity now averages close to 7%, compared to a 2% average during the 1970s. With the improved financial condition, railroads have been spending an average of $6 billion a year on their infrastructure. The rail industry has also demonstrated a notable step forward in safety improvements since the Staggers Act with a reduction in train mishaps by 68%.

Railroad Company Survey

Once the project scope was determined, one or two representatives from the selected five Class I Railroad Companies were surveyed. The railroad company representatives were asked about the NCDC products they had ordered, the general manner in which they use the products, the frequency with which they had purchased NCDC products, and the overall application of historical weather and climate data to their job within the company. More than one company representative was interviewed when the representatives worked in different departments within the company and utilized the data differently. The multiple company surveys were conducted to acquire a more accurate perspective of the manner in which NCDC products are used in the freight railroad sector.

NCDC Products Used by the Railroad Sector

Table 6 summarizes the number of NCDC products purchased by the five Class I Railroad Companies from 2000 through 2004. These companies have heavily utilized NOAA's e-Government avenue for ordering and obtaining NCDC products online as evidenced by the manner in which they purchased and obtained the products. Nearly all the products were purchased through the online service with only 9% purchased over the phone. Almost half of the products were online data products, while 40% of the products were papers primarily available as digital images. The interviews indicated that the majority of the products were purchased on an as-needed basis for analysis and special reports; however, some products were purchased on an annual basis to maintain a database of historical weather data.

The most frequently purchased products were derived from weather observations from NOAA’s Cooperative Observer (COOP) and Automated Surface Observation System (ASOS) network and were maintained at NOAA’s National Climatic Data Center (NCDC). These included COOP Data, Local Climatological Data, and Surface Weather Observations. The COOP Data product is a monthly log that includes a daily account of maximum and minimum daily temperature (at participating locations) and a daily observation of precipitation, snow, and snow depth. This product is available for more than 8,000 sites that are a part of the cooperative observing network in the US. These data have a lag time of 2-3 months, although a small percentage is available closer to real-time.

Local Climatological Data (LCD) products are for several hundred weather stations across the U.S. and are primarily located at larger airports and major cities. These products come in several forms. The customer can purchase observations for only one major airport weather station or an annual unlimited subscription for all the stations. The data can be purchased in an unedited form with generally a one to three day time lag or in edited form with a four to six week time lag. The Unedited LCD products are monthly summaries consisting of an hourly and daily account of temperature, degree days, precipitation, pressure, visibility, clouds, weather, and winds. Hourly precipitation and an abbreviated version of hourly observations are also included. The Edited LCD product consists of edited observations at 3 hourly intervals, daily, and monthly summaries. The monthly summary includes a daily account of temperature extremes, degree days, precipitation and winds.

The Surface Weather Observations product is a detailed hourly log for a specific day containing several data points including temperature, precipitation, winds, humidity, pressure, weather types, and obstructions to vision from several hundred major airport weather stations in the U.S.

Table 6. Number of NCDC Products Purchased by Railroad Companies During 2000-2004

	Online?		Media				
Product Name	**No**	**Yes**	**CD ROM**	**Online**	**Paper**	**Publication**	**Total**
Annual Climatological Summary Online Annual Subscription, Individual Station (All Years)		1		1			1
Annual Climatological Summary Online Individual Station		1		1			1
Climate Atlas of the U. S. Version 1.0, Contiguous U. S. ONLY		1	1				1
Climatological Data Online Individual Copy		3		3			3
COOP Data / Record of Climatological Observations Form		13			13		13
COOP Data / Record of Climatological Observations Form Online, Individual Station		2		2			2
Hourly Precipitation Data		1				1	1
Hydrologic Bulletin	1					1	1
International Station Meteorological Climate Summary Ver 4.0		1	1				1
Local Climatological Data Edited, Hardcopy Individual Station		4				4	4
Local Climatological Data Edited, Online Annual Subscription, ALL Stations/ASCII Only		1		1			1
Local Climatological Data Edited, Online Annual Subscription, One Station		3		3			3
Local Climatological Data Edited, Online Individual Station		7		7			7
Local Climatological Data Preliminary	3				3		3
Local Climatological Data Unedited		3				3	3
Local Climatological Data Unedited, Online Annual Subscription, Unlimited		1		1			1
Local Climatological Data Unedited, Online Individual Station		12		12			12
Miscellaneous	2				2		2
Surface Weather Observations	3				3		3
Surface Weather Observations ASOS, MF1-10 A & B		19			19		19
Surface Weather Observations Online Individual Station		8		8			8
TD 3220 - US Monthly Surface Data Online via User Selection		1		1			1
TD 3240 - Hourly Precipitation Data Online via User Selection		1		1			1
TD 3505 - Integrated Surface Hourly Online via User Selection		1		1			1
TD Summary of the Day Online via User Selection		7		7			7
Grand Total	9	91	2	49	40	9	100

Interviews with the five Class I railroad personnel who had purchased NCDC products indicated that the manner in which historical weather and climate data are used by the railroad sector is complex. A comprehensive understanding of historical weather and climate data utilization required supplemental interviews with researchers and employees of commercial weather services[5]. The following two sections synthesize the findings from the NCDC customer interviews, and supplemental interviews and research.

[5] Commercial weather services provide products and consulting services to the railroad industry. The products include forecasts, storm tracking systems, and decision support systems. These companies utilize real-time and historical weather and climate data to develop their products and deliver their services.

Weather and Climate Data Needs of Long-haul Railroads

The modern railroad sector is in a state of transition. Union Pacific (UP) indicated in its 2004 annual report that for the first time in decades, demand for rail freight transportation exceeds supply of rail transportation *(Union Pacific 2004 Annual Report)*. Meeting this increased demand for railroad companies is being challenged by high fuel prices and operational inefficiencies. Warehousing is considered inefficient and expensive, so modern business plans call for "on-time delivery" instead *(Weather Information for Surface Transportation National Needs Assessment Report (WIST Report))*. Accounting for the effects of weather conditions on this time-sensitive delivery system is essential for efficient and effective operations. Decisions made with inadequate or erroneous weather information reduce efficiency, increase operating costs, and decrease customer satisfaction. According to the WIST Report, four major rail carriers either have their own weather forecast staff or contract for weather support services, and one Class I railroad interviewed for this study indicated that it utilizes consultants about 50% of the time.

Given the nature of the railroad business, its operations and construction are susceptible to climatic influences and weather conditions. Climate influences long-term strategic decisions while weather impacts day-to-day operations. The ways weather or weather-related conditions impact long-haul railway activities are summarized in Table 7. The table also summarizes the manner in which weather-related data assist in addressing the activities and the types of data needed for the applications.

Table 7. Railway Applications for which Weather and Climate Data are Needed

Activity	Application	Data Needs	
		Real-time	Historical
Operations			
Scheduling - train schedules, train and track maintenance, inspections	Short and Long Range Forecasts	✓	✓
Local operations	Short and Long Range Forecasts	✓	✓
Operational inefficiency resulting from severe weather events - derailment recovery; traffic disruption minimization	Weather monitoring and hazard warnings via Decision Support Systems such as weather monitoring systems, precision storm tracking tools, and site specific severe weather warnings	✓	✓
Planning			
Construction	Data summarization; analysis		✓
Weather hazard prediction	Weather monitoring and hazard warnings via Decision Support Systems such as weather monitoring systems, precision storm tracking tools, and site specific severe weather warnings	✓	✓
Historical Event Analysis			
Severe weather conditions related to temperature and precipitation such as landslides, erosion events and flooding	Data summarization; analysis		✓
Legal/Claims/Litigation/Forensic	Data summarization; analysis		✓
Safety (regulatory requirements)	Weather monitoring and hazard warnings via Decision Support Systems such as weather monitoring systems, precision storm tracking tools, and site specific severe weather warnings	✓	✓

These specific activities can be impacted by any number of weather conditions or consequences of weather conditions. Participants of a survey conducted for the WIST study identified the weather conditions or consequences of weather conditions that affect transportation system operations, or the safety, economic value or efficiency of transportation activities using those systems. These conditions and consequences were categorized by weather element, and the survey respondents indicated which elements impacted them (Figure 6). Temperature-related conditions or consequences and precipitation were the most frequently indicated weather elements that impact long-haul railways according to the participants.

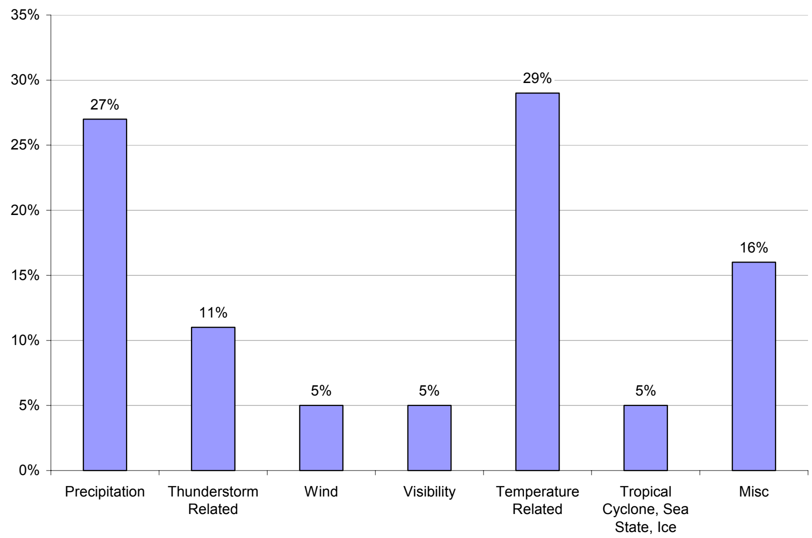


Figure 6. Frequency of Railway Activities Impacted by Weather Elements

These weather elements can create severe weather conditions which, in turn, can adversely impact railroad operations. Excess precipitation can increase the chances of landslide hazards, flooding, erosion and damage to culverts and bridges. Temperature-related elements can create numerous problems for the railroads. Low temperatures can break rails and cause frost heaves or jacking of rock slopes, and icing of switches. High temperatures might cause sun kinks in the rails, and rail grinding and tensioning resulting from forest or grass fires. Wind can topple rail cars, and weather-related elements hindering visibility can create safety hazards for rail operators, rail cars, and bystanders.

Management of the railway activities influenced by weather and climate-related elements requires both real-time and historical weather data and climate data, as evidenced in the interviews conducted for this study. Current and forecasted weather conditions impact operations and short-term planning activities, and the management of these weather conditions utilize real-time data (current weather conditions) and forecasting results. This information is provided to the parties requiring the information either by internal personnel and computerized output or by external commercial weather services. The real-time data are utilized as part of the forecasting process, the storm monitoring services, and weather warning decision support systems. Commercial weather services provide products and services such as track-specific warning systems, nowcasts of significant weather events, operating forecasts, long-range forecasts, integrated warning systems, and other weather-related consulting services to the railroad industry. Storm tracking products track and possibly predict the path of a storm for a specified time in the future (e.g., 30 minutes). Historical weather data are used as part of the forecast development process, and when needed for forecast model development, the data are obtained from sources such as NCDC.

While these weather elements impact the railroad companies' operations and planning, they also affect the safety of other parties not employed by the companies. When severe weather impacts operations and potentially affects safety, claims are often made to the rail company about its liability regarding the outcome of the weather-related event. A significant use of historical weather data is for the verification of weather conditions when safety was potentially compromised.

Another use of historical weather data is event analysis where the weather-related events surrounding a specific occurrence are investigated. For example, excessive precipitation might trigger landslides or other erosion events. The analyst then might be interested in understanding the precipitation threshold that would trigger such a weather-related hazard.

Decision support systems (DSS) have become increasingly important in the long-haul railroad sector. They serve several purposes spanning from strategic planning to playing an integral role in the day-to-day operations of the railroads. Examples of the areas in which DSS can be applied include *(Mahoney)*:

- Strategic planning (condition prediction)
- Tactical planning (alert functions)
- Operations management (productivity)
- Incident management (notification function)
- Evaluation of “what if?” scenarios
- Training tool (off-line assessments)

DSS take several different forms, depending on their purpose and technology utilized to develop the system. However, Figure 7 presents a basic framework for a generic DSS applied to railroad use. The raw weather data consist of national, regional, and local forecast data with or without networks of local weather sensors and instrumentation (wayside and on-board locomotive) *(Ditmeyer)*. The raw real-time weather data are then converted into the appropriate format for the DSS structure now including GIS-based formats. Data from the railroad company’s operations are incorporated into both the surface condition module (e.g., location of tracks) and the decision support logic and rules of practice (e.g., thresholds for severe weather alerts). The graphical user interface might consist of GIS displays and alert messages, among other components. Potential alert messages include advance warning of weather-caused hazards such as flooding; track washouts; snow, mud or rock slides; high winds; fog; high track-buckling risk; or other conditions that require adjustment to train operations or action by maintenance personnel *(Ditmeyer)*. The user interfaces can occur on personal computers or via the Internet.

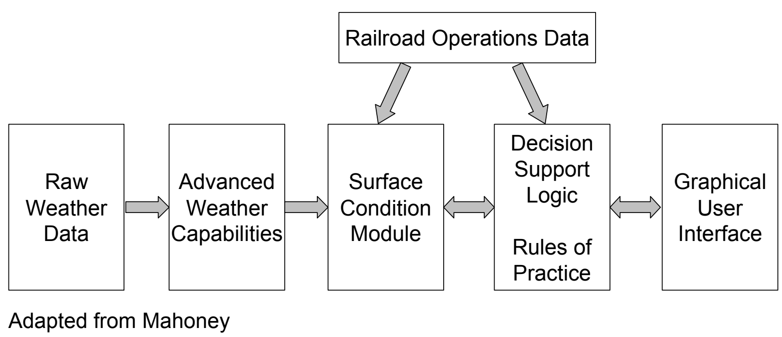


Figure 7. General Components of a Weather DSS

Data requirements for these DSS include real-time weather data, long lead-time forecasts, surface information, GIS information, and probability metrics for meteorological events

(*Mahoney*). The probability metrics are derived from analysis of historical weather data (most probably maintained at NCDC), and the rules of practice can be based on either decision rules established by management or thresholds based on historical data.

The implicit motivation behind the DSS is to minimize the risk associated with weather-related events. These DSS assist the railroad companies in identifying the areas in which they are most vulnerable and specify means to minimize the consequences of their risk exposure. Risk minimization is a prominent economic theme, and unnecessary exposure to risk relative to other participants in the market can put a firm at an economic disadvantage. In other words, these DSS and their application of weather data have significant economic implications to the railway companies.

How the railroads conceptualize and respond to risk created by adverse weather can be illustrated conceptually through a risk matrix (Figure 8). The vertical axis represents the chances of severe weather events occurring. This is determined by the probability metrics for meteorological events derived from the historical weather data. The horizontal axis symbolizes the consequences to the railroad company if the severe weather event was to occur. If the chance of the severe weather event and the consequence of severe weather event are small, the railroad company would be prepared to continue its normal operations. As the chances and consequences of severe weather events increase, the degree to which the railroad companies alter their operations and respond to the severe weather event increases. As the response intensity increases, the greater the cost to the firm, and thus the greater the importance of accurate assessment of the firm's risk exposure.

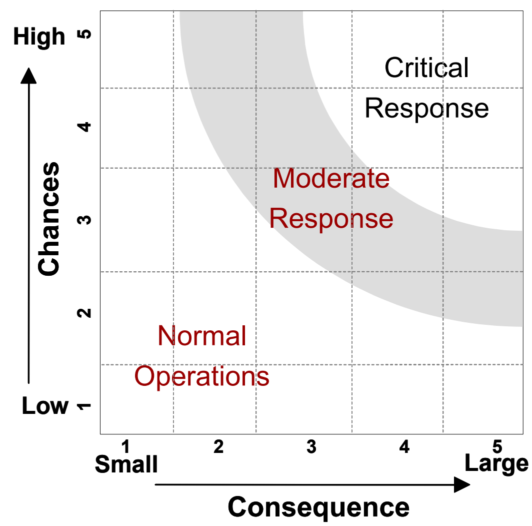


Figure 8. Railroad Weather Risk Matrix

Application of NCDC Products by the Railroad Sector

Interviews with the NCDC railroad customers revealed that there are two primary types of users of their products – personnel in the company's legal department and engineers. Table 8 summarizes categorized NCDC products by User Type for products purchased from 2000 through 2004[6]. User Type was determined through the phone interviews or if the customer had indicated in which department he was located in the COMPS database. However, it was not possible to determine the departments in which all personnel were because each person could not be contacted. The majority of the products purchased are for legal purposes. It should be noted, however, that this tabulation probably underestimates the historical weather data used by the Railroad Companies for engineering operations, and even legal applications[7]. This is due to their utilization of commercial weather services and other third party service providers that are not captured in this summarization.

[6] The information source of this table is the COMPS database. The total number of products differs from Table 6 because NCDC provided the data directly to Centrec for Table 6.

[7] Railroad companies utilize consultants to compile reports for litigation support if they do not have an internal legal department. These reports verify weather conditions at the time of severe weather events.

Table 8. NCDC Product Purchased by User Type

Product Category	User Type: Engineer	Legal	Unknown	Total
Climatological Data	6	6	5	17
COOP Station Reports	1	16	3	20
Local Climatological Data	1	28	9	38
Miscellaneous	1			1
Publication	1	1	2	4
Surface Weather Observations	1	30	5	36
Grand Total	11	81	24	116

The five Railroad Companies purchased an average of 4.4 products per year from 2000 through 2004.

Personnel in the legal departments acquire historical data either to determine weather conditions for specific times or to verify a claim made by another party. The frequency of claims and the number of NCDC products purchased per railroad company are heavily influenced by the size of the company. The frequency of claims varies greatly from one to two per year to ten per month. For one company, 15% to 20% of derailment or landslide events result in lawsuits. In some instances, the legal personnel obtained subscriptions to data products for input into a database of historical weather data maintained for their department. These subscriptions allow unlimited access to certain climate products for a year. Since a subscription counts as one purchase and allows unlimited access to these climate products, this would result in an underestimate of the number of products purchased by the Railroad Companies.

Event analysis utilizes a wide variety of historical weather data, depending on the event being studied. These data include precipitation, wind conditions, weather and sky conditions, and temperature. These analyses are instigated by management to facilitate the operational efficiency of the company and performed by engineers. The interviewees indicated that they conduct event analyses on average two times per year. Examples of event analysis identified in the interviews include:

- Landslides where excessive rainfall triggers the event
- Erosion events – these impact culvert capacity
- Flooding
- Derailment

In the case of a derailment, the environmental conditions such as wind, temperature and sky conditions at the time of the event need to be understood. High temperatures impact the integrity of the rails and can cause derailments. Other causes of derailments include extreme weather storms (e.g., tornados) and bridge or track washouts. All these weather conditions are considered when derailments occur.

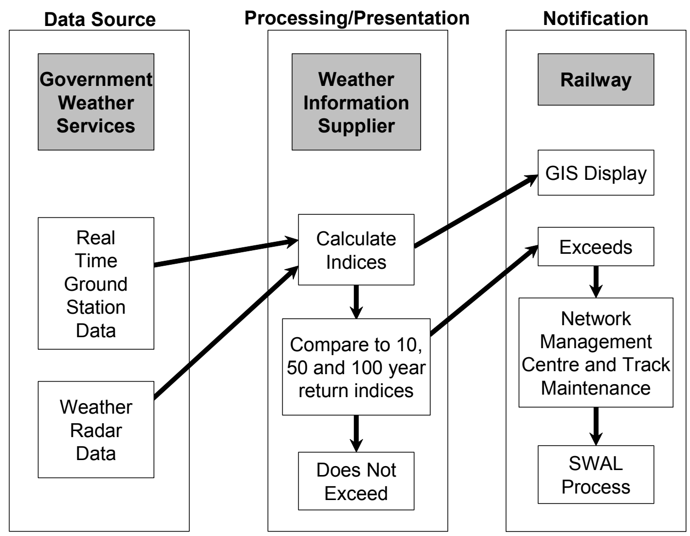
As part of the event analysis, the analyst might evaluate the return period[8] to assess the frequency of the event as part of the company's risk management plan. The railroad might alter its operations based on the findings of the analysis.

[8] Return period as it relates to weather is the average time interval between occurrences of a specific weather event of a given or greater magnitude, usually expressed in years.

The railroad sector has not been in an expansion mode for many decades. As a result, the majority of rail infrastructure already exists, and most of the track has been adapted to potential problems that might occur as a result of weather-related events. However, if land use has changed, historical data might be used in the analysis for track construction, maintenance or repair. Some railroads are building new track, and as a result, they consider 50 or 100 year precipitation return period events to determine appropriate specifications for new bridge construction.

As part of the study, Centrec personnel were able to view a proprietary DSS employed by one of the Railroad Companies interviewed. This company, hereafter referred to as Railroad Company, has developed a DSS to provide its operating personnel with weather-related information regarding current weather conditions, forecasts, and severe weather alert levels (SWAL).

Figure 9 shows the basic structure of the Railroad Company's DSS. It obtains real-time ground station and radar weather data from multiple sources. The DSS then converts the data into its architecture, calculates indices relevant to establishing thresholds for the SWAL, and compares the calculated indices to 10, 50 and 100 year return indices. These return indices are based on historical weather data obtained from NCDC and other governmental agencies. It is expected that the return indices will be updated every ten years and more frequently in the event of a severe climatic incident. The calculated indices are displayed on a GIS map showing the Railroad Company's stations. If the calculated indices do not exceed the historical indices, no SWAL is issued and no changes are made to operations. If the calculated indices exceed the appropriate indices, a SWAL is issued, and the network management centre and track maintenance institute the SWAL process.



Source: Railroad Company

Figure 9. Railroad Company's Basic DSS Structure

The anchor of the Railroad Company's DSS is a GIS map available to all regions of the railroad via the Internet. The map shows color-coded and shape-coded points representing synoptic, current, and forecast weather information for specific weather stations. Data available at each point include temperature, wind speed, direction and gust speed, and temperature average. Available forecasts range from 6 to 48 hours, and forecasts include rainfall, snowfall, temperature average, and wind speed average. The DSS also incorporates SWAL levels and mechanisms for alerting the user when a station reaches alarm status. The color of the station points indicates SWAL status. Radar data are also available from the DSS. Unlike other sources of weather radar data, the DSS provides rainfall intensity averaged over the last 10 minutes, 60 minutes, 12 hours, and 24 hours. This provides a representation of accumulated rainfall relative to the railroad track for each antecedent time period. All National Weather Service (NWS) flash flood and weather alerts relevant to the railroad's tracks are posted and retrievable from the DSS.

Cost Estimation of an Alternative System

This section employs the Alternative Cost Approach to compute an estimate of the economic value of NCDC products to the railroad sector. To calculate the economic value, the typical annual data acquisition costs for the NCDC products are calculated. The average annual data costs for the five Class I Railroad Companies from 2000 through 2004 were $825. In other words, these five companies spent an average of $825 each year on NCDC products from 2000 through 2004. The following step is to estimate the general costs of establishing and operating a system that would provide the Railroad Companies with the same information. This cost is considered to be the "benefit" provided by the NCDC products to the Railroad Companies, and its estimation is explained in the following section. Next, the cost-benefit ratio is calculated and is also discussed in the next section. The last step is to extrapolate the cost-benefit ratio to the Class I freight railroad sector level.

Calculation of Cost-Benefit Ratio

NCDC had a FY04 budget of $56.9 million, and NCDC personnel provided cost estimates for providing the data products ordered by the five Class I Railroad Companies. The basic functionality required by NCDC to provide the five Railroad Companies with the breadth of data products they ordered costs, on average, about $2.17 million per year (or 3.8% of the entire NCDC budget).

Table 9 presents the total NCDC budget for staffing and maintaining the divisions providing NCDC's current level of service and data products. These costs are shown on the first line – the total NCDC budget for each "Work Breakdown Structure (WBS)" of NCDC. The following section in Table 9 outlines the data management functions and from which WBS the allocated costs come. For example, of the total $12.2 million NESDIS Base Funds appropriated to NCDC, $1.2 million are allocated to the ingestion, calibration and validation of data the Railroad Companies have utilized. With archiving, metadata and cataloging of the data costs to be estimated at $0.46 million, the total NESDIS Base Funds attributable to costs involved in providing climate in-situ products and data to the Railroad Companies is $1.66 million or 13.6% of the WBS category budget (in this case, NESDIS Base Funds). The only data management work area for which costs are not allocated is "Collect or Rescue". The summary indicates the largest cost stems from the ingestion, calibration and validation of the data.

Table 9. Annual NCDC Costs to Provide Climate In-Situ Products and Data to Railroad Companies, FY 04

Work Breakdown Structure (WBS) of NCDC's budget	NESDIS Base Funds[1]	Regional Climate Centers	Climate Data Modern. Program	GOES Active Archive	ESDIM[2]	National Virtual Data System[3]	Climate Ref. Network	Other NOAA	Non-NOAA Cost Recovery[4]	Manage Fund[5]	Total
NCDC FY04 Budget (Million)	**$12.2**	**$2.0**	**$22.1**	**$0.5**	**$1.6**	**$0.9**	**$0.9**	**$9.3**	**$3.2**	**$4.2**	**$56.9**
End to End Data Management											
Planning										$0.16	$0.16
Collect or Rescue											$0.00
Ingest, Calibrate & Validate	$1.20										$1.20
Archive, Metadata & Cataloging	$0.46										$0.46
Access						$0.05			$0.25		$0.30
Migrate					$0.05						$0.05
Total (Million)	**$1.66**	**$0.00**	**$0.00**	**$0.00**	**$0.05**	**$0.05**	**$0.00**	**$0.00**	**$0.25**	**$0.16**	**$2.17**
Percent of Total Budget	**13.6%**	**0.0%**	**0.0%**	**0.0%**	**3.3%**	**5.0%**	**0.0%**	**0.0%**	**7.8%**	**3.8%**	**3.8%**

[1]Ingest & Calibrate & Validate: costs $2.39 million for all NCDC data streams; Climate in-situ products ordered by Railroad Cos. require 50% of $2.39 million =$1.20 million (Validation of products ordered by Railroad Cos. is labor intensive). Archive, Metadata & Cataloging: costs $1.82 million for all NCDC data streams; Climate in-situ products ordered by Railroad Cos. require 25% of $1.82 million = $0.46million.

[2]Migrate accounts for 66% of $1.6 million of NCDC ESDIM funds = $1.06 million; Climate in-situ is 5% of total archive and would require 5% of $1.06 million=$.05 million to perform migration.

[3]Online Orders: $0.9 million required to maintain and update E-Gov Systems; Even though Railroad Cos. must use the complete E-gov systems, only 5% of the system cost is assigned since Railroad Cos. ordered an estimated 5% of the products in the entire E-gov system.

[4]Offline Orders: Processes include technical advice, order placing, gathering products and shipping.

[5]Planning includes consulting with climate in-situ network managers on end-to-end data management principles for current climate in-situ networks.

The total cost of maintaining a portion of the NCDC data center to provide the products and services each of the five Class I Railroad Companies purchase is estimated to be $2.17 million. Based on the review of the orders placed by the Railroad Companies, their mix of NCDC products does not differ significantly company to company, even though the number of products ordered differs. Therefore, the concept of high fixed costs as described in the "Relevant Economic Concepts" section applies to each firm.

It is thus assumed that each company would have to incur the estimated $2.17 million to obtain the weather information that it acquires from NCDC. Therefore, the cost to maintain a portion of the NCDC data center ($2.168 million) is multiplied by five. The total ($10.839 million) is divided by the average annual data costs for the five Class I Railroad Companies ($825), resulting in a cost-benefit ratio of 13,139.8. This implies that for every $1 an average Class I railroad company spends in acquiring the data, it receives the potential benefit of not spending $13,139.80. In other words, each Class I Railroad Company, on average, saves almost $2.17 million annually in climatological data collection fees.

This is a very large cost-benefit ratio measuring the economic benefit from information management and distribution for the Railroad Companies. In addition, this cost-benefit ratio might be underestimated because of the companies' reliance on commercial weather services to provide products and services that utilize historical weather data. While it was verified that some of the known commercial weather services serving the railroad sector have purchased NCDC products, it is unknown for which purpose the data products were purchased. In-depth research of the utilization of NCDC products by the commercial weather services was beyond the scope of this study. Nonetheless, even without the inclusion of the benefits of the data used by the commercial weather services, engaging in data collection, calibration, validation and maintenance by the individual Railroad Companies would be extremely costly and impractical for them.

Calculation of Sector Level Benefits

For purposes of this report, the economic benefit of the NCDC products is being measured for the Class I railroad companies, the primary participants of the railroad freight sector from a revenue perspective. According to the Association of American Railroads (AAR), freight revenue for railroad companies providing freight services in the U.S. in 2003 was $38.27 billion. Revenue for the seven Class I railroad companies providing long-haul freight services in the U.S. in 2003 was $35.41 billion or 92.5% of the total freight railroad revenue. The five Class I Railroad Companies' total U.S. freight revenues totaled $33.42 billion in 2003, or 94.4% of the total Class I freight revenue and 87.3% of total freight railroad revenue. The remaining non-Class I railroads, consisting of regional railroads, local linehaul carriers, and switching and terminal carriers, are impacted by current weather conditions. However, it is assumed these companies do not utilize DSS, conduct event analysis, and experience the degree of legal activity the long-haul railroads do. Therefore, these remaining railroad companies' use of historical weather data are not considered to be the same as the Class I railroads and are excluded from the calculation of sector level benefits.

Assuming total annual costs for the NCDC products for the five Railroad Companies are $825, and the utilization of NCDC products by the five Class I railroads is representative of the remaining two Class I railroad companies, total expenditures by the seven Class I freight railroad companies for climatological data are computed as $825 ÷ 94.4% = $874. These results imply that the entire Class I railroad sector spends about $874 annually on climatological data for the purposes of:

- Investigating claims regarding weather conditions at the time of railroad incidents,
- Event analysis,
- Validation of weather DSS, and
- Other miscellaneous purposes.

Multiplying the annual Class I freight railroad sector level climate data expenditure of $874 by the previously calculated cost-benefit ratio of 13,139.8 yields a total potential sector benefit of about $11.5 million.

As previously mentioned, this study determined that Class I railroads utilize commercial weather services for products and services including DSS and consulting services that include event analysis and compilation of weather information for claim verification purposes. In addition, while the non-Class I railroad companies are not expected to utilize weather data to the same degree that the Class I railroad companies do, COMPS data indicate that these smaller companies do purchase NCDC products. Therefore, exclusion of these two user categories of historical weather and climate data likely underestimates the actual use of NCDC data to the entire railroad sector of the freight transportation industry.

Interpreting the Findings

This study utilized the same approach as in "Investigating the Economic Value of Selected NESDIS Products". In doing so, it is acknowledged that a similar limitation in the first study exists in this study – the difficulty of validating the use of an existing information system. The ideal analysis would be to compare the performance of relevant economic agents when they use the information system versus when the information system services are not available. However, it is not practical or possible to observe the alternative scenario since NOAA e-Government activities strive for 100% uptime 24 hours a day and 7 days a week. Thus, the "with information" scenario is the only observable alternative. Nonetheless, it is not unreasonable to assume that the "without information" scenario would be the railroad companies implementing their own data collection system or relying on commercial weather services companies to provide the data. The cost assumption appears to be reasonable.

Several conclusions can be drawn from this analysis:

- The interviews conducted and data collected for this study describe the role NCDC products play in the railroad sector. The absence of the historical weather data would significantly impact the railroads' abilities to operate efficiently and effectively in a very competitive freight transportation environment. Without such information, the railroads would be placed at a competitive disadvantage to the trucking sector, and this lack of competitiveness would negatively impact the flow of goods throughout the U.S.
- As with any economic analysis, assumptions were made in this study regarding the manner in which historical weather data are used across the freight railroad sector. Excluding the manner in which commercial weather services and the non-Class I railroad companies use historical weather data alters the "true" economic benefit of NCDC products to the railroad sector. However, surveying five of the seven Class I railroads whose revenues represent 87.3% of the entire freight railroad sector increases the accuracy of the assumptions made for this study.
- "Investigating the Economic Value of Selected NESDIS Products" considering the economic value of NCDC products to the energy industry calculated a cost-benefit ratio of 495.8 with a total economic benefit to the industry of $65 million. Railroad companies in general operate on a smaller scale than the Energy Company considered in the previous study. Even though the Railroad Companies operate on a smaller operating scale than the Energy Company, the costs involved in ingesting, calibrating, validating, and maintaining the weather and climate data remain the same whether it be for a larger energy company or a smaller railroad company. Therefore, a cost-benefit ratio of 13,139.8 and a resulting total sector benefit of about $11.5 million do not seem unreasonable.
- An alternative means for securing the necessary data and information services would be for a private sector firm, such as an existing commercial weather service, to perform the range of functions now provided by NCDC. This alternative could possibly result in a dominant firm market structure, lowering consumer benefits due to monopolistic pricing behavior relative to competitive market pricing. It could result in a structure providing a lesser amount of data and information services at a higher price than if the data were provided through the current "public goods" structure now provided by NCDC.

Summary and Recommendations

Summary

NOAA provides a unique service by ingesting, calibrating, validating, migrating and archiving weather and climate data, and ultimately, making data products available to the public. The NOAA services and products analyzed for this study were provided by NCDC. The economic value of NCDC's service and products are based on three basic economic assumptions. The first assumption is that the service and data products NCDC provides are considered public goods – more than one person can consume a particular "good"; no person can be excluded from consuming the good; and the NCDC products are not traded in the market place, even though minimal charges to recover some of the delivery of the data are made. NCDC products can be "consumed" multiple times, and any person can order data products from the agency. Secondly, the fixed costs involved in NCDC's data processing steps are significant. However, once the data are collected, organized, validated, and archived, the marginal costs of providing data products to NCDC's customers are very low. Lastly, if the private sector were to perform the same function as NCDC does, a dominant firm market structure would probably emerge. The high fixed costs are barriers to entry for most firms. If a firm is the sole participant, it is in a position to price its products higher and provide fewer products than would be the case in a competitive market. This outcome lowers consumer benefits. NCDC is able to provide these unique services and products as public goods and at prices significantly lower than the costs incurred in providing the products. NCDC's ability to do this provides substantial economic benefit to the economy.

NCDC's customers range across the spectrum of society from governments to academia to private individuals to business and industry. Understanding the economic benefit of the services and products NCDC makes available helps the agency better understand its customers and improve its products and services. It is not practical to measure the economic benefit across society in total. However, it is possible to understand the economic benefit at the sector level. It was determined that the freight transportation industry would be analyzed, and after queries of the COMPS database and discussions with NCDC customers, the freight railroad sector was identified as the subject of this study.

Phone interviews were conducted with several NCDC customers from five Class I railroads, the companies responsible for long-haul freight. These discussions provided insight into how NCDC products were used within their organization. It was determined that the surveyed Railroad Companies use NCDC products principally for three purposes: (1) validation of historical weather conditions for legal claims and other legal proceedings; (2) analysis of extreme weather-induced events to understand the weather conditions that contributed to or caused an event; and (3) validation of decision rules for decision support systems (DSS). The freight transportation industry is very competitive across sectors. To remain competitive, particularly with trucking, railroad companies must deliver their freight in a timely and efficient manner. Weather impacts rail operations, safety and profitability, and the companies have incorporated several mechanisms (such as use of climate-based DSS tools) into their operations to decrease their weather-related risk, a key economic factor. Therefore, if the railroad companies are to remain competitive, they need historical weather data to decrease their weather-related risk.

It would be costly for railroad companies to obtain and maintain their own historical weather data. This is verified by a benefit ratio calculated for this analysis. The annual average cost for the five Class I Railroad Companies to obtain the weather-related products from NCDC is $825 per year while the approximate cost to NCDC to ingest, calibrate, validate and archive the data is $2.17 million per company. The calculated cost-benefit ratio is 13,139.8, implying that for every $1 each of the Railroad Companies spend in acquiring data, they receive a potential benefit of not having to spend $13,139.80 to acquire the data on their own. When extended to the entire Class I railroad sector, the potential benefits are approximately $11.5 million.

Recommendations

This study generated specific recommendations for additional analysis:

1. This project revealed that companies are actively attempting to mitigate their weather-related risk. They are doing this either by internally developing the means to decrease their risk exposure or by hiring third-party commercial weather or consulting services to provide them with the expertise and tools to mitigate their risk. An additional study could focus on the products and services provided by third parties that utilize NCDC products. These third parties would be entities that purchase the historical data and either re-package the data or use the data in products and with services they offer to their customers. Often these companies are on the leading edge of technology and applications utilizing historical weather data, and could provide a rich source of information regarding how the current data products are being used and what products might be of value in the future.
2. Weather-related risk can be defined as financial gain or loss due to a change in weather conditions over a period of time *(GuaranteedWeather)*. Managing weather-related risk has become an important management area for companies that can be significantly impacted by severe weather[9]. In addition to the products and consulting services offered by commercial weather services, an industry providing weather risk management tools has emerged. These services provide products such as weather insurance and weather derivatives, options, collars, or swaps. These product prices are based on probabilities of weather-related events. As previously mentioned, these probabilities are based on historical weather data. A supplemental study could be conducted that would investigate the manner in which the companies offering these weather risk management tools are utilizing historical weather data.
3. This is the second analysis of application and economic value of NCDC products for a sector of a specific industry. These two analyses have uncovered that each sector utilizes historical weather data in different ways. Further research on additional industries or sectors would provide a deeper understanding of the way in which the products are used and provide NCDC personnel with ideas for improved products and services. Examples of additional industries or sectors that could be studied include:
    a. Agriculture, including agribusiness
    b. Insurance industry
    c. Airline sector of the transportation industry
    d. Energy distributors for natural gas, crude oil, heating oil, and propane
    e. Construction
    f. Recreation – resorts, theme parks

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[9] The U.S. Dept of Commerce estimates that nearly one-third of the U.S. economy, or $3.5 trillion, is modulated by the weather.

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