Continental Airlines Takes Off with Real-time Business Intelligence

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Introduction

Data warehousing and real-time business intelligence (BI) are taking Continental Airlines to new heights. Powered by a real-time[1] or "active" data warehouse, the company has dramatically changed all aspects of its business, resulting in industry-leading customer service and generating considerable financial "lift." Continental's president and COO, Larry Kellner, describes the impact of real-time BI in the following way: "Real-time BI is critical to the accomplishment of our business strategy and has created significant business benefits." Some of the ways that Continental is using and benefiting from data warehousing and real-time BI include:

- Flight attendants, gate agents, and all "customer-facing" employees know at all times who Continental's high-value customers are, and they provide outstanding service to these customers, contributing to Continental's track record of being the most admired US airline for quality and customer service.
- The Operations staff at the hubs monitors on-time performance throughout the day and makes operational decisions about catering, personnel, and gate traffic flow, thus solidifying Continental's ranking as the most on-time airline.
- Pricing specialists track in real-time the impact of price changes on reservations and make adjustments that optimize revenues.
- In the hours after 9/11, passenger reservations and flight manifests were checked against the FBI's "watch list" to determine if it was safe to fly. The FBI recognized Continental for its assistance.
- Continental has realized more than $500 million in cost savings and revenue generation over the past six years from its business intelligence initiatives, producing an ROI of more than 1,000 percent.

Continental's current position is dramatically different from only ten years ago. Gordon Bethune arrived as CEO and led Continental from a "worst to first" position in the airline industry. A key to this turnaround was the Go Forward Plan, which continues to be Continental's blueprint for success and is increasingly supported by data warehousing and real-time BI. Currently, the use of Teradata's active technologies has been critical for Continental in moving from "first to favorite" among its customers, especially among its best customers.

Continental's Teradata active data warehouse provides a powerful platform for quickly developing and deploying applications in revenue management, customer relationship management, flight and ground operations, fraud detection, security, and others, and the applications are generating quantifiable benefits for Continental. Collectively, they illustrate how data warehousing and real-time BI are affecting almost all of the ways that Continental does business.

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[1] Some people prefer the term "right-time" over real-time in order to emphasize that data only needs to be as fresh as the decisions or business processes require. Depending on the business need, data can be hourly, daily, and even weekly or monthly and still be real-time. We use the terms real-time and right-time synonymously.

The successful implementation of real-time BI requires an active data warehouse. Data must be captured from source systems, loaded into a warehouse, and made available as "actionable" information for applications and users; however, active data warehousing poses challenges beyond those associated with traditional data warehousing. These challenges and how they are handled at Continental are discussed.

Continental's experiences with data warehousing and real-time BI have resulted in insights and practices from which other companies can benefit. The lessons learned are discussed and illustrated using Continental examples.

Data warehousing is often referred to as "a journey rather than a destination" to emphasize that there is no end point; rather, a data warehouse continues to evolve over time. At Continental, data warehousing has evolved from traditional to active and is continuing to change as new subject areas and applications are added. Continental, with its use of Teradata technologies, is well positioned for future business, financial, and customer service success.

Company Background Information

Continental Airlines was founded in 1934 with a single-engine Lockheed aircraft on dusty runways in the American Southwest. Over the years, Continental has grown and successfully weathered the storms associated with the highly volatile, competitive airline industry. With headquarters in Houston, Texas, Continental is currently the USA's fifth largest airline and the seventh largest in the world. It carries approximately 50 million passengers a year to five continents (North and South America, Europe, Asia, and Australia), with over 2,300 daily departures, to more than 227 destinations. Continental, along with Continental Express and Continental Connection, now serves more destinations than any other airline in the world. Numerous awards attest to its success as an airline and as a company (see Appendix A).

An Airline in Trouble

Only ten years ago, Continental was in trouble. There were ten major US airlines, and Continental consistently ranked tenth in the Department of Transportation metrics used to monitor the industry's performance: on-time arrivals, baggage handling, customer complaints, and denied boardings because of overbooking. Not surprisingly, with this kind of service, Continental was in financial trouble. It had filed for Chapter 11 bankruptcy protection twice in the previous ten years and was heading for a third, and likely final, bankruptcy. It had also gone through ten CEOs in ten years. Employees joked that Continental was a "Perfect 10."

Enter Gordon Bethune and the Go Forward Plan

The rebirth of Continental began in 1994 when Gordon Bethune took the controls as CEO. He and Greg Brenneman, who was a Continental consultant at the time, conceived and sold the Board of Directors on the Go Forward Plan. It had four interrelated parts that had to be executed simultaneously.

- *Fly to Win.* Continental needed to better understand what products customers wanted and were willing to pay for.
- *Fund the Future.* It needed to change its costs and cash flow so that the airline could continue to operate.

- *Make Reliability a Reality.* It had to be an airline that got its customers to their destinations safely, on-time, and with their luggage.
- *Working Together.* Continental needed to create a culture where people wanted to come to work.

Additional details about the first Go Forward Plan are presented in Appendix B.

Most employees were supportive of the plan, and those who weren't, left the company. Under Bethune's leadership, the Go Forward Plan, and a re-energized workforce, Continental made rapid strides. Within two years, it moved from "worst to first" in many airline performance metrics, including on-time performance, lost baggage claims, and customer satisfaction.

Information Wasn't Available
The movement from "worst to first" was only partially supported by information technology. Historically, Continental had outsourced its operational systems to EDS, including the mainframe systems that provided a limited set of scheduled reports but no support for ad hoc queries. Each department had its own approach to data management and reporting. The airline lacked the corporate data infrastructure that would allow a broad range of employees quick access to information that would provide key insights about the business. However, senior management had a vision of merging, into a single source, information that was scattered across the organization, enabling employees in all departments to conduct the business analyses required to execute better and run a better and more profitable airline.

Enter Data Warehousing
The decision was made to develop an enterprise data warehouse that would provide a single source of information and give employees quick access to key information about the business and its customers. Then-CIO, Janet Wejman, recognized that the creation of a data warehouse was a strategic project and brought the development and the subsequent maintenance and support in-house. She also believed that the data warehouse was to be core to Continental's business strategy and should not be outsourced. After careful consideration, Teradata was selected as the best vendor to meet Continental's needs. Work on the Teradata data warehouse began, and after six months of development, the warehouse went into production in June 1998.

The initial focus of the data warehouse was to provide accurate, integrated data for revenue management applications. As an example, before the data warehouse, only leg-based (a direct flight from one airport to another) data was available to the revenue management department, which severely limited the analyses that could be performed. This area could not track a customer's itinerary from origin to destination when it involved more than one stop. The data warehouse integrated multiple data sources, including flight schedule data, customer data, and inventory data to support pricing and revenue management decision making based on journey information.

The data warehouse environment provided a variety of early, big "wins" for the business. The initial applications for pricing and revenue management decision support were soon followed by applications that required the integration of customer information, finance, flight information, and security. They created significant financial lift in all areas of the Go Forward Plan. Figure 1 provides three examples of how integrated, enterprise data was initially used at Continental.

Figure 1: Some of the Initial Teradata Warehouse Applications

Demand-driven Dispatch

Prior to the Teradata Warehouse, flight schedules and plane assignments were seldom changed once set, regardless of changes in markets and passenger levels. Continental operated flights without a detailed, complete understanding of each flight's contribution to profitability. After the data warehouse, Continental created the Demand-driven Dispatch application that takes forecast information from the revenue management system (which is integrated with the enterprise data warehouse) and flight schedule data from the data warehouse, and identifies opportunities for maximizing aircraft usage. The application identifies opportunities to make short-term adjustments that do not disrupt operations. For example, it may be possible to swap one routing of an aircraft without disrupting the crews or the maintenance operations. The swap may assign a larger plane to a flight with unusually high demand. This application is very useful when large events, such as the Super Bowl or Mardi Gras occur. Continental uses this application to "cherry pick" schedule changes that increase revenue. Demand-driven Dispatch has lead to an estimated $5 million dollars a year in incremental revenue.

Good Will Letters

An eight-month good will test showed that even small gestures are very important to building loyalty. This is how it was done. The data warehouse first allowed marketing analysts to identify Continental's high-value customers by marrying profitability data and algorithms with customer records. The marketing department then pulled this information from the warehouse and created a sample of Continental's high-value customers. This sample was divided into three groups. When individuals were delayed more than 90 minutes, one group received a form letter apologizing, a second group received the letter and a trial membership to the President's Club (a fee-based airport lounge) or some other form of compensation, and a third group received no letter at all. Customers who received regular written communication spent 8 percent more with the airline in the next 12 months. Another unexpected benefit was that nearly 30 percent of those receiving the President's Club trial membership joined the club. This translated into an additional $6 million in revenues. The concept was expanded across the company to include the top 10 percent of Continental's customers.

Group Snoop

Group Snoop refers to a fare rule and contract compliance application that attempts to reduce the risk and financial impact of customers that "no show" for any given flight. Because of the impact that groups can have on the final number of passengers boarded on a flight, advanced deposits and other contractual obligations are required for bookings of groups of 10 or greater that are traveling together. However, travel agents can bypass this requirement and book a group of 16 by making two bookings of seven and nine without deposits or contracts. This creates an incentive for agencies to block space in smaller groups in order to avoid making a deposit. Should the group not materialize, the financial impact to the airline can be significant. Sometimes the agents would convert the smaller bookings to a group, but sometimes the bookings would merely hold inventory space. Using booking and agency data from the warehouse, this application sorts by booking agent and travel agent and then queries all groups of less than ten and identifies the same travel agent ID and itinerary. Continental can then assess seat inventory more accurately and get travel agents to comply with group booking requirements. Group Snoop has provided an annualized savings of $2 million for Continental.

Taking Things a Step Farther, with "First to Favorite"

Once Continental achieved their goals of ranking first in the airline industry in many performance metrics and of returning the company to profitability, Gordon Bethune and his management team raised the bar by expanding the vision. Instead of merely performing best, they wanted Continental to be their customers' favorite airline. The First to Favorite strategy builds on Continental's operational success and focuses on treating customers extremely well, especially the high-value customers (which have been given the name CoStars), and thereby creating customer loyalty. Figure 2 shows a poster in Continental's headquarters that is a reminder to employees of the First to Favorite initiative.

Figure 2: Continental Airlines Internal Communications Poster
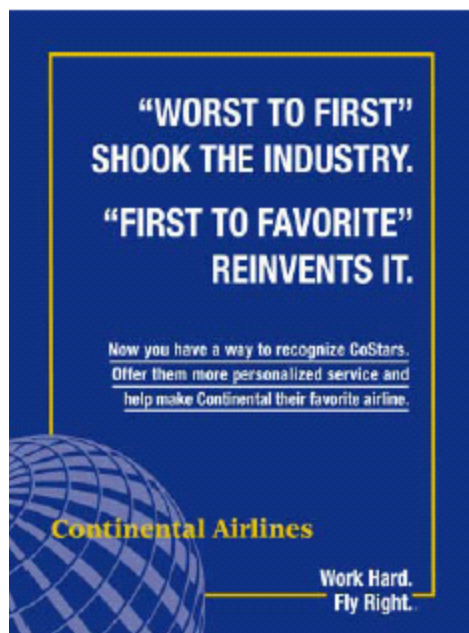
The Go Forward Plan identified additional actionable ways the company could move from first to favorite. Technology became increasingly critical for supporting the plan's initiatives. At first, having access to historical, integrated information was sufficient to support the Go Forward Plan and to generate considerable strategic value for the company. However, as Continental moved ahead with the First to Favorite strategy, it became increasingly important for the data warehouse to provide real-time, actionable information to support enterprise-wide tactical decision-making and business processes.[2]

Fortunately, the data warehouse team had anticipated and prepared for the ultimate move to real-time. Real-time meant that the data warehouse team had to introduce real-time feeds of data into the data warehouse, integrate the data from the multiple source systems in order to make the data more valuable, extract information that was created in the data warehouse and incorporate that

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[2] For many years, decision making was described as either strategic, tactical, or operational. More recently, "tactical" is used synonymously with operational. We follow this contemporary usage.

data back into legacy systems, and open the data warehouse to tactical queries with sub-second response time requirements. In preparation, the team had developed a data warehouse architecture that could grow and scale to meet these new real-time and operational needs. While not all applications required real-time data, many did. In 2001, real-time data became available in the data warehouse.

Real-time BI Applications

The amount of real-time data in the data warehouse grew quickly. From its main operational systems, Continental moves real-time data (ranging from to-the-minute to hourly) about customers, reservations, check-ins, operations, and flights to the data warehouse.

The inclusion of real-time data has transitioned Continental from analyzing and reporting what did happen (using daily batch loads) to influencing current decisions and business processes. The following applications, ranging from customer relationship management to revenue management to flight operations to fraud detection, illustrate the variety of key applications that rely on real-time data.

Customer Relationship Management

The purpose of customer relationship management (CRM) within Continental is to increase revenues, profits, and customer service by understanding customers' preferences and catering to them in such a way that they choose to spend additional dollars with Continental. It's the use of information to change behaviors—on both sides—that makes the difference. Continental's marketing department uses the data warehouse for customer segmentation and target marketing, loyalty/retention management, customer acquisition, channel optimization, and campaign management. In addition to these conventional CRM applications, the marketing team has created other innovative CRM applications that leverage the data warehouse's real-time capabilities.

Customer Value Analysis

A customer value model using frequency, recency, and monetary value gives Continental an understanding of its most profitable customers. Every month, the customer value analysis is performed using data in the data warehouse, and the value is fed back to Continental's operational customer databases. The value is provided to Continental's customer–facing systems so that employees across the airline, regardless of department, can recognize who their best customers are when interacting with them.

This understanding helps Continental react effectively and intelligently in tough situations. For example, post 9/11, Continental used the results of its customer value model to understand who and where their best customers were stranded around the world. Continental applied this information to its flight scheduling priorities. And, while the schedules were being revised, the company worked with its lodging and rental car partners to make arrangements for its stranded customers. The highest value customer was in Zurich, and he used Continental's offices to conduct business until he was able to get home.

Marketing Insight

Marketing Insight was developed to provide sales personnel, marketing managers, and flight personnel (e.g., ticket agents, gate agents, flight attendants, and international concierge) with customer profiles. This information includes seating preferences, recent flight disruptions, service history, and customer value, and it is used to personalize interactions with customers. Gate agents are able to pull customer information up on their screen and drill into flight history to see which high-value customers have had flight disruptions. Flight attendants receive the information on their "final report," which lists the passengers on their flights, including customer value information. A commonly told story is about a flight attendant who learned from the final report that one of the high-value customers on board recently experienced a serious delay. She apologized to the customer and thanked him for his continuing business. The passenger was floored that she would know about the incident and would care enough to apologize.

President and COO, Larry Kellner finds Marketing Insight extremely valuable because it provides him with the background information he needs when he interacts one-on-one with customers. For example, it helps him determine the best means of addressing a customer inquiry that made its way to his desk and requires his personal response. He inputs the customer's OnePass (Continental's frequent flyer program) number and he knows immediately the customer's value, when and where the customer last flew, and if there were any recent service issues. High value customers do not always travel on the highest fare. Basing decisions on the fare paid runs the risk that the customer may receive inconsistent service, and in a worst case scenario, may defect to another airline. The customer value score that the COO uses allows him to recognize those customers who consistently provide the greatest value, regardless of the fare that they are traveling on at the time.

A Personal Touch

At Continental, like at most companies, a relatively small percentage of customers are responsible for a disproportionate amount of the company's profits. Using data from the data warehouse, each quarter Continental's top 3,000 customers are sent hand-written notes from senior management. A note may say, "I see that you live in Houston. Hope that you have tried the Presidents Club, it has wireless Internet access," or "You checked in on Continental.com. I hope that you liked the service." Sometimes these customers are sent a personalized report card (based on up-to-the minute warehouse data) that shows the on-time performance of the flights that they were on. The response to this personal touch has been outstanding. Many fliers select carriers on the basis of price, but many of the most profitable customers do it on the basis of the relationships that are created and the attention and service that go along with the relationships.

Elite Access

Elite Access is one of the perks that Continental extends to its high-value customers. Prior to the data warehouse, marketing assumed that Continental's high value customers were OnePass members. This proved to be incorrect. Through an analysis of warehouse data, Continental discovered that 60 percent of the high-value customers were not OnePass members. Therefore, many of Continental's high value customers were receiving baseline service. As a result, marketing created a program called Elite Access. Qualifying travelers receive priority check-in, priority security screening, priority boarding, priority baggage handling, seat upgrades when available, and additional mileage credit when they happen to be assigned to a middle seat. Now,

with the real-time data warehouse in place, high value customers are identified as soon as they check in. They do not have to be OnePass members to be recognized and receive priority service.

Elite Upgrade Monitoring

One of the key benefits of being a frequent traveler on Continental is the opportunity to be upgraded to a first class seat when there is a seat available. The data warehouse provides a tool to monitor this process. Airport personnel are able to view a report each morning that shows which flights departed the day before with open seats in first class while there were Elite passengers seated in coach. This information is used to develop awareness so that agents optimize every opportunity to provide the highest level of service, which is not always easy when their primary objective is to get the flight out on time. In addition, the tool is used on a quarterly basis to recognize those employees with the greatest upgrade program compliance.

As often happens in a successful enterprise data warehouse implementation, the data needed by a new application is already available in the data warehouse. The development of the Elite Upgrade Monitoring application was simply a matter of exploring the requirements and building the report. It was the beneficiary of having the reservations and flight statistics stored in the centralized warehouse. An enterprise data warehouse allows data to be used for multiple applications, including some that were not anticipated when the warehouse was originally built.

Revenue Management and Revenue Accounting

The purpose of revenue management is to maximize revenue given a finite set of resources. An airline seat is a perishable good, and an unfilled seat has no value once a plane takes off. The revenue accounting area seeks to quickly and accurately record the revenues that Continental generates.

Fare Design

Continental understands how important it is to offer competitive prices for flights to desired places at convenient times. Continental uses real-time data to optimize airfares (using mathematical programming models). Once a change is made in price, revenue management immediately begins tracking the impact of that price on future bookings. Knowing immediately how a fare is selling allows the group to adjust how many seats should be sold at a given price. Last minute, customized discounts can be offered to the most profitable customers, to bring in new revenue, as well as to increase customer satisfaction. Continental has earned an estimated $10 million annually through fare design activities. Prior to the availability of real-time data, Continental's pricing was a (considerably) less effective balance of filling seats and optimizing fares.

Ticket Facsimile

Prior to the data warehouse, paper tickets were scanned and archived on microfiche. To access a ticket for research purposes required finding the ticket number, accessing microfiche, locating the particular ticket, and finally printing it. In 2001, the data warehouse team built a report in Hyperion Intelligence (the software was called Brio at the time) to "look like" a facsimile of the ticket, and other airlines and agencies agreed to use this as the standard ticket copy for inter-airline transactions. The report is used to interactively search for one or more tickets in a variety of ways and query the real-time booking, customer, and flight information in the data warehouse.

The ability to find and print tickets from the data warehouse reduced headcount by eight and saves hundreds of thousands of dollars for Continental.

Airline Reservations

The ability of customers to make reservations and airlines to accurately process those reservations is critical. While a data warehouse is not typically thought of as supporting airline reservations, Continental's data warehouse sometimes serves as an emergency backup system because it includes real-time reservation data.

Recovering Lost Reservations

In 2002, an error in Continental's reservation system resulted in a loss of 60,000 reservations. Within a matter of hours, the warehouse team developed an application whereby agents could obtain a customer's itinerary and confirm whether the passenger was booked on flights.

Another similar situation happened in 2004 when the reservation system had problems communicating with other airlines' reservation systems. In certain circumstances, the system was not sending reservation information to other airlines, and, consequently, other airlines weren't reserving seats for Continental's passengers. As a result, Continental customers would arrive for a flight and not have a seat. The data warehouse team was able to run a query to get the information on passengers who were affected and who had not yet flown. This information was fed back into the reservation system so that seats could be assigned, thus avoiding a serious customer relations problem.

Flight Operations

Special real-time applications have been developed for all aspects of getting people to their destinations safely, on-time, efficiently, and with their luggage. This is where customers have either a good or bad flying experience, and Continental works hard to provide consistently excellent service. Good operations also can reduce costs by ensuring that ground personnel are in the right place and the right time.

Flight Management Dashboard

The Flight Management Dashboard is an innovative set of interactive graphical displays developed by the data warehouse group. These displays are intended to help the operations staff quickly identify issues in the Continental flight network and then manage flights in ways to improve customer satisfaction and airline profitability.

Some of the dashboard's displays help Operations to better serve Continental's high-value customers. For example, one of the displays is a graphical depiction of a concourse, which is used to assess where Continental's high-value customers with potential service issues are or will be in a particular airport hub (see Figure 3). The display shows gates where these customers have potential gate connection problems so that gate agents, baggage supervisors, and other operations managers can assess where ground transportation assistance and other services are needed so these customers and their luggage avoid missing flights. In Figure 3, it can be seen that Flight 678 is arriving 21 minutes late to Gate C37 and eight high-value customers (3 and 5) need assistance in making their connections at Gates C24 and C29, which takes 12 minutes and 20 minutes to reach, respectively.

Figure 3: Concourse Display of High-Value Customer Activity
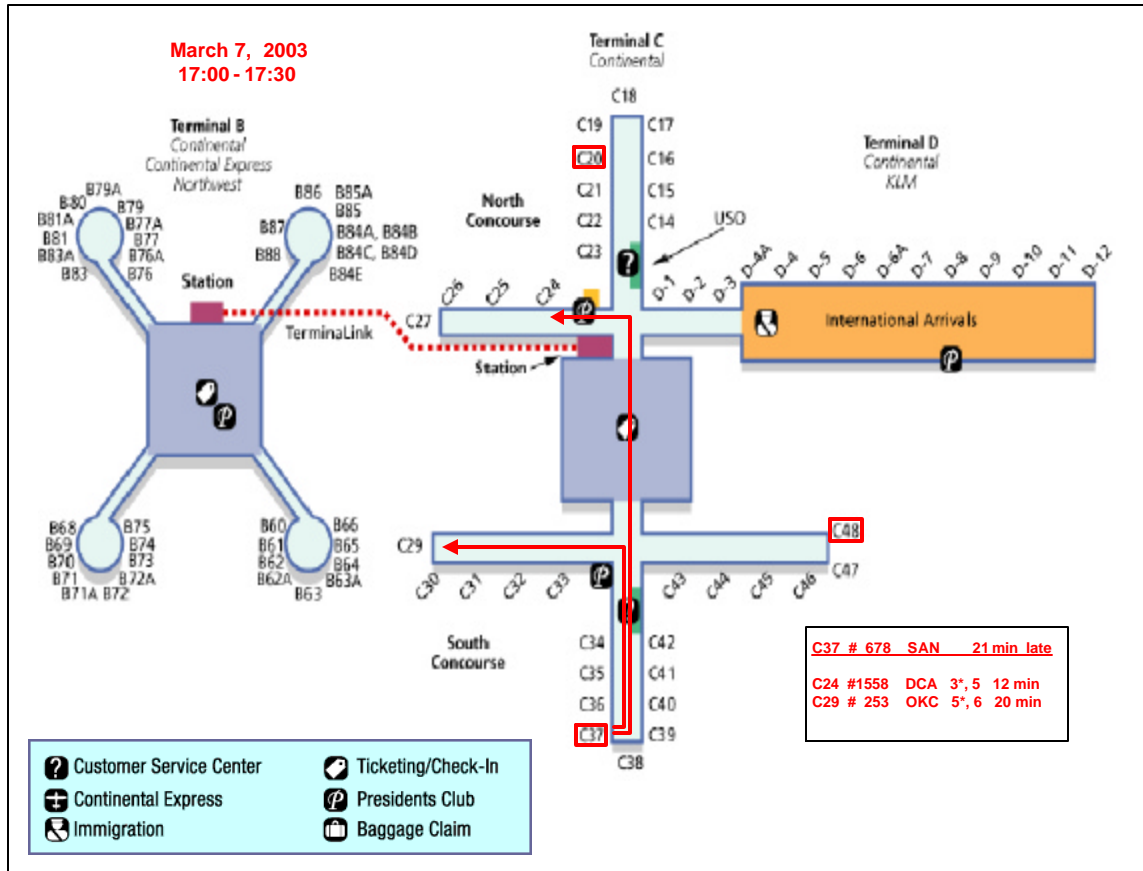
On-time arrival is an important operational measure at Continental. The Federal Aviation Administration requires airlines to report arrival time numbers and provides the summary statistics to the flying public. Therefore, another critical set of dashboard displays helps Operations keep the arrivals and departures of flights on time. One display shows the traffic volume between the three Continental hub stations and the rest of their network (see Figure 4). The line thickness between hub locations is used to indicate relative flight volumes and the number of late flights so that the operations staff can anticipate where services need to be expedited. The ratio of the number of late flights to the total number of flights between the hubs also is shown. The operations staff can drill down to see individual flight information by clicking on the lines between the hub locations. Another line graph summarizes flight lateness. Users can drill down to more detailed pie charts that show degrees of lateness, and then, within each pie, to the individual flights in that category. Another chart concentrates on flights between the US and Europe and the Caribbean, and it can show similar critical flight statistics. In all of these elements of the dashboard, high-level views can be broken down to show the details on customers or flights that compose different statistics or categories.

Figure 4: Display of Flight Lateness From/To Hubs
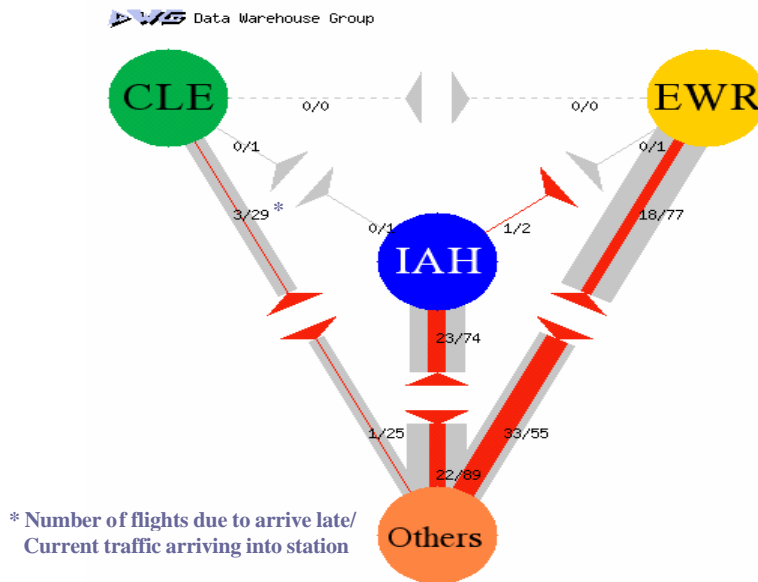
Real-time Flight Statistics

Continental management believes, "You can't manage what you can't measure," and they now have the numbers to manage the company. For example, management has an operations meeting every morning to review airline performance in terms of on-time arrival, on-time departures, baggage handling, and other key performance indicators. Prior to the real-time Teradata Warehouse, information was refreshed at the end of each day; therefore, managers would receive yesterday's measures at the morning operations meeting, and they then had to use historical information to try to improve today's operations.

Operational data are now available in real-time (updated each minute), and users can submit queries and understand how the airline operation is performing at any moment. Upper management can see in real-time the revenue projections for any flight, where the most valuable customers are while in flight, which ones are affected by delays and cancellations, and bookings as they are made. This helps management make decisions in the event flights need to be delayed or cancelled for weather and other disruptions. They can also run "what-if" scenarios to determine the impact of cancellations, delays, or changes to specific flights. Now managers come prepared for morning operations meetings, and the team can address more strategic issues in proactive ways.

Crew Operations and Union Negotiations

The Crew Operations group is concerned with issues related to pilots and flight attendants. It is involved in crew pay, crew scheduling, crew performance, crew efficiency, and crew contract negotiations. Crew Operations is usually the top expense at any airline. Most airlines enter into contractual relationships with the various labor groups, and when making multi-year commitments, it is critical that the company fully understands the impact of these negotiations on labor costs and productivity levels. At Continental, this information is obtained from the data warehouse to provide real-time, factual information to support union negotiations.

Recently, Crew Operations used the data warehouse to help understand whether Continental was fair in the use of reserve pilots, which are pilots who back up full-time pilots when they call in sick or cannot make a flight for some reason. The union's perception was that Continental was overly relying on reserve pilots so that the company could avoid the expense of re-employing pilots who were on furlough. Continental did not believe that this was the case.

Crew Operations used data from the data warehouse to understand how often reserve pilots were flying, how they were being assigned, and when they were being assigned. The analysis revealed that the perceived problem was occurring only on rare occasions when there were unexpected spikes in bad weather and pilot sick days. Continental's staffing was correct. The problem was created with factors that were out of Continental's control, such as weather patterns that fell far outside of the norm. Crew Operations presented their analyses (along with the detail data down to the actual people who were affected), and the union agreed with Continental's assessment. The rhetoric that Continental was refusing to bring furloughed pilots back to work was stopped. Pilots and other crew members understood that reserve pilots were being used fairly.

Fraud Detection and Security
Continental uses its warehouse to identify reservations that are not in fare and contract compliance and to profile suspicious booking and ticketing transactions. Fraud also includes the blocking of seat inventory, the selling of tickets at prices lower than allowed (an estimated $60 to $70 million annual risk), fictitious booking records, fraudulent lost baggage claims, and OnePass account redemption abuse. Continental also uses its real-time data warehouse to support airline security efforts.

Too Much Travel to be True
A daily report lists Continental's most profitable customers. A man appeared out of nowhere one day as #1 on the list. An alert user did not recognize the name and investigated. She discovered that he had made all of his deposits for frequent flyer points on the same day. She then looked at all of the deposited flights and discovered that he had not flown on any of them. He had counterfeited boarding passes and tickets and bundled them together and sent them in to the OnePass service center for retroactive flight credit. The "revenue" from the dummy tickets shot him to the top of the customer profitability report. A timely report, an alert employee, and the ability to drill into OnePass and flight data caught this attempted fraud.

Is it Safe to Fly
Immediately after 9/11, planes were ordered to land at the nearest airport. Continental had 95 planes that did not reach their planned destination. Sometimes there were three or four planes at a little airport in a town with no hotels, and passengers had to move in with the local people. At Continental's headquarters, FBI agents moved into a conference room with a list of people they had authority to check. Queries were run against flight manifest data to see if potential terrorists were on flights, and it was only after a flight was deemed safe that it was allowed to fly. Continental Airlines was recognized by the FBI for its assistance in the investigations in connection with 9/11.

Fraud Investigations

In the wake of 9/11, Continental realized that they had the technology and data in place to monitor passenger reservation and flight manifests in real-time. A "prowler application" was built so that corporate security can search for names or patterns. More than 100 "profiles" are run regularly against the data to proactively search for fraudulent activity. When matches are found, an email and page message is sent immediately to a contact at corporate security. This capability helps corporate security identify fraudulent activity as it occurs. Not only does this feature allow corporate security to prevent fraud that is occurring, but it also enhances their ability to gather critical intelligence through more timely interviews with suspects, victims, and witnesses.

One profile, for example, looks for reservations agents who make an extraordinary number of first-class bookings. Last year, Continental was able to convict an agent who was manufacturing false tickets and then exchanging them to purchase new first-class tickets that she would then sell to friends. Continental received over $200,000 in restitution from that one case. In total, Continental was able to identify and prevent more than $15 million in fraud last year alone.

Business Strategy and Technology are Critical, but so is Culture

Regardless of how exciting a strategy and the supporting applications are, value is not created until people act. A key to Continental's success is a service-oriented culture – to one another and to customers. Continental's employees believe that people should be treated with dignity and respect, and this tenet is a major component of the Go Forward Plan (e.g., Working Together). The combination of a well-thought out business strategy, a service-oriented culture, and real-time technologies that are consistent with this culture has been responsible for Continental's turnaround and current success.

This wasn't always the case. When Gordon Bethune took over, employees were often surly to customers and one another. Both had been treated poorly in the past and were angry. Bethune opened communications (e.g., employees could visit him on the last day of each month) and found ways to measure and reward cooperation rather than infighting (e.g., group financial incentives tied to overall company performance). These actions have helped make Continental a place where people want to work. In 2004, for the sixth consecutive year, Continental was named as one of the "100 Best Companies to Work For" by *Fortune* magazine.

The data warehouse supports this culture by providing employees with information and tools that they can use to do a better job. Continental's managers praise and reward employees who use and share information. One manager explains, "At Continental, we have proven that by giving people access to data, they can go out and change their world."

Continental does an excellent job of communicating news, plans, and issues through meetings, posters, electronic wall displays, and emails. Employees regularly share stories of outstanding customer service. One that is frequently told is about a customer who entered the Presidents Club, bent down to pick up his attaché case, and split his pants. Recognizing the problem, an employee took the customer to a conference room and mended his pants. This story has a real-time BI twist. The employee knew the customer was high-value from the value analysis score

that appeared on her screen when he checked in. The sharing of stories helps to build and maintain a service-oriented culture, and this has helped spread exciting uses of real-time BI.

Supporting First to Favorite with Technology

Real-time BI requires the use of appropriate technologies, which build upon and extend those that are used with traditional BI and data warehousing. At Continental, real-time technologies and the associated processes are critical for supporting the First to Favorite strategy.

The Teradata Warehouse

Continental's real-time BI initiative is built on the foundation of an 8-terabyte enterprise Teradata Warehouse running on a 3 GHz, 10-node NCR 5380 server. The data warehouse supports 1,292 users who access 42 subject areas, 35 data marts, and 29 applications. Table 1 shows the growth of the data warehouse over time.
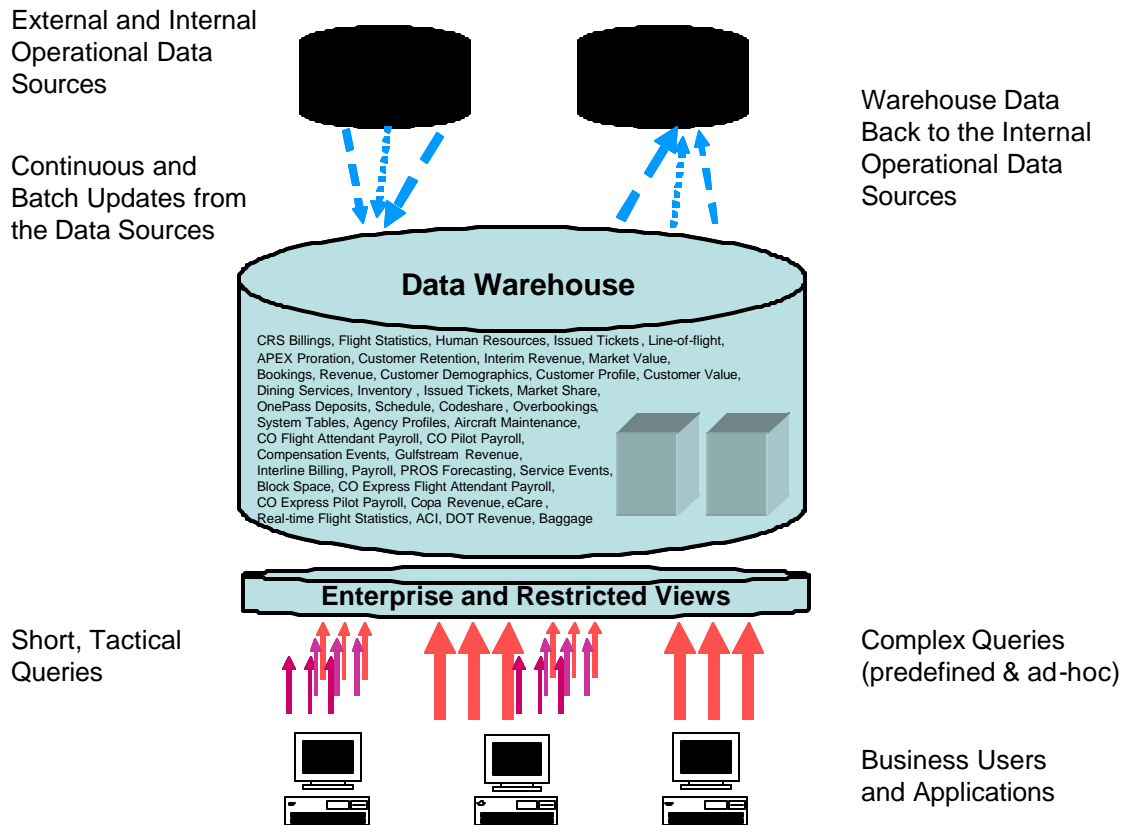
Table 1: Warehouse Growth Over Time

	1998	2001	Current
Users	45	968	1,292
Tables	754	5,851	16,226
Subject Areas	11	33	42
Applications	0	12	29
DW Personnel	9	15	15

The basic architecture of the data warehouse is shown in Figure 5. Data from 25 internal operational systems (e.g., the reservations system) and two external data sources (e.g., standard airport codes) are loaded into the data warehouse. Some of these sources are loaded in real-time and others in batch, based on the capabilities of the source and the business need. Critical information that is determined from analysis within the data warehouse (e.g., customer value) is fed from the data warehouse back into the operational systems.

All of the data are stored at the lowest level of detail in the Teradata database. The same database also contains a work area for each department so that they can store specialized data, such as summary tables with department-specific calculations and aggregations. These work areas are purged every two weeks. Departments can work with the data warehouse team to create logical dependent data marts within the Teradata Warehouse.

Figure 5: The Teradata Warehouse Architecture

External and Internal Operational Data Sources

Continuous and Batch Updates from the Data Sources

Warehouse Data Back to the Internal Operational Data Sources

Data Warehouse

CRS Billings, Flight Statistics, Human Resources, Issued Tickets , Line-of-flight,
APEX Proration, Customer Retention, Interim Revenue, Market Value,
Bookings, Revenue, Customer Demographics, Customer Profile, Customer Value,
Dining Services, Inventory , Issued Tickets, Market Share,
OnePass Deposits, Schedule, Codeshare , Overbookings,
System Tables, Agency Profiles, Aircraft Maintenance,
CO Flight Attendant Payroll, CO Pilot Payroll,
Compensation Events, Gulfstream Revenue,
Interline Billing, Payroll, PROS Forecasting, Service Events,
Block Space, CO Express Flight Attendant Payroll,
CO Express Pilot Payroll, Copa Revenue, eCare ,
Real-time Flight Statistics, ACI, DOT Revenue, Baggage

Enterprise and Restricted Views

Short, Tactical Queries

Complex Queries (predefined & ad-hoc)

Business Users and Applications

When users send queries to the data warehouse, the queries do not "hit" the actual tables in the database. Instead, they hit one of the hundreds of views that were set up for users and applications to access. These views simplify and standardize table joins and business logic. It is much simpler and more consistent for users to query views as opposed to the base warehouse tables. Additionally, real-time loads can lock up base tables; whereas, views remain unaffected by the continuous changes to the warehouse.

Some views are created for security purposes. When data is too sensitive to be placed in the enterprise views for all to see, it is placed in views with restricted access. The Data Warehouse Director explains, "Our policy is that every piece of data in a subject area should exist in the enterprise view layer unless there is a strong reason to not include it. We default on giving as much access to data as possible to our users. But, a subject area like ticket sales might include credit card number, which we want to restrict. In this case, you must have access to the restricted view for ticket sales to see that information."

The Enterprise Data Model
Data in the warehouse are completely integrated into a physical enterprise data model. The warehouse team started with a data model for the revenue management subject area, which was the initial subject area for the data warehouse. From the start, the team's vision was to have an

enterprise-wide view of the data; therefore, the initial modeling efforts modeled revenue management with the entire company in mind.

As new subject areas are added, the data model evolves. A subject area expert works with a user group to create a proposed model. Then, after extensive data analysis and discussion, the new subject area is integrated into the enterprise data model. Although most people on the warehouse team are database administrators and are capable of developing data models, the modeling efforts are funneled through the Master Data Modeler. This person is responsible for updating the enterprise data model and ensuring consistency across all subject areas. She makes sure that all modeling efforts follow standards and naming conventions.

The data in the enterprise data model is in strict 3rd normal form. The Master Data Modeler believes that 3rd normal form makes the data warehouse much easier to administer. In her words, "Our discipline in sticking to 3rd normal form means that our data are not duplicated throughout our data model. In terms of size, Continental is not one of the biggest databases, but I believe that we have more actual information than most companies."

Data Access
A Data Warehouse Steering Committee member/representative oversees access to the basic enterprise views of the data warehouse, and management controls access to the restricted views. For example, a manager from human resources controls who can see compensation data.

The users access warehouse data in various ways (see Table 2). Some use standard query interfaces and analysis tools, such as Teradata's QueryMan, Microsoft Excel, and Microsoft Access. Others access data using custom-built applications. Still others use either the desktop (i.e., "fat client") or web versions of Hyperion Intelligence to access data. An estimated 500 reports have been created in Hyperion Intelligence, and many of these reports are pushed to users at scheduled intervals (e.g., at the first of the month, after the general ledger is closed). Other products include SAS's Clementine for data mining and Teradata CRM for campaign management.

Table 2: Data Warehouse Access

Application or Tool	Types of Users	Number of Users
Hyperion Intelligence – Quickview (web)	Enterprise	300
Hyperion Intelligence – Explorer (desktop)	Enterprise	114
Microsoft Access	Enterprise	200
Custom Applications	Enterprise	700
Teradata CRM	Marketing	20
Clementine Data Mining	Revenue Management	10
Teradata QueryMan	Enterprise	150
Microsoft Excel	Enterprise	many

Real-time Data Sources
The data warehouse's real-time data sources range from the mainframe reservation system, to satellite feeds transmitted from airplanes, to a central customer database. Some data feeds are pulled from the sources in batch mode. For example, files of reservation data are extracted and sent using FTP (file transport protocol) from a mainframe application on an hourly basis. An application converts the data into 3rd normal form and writes the updated records to queues for loading into the data warehouse.

Other data feeds are streams of data that are loaded to the warehouse in seconds. The flight data (called FSIR, or flight system information record) is sent real-time from the airplanes via satellite to an operations control center system, which supports the command center for Continental where the actual flights are coordinated throughout the flight network. The data warehouse team took advantage of the command center infrastructure already in place, and set up a Windows NT machine that "listens" to the FSIR data and feeds the appropriate data (as they occur real-time) into a data warehouse queue, which is then immediately loaded into the warehouse.

Other data sources are pushed real-time by the sources themselves, triggered by events. For example, Continental's reservations system, OnePass frequent flier program, Continental.com, and customer service applications all directly update a central customer database. Every change that is made to a customer record in the customer database activates a trigger in the customer database, which pushes the update as XML encoded data to a queue for loading into the data warehouse. The data is immediately loaded into the warehouse.

Although the data sources each have different characteristics (making the loading process potentially complex), Continental has created an infrastructure called the Service Bureau (see next section) that allows the various sources to be loaded using a single, reusable infrastructure.

The Service Bureau – Teradata Warehouse Loading and Management
Continental's vision from the start was for the Teradata Warehouse to be highly automated. To achieve this, the warehouse team built a set of shared services that run on 10 Windows-based servers called the Continental Service Bureau. The Service Bureau was built using object-oriented design techniques, and it automatically loads and manages the data warehouse. Its object orientation facilitates efficient, parallel, scalable, and re-startable transformation processes. The Service Bureau contains a number of components, which are listed in Figure 6.

Figure 6: Components of the Service Bureau

The Service Bureau consists of:
- a set of components and libraries that implement the common services;
- scheduler, file transfer, and data conversion programs;
- a watchdog service to ensure other services are up;,
- a system for paging on-call personnel through the Skytel service;,
- an e-mail queuing service that connects to the corporate e-mail system;,
- COM + components that provide a uniform Data Access Layer for web and other clients for logging and connection pooling to minimize database connection usage;
- a set of services that transform and load reservations and operational data into the Teradata Warehouse in real-time;

- a process that monitors the performance of the data warehouse, keeps history, and alerts the warehouse staff to exceptionally long-running queries;
- automatically generated meta data that is refreshed and published on the Intranet;
- an SQL Server operational database that stores configuration and status data;
- control of Teradata load utilities, and monitoring of MVS jobs through 3270 emulators; and
- real-time display of what each service is doing in each transformation server machine.

The Service Bureau's scheduler has about 50 tasks that run at intervals from minutes to hours, and others that run at specified times. Many of these tasks check whether a load is ready to run, and, if so, start it. Most of the loads depend on either a file becoming available through the Internet or the completion of another load. The dependencies are quite complex.

The Service Bureau manages a series of automated alerts that page the on-call warehouse staff member when some process needs human intervention. If the on-call person fails to respond and fix the problem, another page is sent to a secondary support person.

The Service Bureau monitors the number of items in the various work queues for the real-time loads, and if the queues fill up beyond certain preset thresholds, it issues an alert, paging the on-call staff. The Service Bureau also notifies the on-call staff member when any data warehouse load fails, or a data feed is not available in time, or a batch load process is taking too long and is projected to finish beyond its allotted time. It also monitors the latency of the data in the warehouse and issues an alert if it gets beyond a predefined value. For batch loads, the Service Bureau notifies the users of the data when their data has been loaded and is ready for the day.

A Standard Data Loading Process
A key benefit of the Service Bureau is that its objects were created for reusability. Therefore, it takes the warehouse staff a minimal amount of time to introduce a new data source into the warehouse process. A standard data loading process also helps to reduce the time to add new data sources. As feeds evolve from batch to real-time, there are minimal changes to the loading process. Regardless of latency, data feeds are transformed and sent to queues, which then are loaded immediately using TPump, the real-time loading utility provided by Teradata. Figure 7 provides an overview of the data loading process.

Because the standard loading process is generic and reusable, as users demand more and more real-time data, and as real-time feeds become available, incorporating real-time data into the warehouse is relatively simple.

Figure 7: The Real-time Data Loading Process

1. Continuous data loads use software, such as CDC (Change Data Capture), or special hooks or triggers on the operational systems to capture events of interest.
2. Special queue middleware, such as MQ Series, Oracle AQ, and MSMQ move the data to dedicated transformation servers.
3. Each update to the operational systems "triggers" a record to the queue.

4. Service processes continuously monitor these queues and transform each piece of data that gets loaded into the Teradata Warehouse using the Teradata continuous load TPump facility.
5. Strategic and tactical queries can run at the same time that data is being loaded.

In the case of batch updates, the operational systems create nightly files that are FTP'd to the transformation servers where they create an event that causes the transformation programs to run. These programs transform the data and push the transformed data through the Teradata Fastload and Multiload utilities to load the data into the Teradata Warehouse.

Managing Mixed Queries

Traditional warehouses are optimized to support strategic queries that require many table joins and aggregations; however, as warehouses become more real-time and support tactical queries, the prior optimization strategies no longer work. The challenge is to optimize real-time warehouses so that all queries can co-exist. Continental's optimization strategy aligns with their overall vision to "keep things simple," and this approach has worked well.

The data warehouse team takes advantage of the data warehouse's existing Teradata Priority Scheduler application to help manage the mixed query loads. The Teradata Priority Scheduler utility allows for concrete rules that determine the priority settings for users and applications. The tactical queries that access single records are set to *high* priority. These queries usually come from applications, such as the continental.com decision-making that require instantaneous response time. All daytime batch data loads are set to *low* priority, and all daytime trickle feed loads are set to *medium* priority. And, users who perform ad-hoc queries are given *medium* priority access.

The Service Bureau continuously monitors all of the queries to identify those that are using too much of the system's resources. For example, when queries run longer than one hour, they are allowed to run while the monitor service alerts someone on the data warehouse team. A team member investigates the query, and the query responses that are not needed immediately are set to the lowest priority. The warehouse team works with users to help them understand how to optimize inefficient queries.

Creating a "Time Machine"

Within Continental's warehouse, data about customers, flights, locations, etc. change due to normal business environment activities.[3] Some groups at Continental, such as Revenue Management, need to understand data as "it was" at any point in time. The Warehouse Director explains how the "time machine" can be used by the Revenue Management group: "With the 'time machine,' Revenue Management can go back and see how last year's bookings looked 50 days before Thanksgiving and see how they eventually came out. Then, they can extrapolate that to [the flight and booking activity of] this year and make pricing recommendations. The

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[3] Ralph Kimball refers to this as slowly changing dimensions.

reservations group can look at bookings as they occur throughout the day to determine peak times and change staffing practices."

To do this, the warehouse team saves every change that is made to a record and uses a combination of timestamp fields and flag fields to keep track of which record is current. For example, a reservation record that changes 100 times would have 100 associated records in the data warehouse, but only one record (i.e., the latest one) would have a flag field set to "active." When queries run, the WHERE clause must contain a date range or a flag field to keep the answer from including all of the changes to a record over time. The warehouse team creates views of "active" records that users can query, thus shielding them from query mistakes.

Continental refers to this capability as the "time machine," and members actively market the warehouse's ability to view data as they change over time. In doing so, the warehouse team creates awareness within the user groups about how the warehouse stores data and how users need to access it. The warehouse team notes that users have a very difficult time understanding how to access data at "a point in time." By keeping a potentially technical topic at a level that is interesting and catchy to users, the users are better able to understand and take advantage of the "time machine" capability.

The Data Warehouse Team

Continental has 15 people on its data warehouse team. They are responsible for managing the warehouse, developing and maintaining the infrastructure, data modeling, developing and maintaining ETL processes, and working with the business units. The organization chart for the data warehouse staff is shown in Figure 8.

The Data Warehouse Director reports to the Chief Information Officer. The warehouse staff is located in Miami and Houston. When the data warehouse initiative began, Continental filled the Director position with a highly experienced woman from Miami who had previously worked with excellent data warehouse professionals in the area, and she was able to hire them if they could continue to live in Miami. The Houston and Miami groups work as a team and share the infrastructure development and maintenance work, including building the processes that source data for the warehouse. The most technical people on the team have degrees in computer science. Everyone on the data warehouse team wears many hats, including providing operational support for the data warehouse. However, they also have specialized roles, such as the Master Data Modeler.

Figure 8: The Data Warehouse Organization Chart
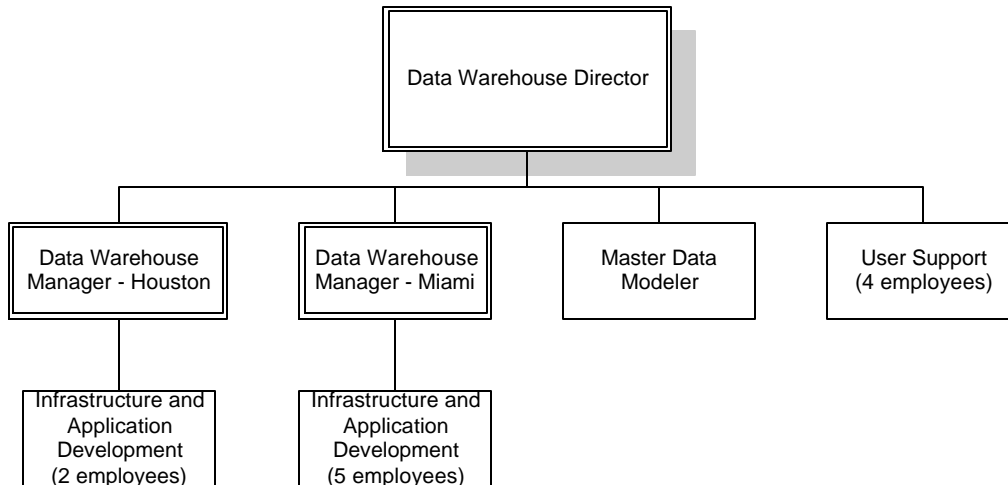
Four team members have specific support roles. Three work with the revenue management, marketing, and crew operations areas. The fourth is responsible for supporting Hyperion Intelligence and miscellaneous tasks. All of the support people originally worked in the user areas they now support and, therefore, are experts on the data for those areas. They assist rather than build applications for the business areas. As one explains, "I am the technical expert for the revenue management subject area. The warehouse team believes that the users own their data. We understand the data, but the user areas write the applications. Revenue Management has a programming staff that writes the applications that they use. They come to me for assistance when they have a problem." Several team members have extensive work experience with operational systems, which has helped them in implementing real-time data warehousing.

Data Warehouse Governance

The Data Warehouse Steering Committee provides direction and guidance for the data warehouse. It is a large, senior-level committee with 30 members, most at the Director level and above. The members come from the business areas supported by the data warehouse and are the spokespersons for their areas. Business areas that intend to participate in the warehouse are also invited to join the committee. The warehouse staff meets with the committee to inform and educate the members about warehouse-related issues. In turn, the members identify opportunities for the warehouse staff to become involved with the business areas. They also help the warehouse team justify and write requests for additional funding. Another responsibility is to help set priorities for future directions for the data warehouse.

Securing Funding
The business areas drive the funding for the data warehouse. There has always been one area that has helped either justify the initial development of the warehouse or encourage its later expansion. Revenue Management supported the original development. The second and third expansions were justified by Marketing to support the Worst to First, and then First to Favorite strategies. Corporate Security championed the fourth, and most recent, expansion. This approach helps ensure that the data warehouse supports the needs of the business.

The funding does not come directly from the business areas (i.e., their budgets). Rather, the funding process treats proposals as a separate capital expense. However, the business areas must supply the anticipated benefits for the proposals. Therefore, any proposal must have a business partner who identifies and stands behind the benefits.

The Benefits of Business Intelligence

Continental has invested approximately $30 million into real-time warehousing over the last six years. Of this amount, $20 million was for hardware and software expenses, and $10 million for personnel costs. Although this investment is significant, the quantifiable benefits from real-time warehousing are magnitudes larger. Specifically, over the last six years, Continental has realized over $500 million in increased revenues and cost savings, resulting in a ROI of over 1,000 percent.

The benefits from real-time BI at Continental range from better pricing of tickets to increased travel to fraud detection. Table 3 identifies some of the benefits that have been realized. Because there are 1,300 users with data warehouse access, it is impossible to keep track of all the ways in which the data warehouse has impacted Continental's bottom line. The data warehouse team knows that many other benefits exist that have not been identified. However, when big "wins" are achieved, the benefits are recorded and communicated throughout the company. This helps to preserve the excitement around data warehouse use, and it encourages business users to support data warehouse expansion efforts.

Table 3: Sample Benefits from Real-Time BI and Data Warehousing

Marketing	• Continental performs customer segmentation, target marketing, loyalty/retention management, customer acquisition, channel optimization, and campaign management using the data warehouse. Targeted promotions have produced cost savings and incremental revenue of $15 to $18 million per year. • A targeted CRM program resulted in $150 million in additional revenues in one year, while the rest of the airline industry declined 5 percent. • Over the past year, a goal was to increase the amount of travel by Continental's most valuable customers travel. There has been an average increase in travel of $800 for each of the top 35,000 customers.
Corporate Security	• Continental was able to identify and prevent over $30 million in fraud over the last three years. This includes more than $7 million in cash collected.
IT	• The Teradata Warehouse technology has significantly improved data center management, leading to cost savings of $20 million in capital and $15 million in recurring data center costs.
Revenue Management	• Tracking and forecasting demand has resulted in $5 million in incremental revenue. • Fare design and analysis improves the ability to gauge the impact of

	• fare sales, and these activities have been estimated to earn $10 million annually. • Full reservation analysis has realized $20 million in savings through alliances, overbooking systems, and demand-based scheduling.

Lessons Learned

The experiences at Continental confirm the common keys to success for any enterprise-wide IT initiative – the need for senior management sponsorship and involvement, close alignment between business and IT strategies, a careful selection of technologies, ongoing communication, a clear vision and roadmap, and letting the business drive the technology.

The more interesting and insightful lessons learned relate to the development and implementation of real-time BI, and include:

Lesson #1: Prepare early on for real-time BI.

Experienced BI professionals know that there are constant demands for ever-fresher data, particularly for applications that are customer-facing or monitoring critical business processes. Even with traditional data warehousing, the trend is always for more frequent data warehouse updates. Companies formally cross the divide into real-time BI when they implement real-time technologies, but the movement begins much earlier. Continental recognized the need and planned for real-time BI at the outset of its data warehousing initiative and created the Service Bureau to support real-time data feeds. Having this foundation in place eased the migration to real-time when the business needed it to happen.

Lesson #2: Recognize that some data cannot and should not be real-time.

The decision to move additional data to real-time should be made with care; data should only be as fresh as its cost and intended use justify. For one, real-time data feeds are more difficult to manage. The real-time processes, such as the flow of transaction data into queues must be constantly monitored, and problems with these processes can occur throughout the day (rather than just when a batch update is run). And, when problems with data occur, they must be addressed immediately. This puts pressures on staffing requirements. Also, there may be a need for additional hardware to run loads and back up the data. Finally, obtaining a real-time data feed from some source systems can be prohibitively expensive (or even impossible) to implement. At times, daily, weekly, or monthly updates may be adequate for the business.

Lesson #3: Show users what is possible with real-time BI.

It is often difficult to get users to initially "think outside the box." Users typically want new systems to give them exactly what the old ones did. To get around this problem, Continental's data warehousing staff develops "cool" prototypes to show what is possible. For example, the warehouse team put together the Concourse Map Application that was described earlier. When the users saw how data could be depicted in graphical ways (e.g., as an actual concourse with colors and lines that have special meaning), they came up with their own ideas for how real-time data could help them operate the hubs better. Once users appreciate what is possible, they are more likely to say: "Help me change the way that we do business." At Continental, the current challenge is to find the time to support the ideas that users have.

Lesson #4: Have the right people in the right positions.

In some companies, the warehousing staff has strong technical skills but limited business knowledge, and the business side has limited technical skills but good business knowledge. At the intersection of the warehousing and business organizations, there is a dramatic change in the technical/business skills and knowledge mix. At Continental, the change is very gradual across the intersection. The warehouse personnel who work most closely with the business users have considerable business knowledge. On the business side, many business users have developed excellent technical skills and build their own warehouse applications (e.g., Revenue Management). By making the shift in technical/business skills gradual across what can be a significant "divide," Continental ensures that the data warehouse is used to support the business.

Lesson #5: Real-time BI requires the automation of ETL processes.

The feeding of real-time data to a data warehouse is analogous to the running of a manufacturing plant. The processes should be as automated as possible. There should be minimal human intervention unless monitoring systems detect a condition that requires attention. Furthermore, the processes should be flexible and reusable so that changes can be made easily. Continental's vision from the start was for the data warehouse to be self-maintaining. The warehouse team developed automated processes (in the Service Bureau) that minimize human intervention and can be used across source systems and with new source systems that come on line. The Service Bureau continuously monitors these processes and immediately notifies the warehouse team via email and pages when a problem occurs.

Lesson #6: Strategic and tactical decision support must be carefully managed to successfully co-exist.

Historically, data warehouses have focused on providing strategic decision support (when needed, operational data stores have supported operational decision-making). With the emergence of real-time technologies, decision support has expanded to the tactical level. Strategic and tactical decision support have different characteristics, yet must co-exist in the same warehouse environment. Strategic decision support typically involves the analysis of large amounts of data that must be "sliced and diced" in various ways. Tactical decision support often requires repeatedly accessing only a limited amount of data. The performance requirements (i.e., response time) are greater for tactical than strategic decision support, since there is a smaller window of time for when the information is useful. The resource demands for strategic decision support are often greater and more varied than for tactical decision support (e.g., data mining versus accessing a customer value score).

The successful co-existence of strategic and tactical decision support requires business and technical solutions. On the business side, priorities must be set for the processing of queries from users and applications. For example, a data-mining query should have a lower priority than a tactical query. There must be capacity planning for each class of query. On the technical side, there must be a query manager that recognizes the priorities of the queries, monitors queries, defers long-running queries for later execution, and dynamically allocates query resources.

Lesson #7: The "Time Machine" must be managed according to business needs.

With real-time data warehousing, users need to be able to analyze data as "it was" at any point in time. Continental calls this powerful capability the "time machine." It is a capability, however,

that must be managed carefully. With real-time warehousing, data can change much more often (e.g., the estimate for a flight's arrival time changes each second at Continental) than with traditional warehousing. If all changed records are stored, then data volumes skyrocket, which impacts computing resources and the complexity of data access. Based on business needs, Continental carefully decides which changes to store in the data warehouse and which changes should be overwritten.

The data warehouse team addresses the data access complexity of the "time machine" by marketing it to users. The team members communicate at a high level what the "time machine" concept is about so that users can use time in their queries appropriately and better comprehend the possibilities of looking at data over time. To further minimize complexity, the data warehouse team creates views that only include active records so that users who need current data are shielded from complex query statements.

Lesson #8: Storing the enterprise warehouse data in 3rd normal form supports and encourages enterprise-wide use.

While there are alternative architectures for data warehouses, the most common is an enterprise data warehouse where the data for all of the subject areas are stored in 3rd normal form. With this approach, data redundancies are eliminated, data are easily maintained, there are agreed upon data definitions, queries can easily cross subject areas, and an enterprise-wide view of the data is provided. Continental's data warehouse team believes that the enterprise view has allowed the data warehouse to be much more widely used throughout the company.

Lesson #9 Real-time BI blurs the line between decision support and operational systems.

In many companies, the operational and decision support systems are "islands." Each has its own staff, processes, and standards. The only significant point of interaction is the extraction of data from operational systems. Real-time data warehousing blurs the distinction between decision support and operational systems. For example, the performance requirements for real-time BI, such as service level agreements for response time and unplanned downtime, are similar for both kinds of systems. The same personnel (or ones with similar skills) may be used. Whereas each group may previously have had their own standards, because of the need for the closer integration of systems, common standards become more important (in nearly all instances, the data warehouse needs to be compatible with the overall IT standards). It is also critical to be aware of any changes to any operational systems that provide real-time data, since the impact is immediate and potentially disruptive to applications that use the data.

Lesson #10 Real-time BI doesn't deliver value unless downstream decision-making and business processes are changed.

There are three sources of latency in real-time BI. The first is the time required to extract data from source systems. The second is the time required to analyze the data. And the third is the time required to act upon the data. The first two sources of latency can be minimized through the use of real-time technologies. It is the third source that can prove most problematic – getting people and processes to change. Unless downstream decision-making and business processes are changed to utilize real-time data, the value of the data decreases exponentially with the passage of time. Continental has found that the more users work with and understand the data warehouse, the more comfortable they become changing the way they work.

Conclusion

The leadership of Gordon Bethune, the Go Forward Plan, and Continental's employees moved the airline from "worst to first." They helped Continental do what an airline should do -- get people to their destinations, safely, on-time, and with their luggage.

Even after Continental had moved from "worst to first," management wanted more; it wanted Continental to move from "first to favorite." Management recognized that real-time BI was needed in order to fully support the First to Favorite strategy. Consequently, Continental moved systems to real-time as much as was possible given the source systems and the current technology and made plans for real-time data warehousing. In 2001, ahead of other airlines and most other companies, Continental implemented real-time BI and active data warehousing. The use of real-time BI has fundamentally changed how the company operates and its ability to compete in the marketplace.

As noted, data warehousing is commonly described as "a journey rather than a destination." This is certainly true at Continental. For example, although the Continental data warehouse currently contains 90 percent of the operational systems' subject areas, the data warehouse team is currently working to enhance existing subject areas and to convert more subject areas to real-time.

Continental's journey is likely to be relatively easy because of the approaches they have taken with real-time BI and active data warehousing. The business strategy and real-time BI are in sync. The business units feel that they own the data warehouse; the data warehouse team maintains the data warehouse, and the business areas develop their own applications, with assistance from the data warehouse staff. Continental has developed an enterprise data model and warehouse in 3rd normal form, which makes it easy to maintain, add subject areas to, and develop applications that use data warehouse data. Maintaining a real-time data warehouse can be difficult and resource intensive. However, Continental has developed automated ways that minimize the need for human intervention, yet are flexible in terms of accommodating changes, such as the addition of new source systems. With its approach, Continental is able to provide decision support information at service levels and with the timeliness that is typically associated with operational systems. All of this is helping Continental achieve its First to Favorite business strategy.

Appendix A: Honors and Awards

Best Customer Service	J.D. Power, SmartMoney, Ziff Davis Smart Business
Best International or Premium Class Service	OAG, National Airline Quality Rating, Nikkei Business Magazine, Travel Trade Gazette Europa, Inflight Research Services, Condé Nast Traveler, Smart Money, Wall Street Journal
Best Airline	Fortune, Air Transport World, Investor's Business

	Daily, Hispanic Magazine, Aviation Week, OAG
Best Technology	#1 Airline, #2 of 500 Companies – InformationWeek, #1 Web, by Forrester, Gomez Advisors, NPD New Media Services and InsideFlyer, TDWI 2003 Best Practice Award – Enterprise Data Warehouse, TDWI 2003 Leadership Award, CIO Enterprise Value Award

Appendix B: The Early Go Forward Plan

The Go Forward Plan had four component parts, all of which had to be executed simultaneously. They dealt with the market, finances, product, and people, and each was given its own name.

The Market Plan: Fly to Win
Continental committed to the seemingly obvious -- stop doing things that don't make money. Losses had to be replaced with profits if the airline were to survive. This required multiple actions. Non-profitable routes had to be dropped. Continental would fly only to places where people wanted to go and were willing to pay a fair price. Relationships with travel agents had to be restored. In its efforts to cut costs, Continental cut agent's commissions, gutted its frequent flyer program, and took away incentives that agents could use as selling tools (e.g., upgrades). Relationships with customers had to be improved, especially with high-value business travelers. Consequently, the award winning frequent flyer program was restored. Any costs that did not create value for the customer were cut.

The Financial Plan: Fund the Future
Continental was quickly running out of money. This wasn't immediately obvious because the cash and cost forecasting systems were so poor, but the bleeding had to be stopped. Loans were renegotiated to stretch over a longer time period. The company was able to get out from under leases for planes that were unprofitable to fly. Boeing agreed to partially refund the down payment for planes that were not needed. Costs were cut wherever possible, such as closing down the Los Angeles maintenance facility. The CFO personally signed every large check. A significant investment was made to improve the financial reporting systems so that there was reliable information.

The Product Plan: Make Reliability a Reality
Continental had to get back to what people expected of an airline. The only way to do this was to motivate employees. Following the dictum, "what you measure and reward is what you get," Continental implemented a measurement and reward system that provided incentives for employees to make Continental a more reliable airline. It also did away with an employee manual that was so restrictive that it sometimes eliminated the employees' ability to do what was most logical. An 800 number with an operational response team on the other end was set up to respond to problems in the field. When customers had problems and complained about service, Continental quickly responded, apologized, and took appropriate steps to correct the problem.

The People Plan: Working Together
Continental had to change its corporate culture. Continental needed to treat its people better and get them working together as a team. People should want to come to work and be proud of their employer. In meetings and through other communications, employees were told the importance of teamwork and treating one another with dignity and respect. A 360-degree review process was put in place to measure how well managers communicated and encouraged their teams. Employees were trusted to use their judgment and to make the right decisions. If they did not buy into this new culture, they were let go.

Source: Descriptions are based on Gordon Bethune, *From First to Worst: Behind the Scenes of Continental's Remarkable Comeback,* John Wiley & Sons, New York, 1998.