USING THE THEORY OF CONSTRAINTS TO IMPROVE COMPETITIVENESS: AN AIRLINE CASE STUDY

by Tony Polito, Kevin Watson, and Robert J. Vokurka

EXECUTIVE SUMMARY

The aim of the discipline of Operations Management is to gain competitive advantage. One more recent and lesser-known Operations Management technique that is finding greater acceptance is the Theory of Constraints (TOC). This paper illustrates the use of a specific TOC technique termed "The Thinking Processes" to solve an airline industry case toward improved competitive outcomes.

INTRODUCTION

The discipline of Operations Management, the design and control of organizational systems responsible for the productive use of raw materials, human resources, equipment, facilities and other productive resources, provides critical direction in gaining and maintaining competitive advantage (Chase, Aquilano, & Jacobs, 2001). One recent Operations Management textbook (Russell & Taylor, 2000) states that its first purpose is to allow the reader to gain an appreciation of how operations can provide a competitive advantage in the marketplace, and, toward that end, the text is thoroughly side-barred with exemplars of improvement in competitiveness through operational techniques.

Operations management (OM) as a discipline embraces a number of techniques, tools and philosophies toward that competitive aim. Materials Requirements Planning (MRP), distribution planning, enterprise resource planning, supply chain management, forecasting, just-in-time systems, queuing management, and project management are but a few of the more widely known and generally accepted OM concepts and techniques. One of the newer and lesser-known OM concepts that is finding increasing acceptance is the Theory of Constraints (TOC). This paper briefly outlines the nature of the Theory of Constraints, then describes and illustrates the use of one specific TOC technique, The Thinking Processes, in the solution of a specific case in the airline industry geared towards improving competitive outcomes.

THEORY OF CONSTRAINTS

Theory of Constraints techniques were, for the most part, developed by Dr. Eli Goldratt, beginning with his best-selling book *The Goal* (Goldratt, 1992). The most widely known Theory of Constraints technique is scheduling and managing operations centered upon those operational activities that constrain, or bottleneck, the entire system. Under TOC theory, it is the process that possesses the least capacity in the system that should be managed toward increased capacity, as it is that process that restricts the entire system from increased output. Common alternate terms for this TOC technique include synchronous manufacturing and bottleneck management.

This perspective differs radically from many traditional management techniques. For example, traditional variance reporting attempts to focus managerial activity upon all processes in the system that deviate from standardized measures. The focus is on maximizing efficiency on each operation. Unlike MRP-based scheduling that essentially "counts backward" from the end of the production line to determine workstation schedules and material releases, TOC-based scheduling "counts backward" from the bottleneck process to determine workstation schedules and material releases, in order to maximize the productivity of the bottleneck process. This approach is commonly termed Drum-Buffer-Rope, or DBR. The aim of TOC is to maximize the productivity of the entire system.

While TOC is best known for its advocacy of bottleneck management, the term Theory of Constraints also refers to a number of other related productivity concepts advocated by either Dr. Goldratt or other major proponents of his overall philosophy. One lesser-known technique developed by Dr. Goldratt is generally referred to as The Thinking Processes. Goldratt developed and presented The Thinking Processes in his book *It's Not Luck* (Goldratt, 1994). The Thinking Processes are intended as a set of structured steps that lead decision-makers to identify the root cause of "undesirable effects," to identify the faulty and/or incomplete logic regarding the root cause and to develop an improved logic regarding the root cause that, in turn, leads to more desirable effects. A case study regarding the in-flight inventory of "Best Airlines" is used in the balance of this paper to illustrate the use of The Thinking Processes toward improving outcomes.

The Best Airlines case was originally presented to the authors as an academic exercise. As the analysis of the case progressed, however, it was revealed that the case was factual in nature and that the facts of the case had been outlined by a Best Airlines Vice President. The analysis of the authors, as well as the analyses of several other individuals also given the exercise, contributed to the key case analysis presentation made to Best Airlines. In the next section, the facts of the Best Airlines case study are stated in the exact form in which they were presented for the initial case analysis.

THE "BEST AIRLINES" CASE

Best Airlines is an international airline that services over 750 million passengers a year on 5,000 flights per week. While Best is known for its customer service, this reputation has a tremendous price – $15 million investment of in-flight supporting inventory. Even with this high investment in about 300 different items, Best Airlines stocks out of a number of items, expedites other items to prevent stockouts, and substitutes similar items when needed (eg, coach plates, cups and saucers for first-class or international).

Best Airlines' supply chain links the consumer (750 million passengers/year) to the flight attendants (17,000) to the flights (5,000 / week), to the aircrafts (540), to the kitchens (150), to the regional warehouses (6), to Sage (a contracted inventory management firm with a central storage area in Chicago), to the purchasing department, and finally to manufacturers. Remember – Best Airlines is in the service industry as a passenger travel provider and not in the food service business.

Inventory items include expendables (e.g., sodas, water, cups) and non-expendables (e.g., carts, china, silver, coffee pots, blankets). Wines and liquor create special problems and will not be included in this analysis. A caterer generally supports the kitchen and orders food items for in-flight meals. Some of the 300 items include foods. The caterer manages these items.

A description of the general flow of materials and the supporting policies and procedures is provided. A plane's in-flight inventory is set at 110 percent of item demand, rounded up to the next container size. The flight attendant generally "squirrels away" additional quantities of inventory items. In fact, in a recent inspection of several aircraft, an average of 400 pounds of excess inventory was identified. This excess represents several million dollars a year in fuel cost just to carry the unauthorized inventory. Beverages were found in the ovens and overhead bins. Excess blankets were found in storage compartments. The flight attendant feels he/she is the link to the consumer and therefore he/she must have enough inventory to provide superb service.

The aircraft is serviced between flights by kitchen trucks. Each truck carries enough inventories to re-supply 5-6 flights then the truck must return to the kitchen warehouse for replenishment. Each truck carries excesses of many items. The trucks are re-supplied from an open picking area that holds approximately 1.5 days of inventory and is replenished daily or when an item is low.

The picking area draws it materials from a secured kitchen warehouse which has varying amounts (two weeks to over a year of demand in some instances) of the approximately 180 used by that kitchen. The kitchen orders weekly from a centralized inventory management (CIM) team and receives weekly delivery (item lead time is less than a week in most cases.). In a recent visit to a large kitchen, a shipment receipt from the region warehouse was being inventoried. Twenty different items were included in the shipment. Most items had several weeks of demand. Kitchens use a min-max inventory system. The quantity ordered is rounded to the nearest logical container size.

Kitchens are regularly shorted on items ordered. Occasionally, the CIM team notices that the item ordered is in excess of the average demand for that item at that kitchen and therefore sends the average amount. CIM expects the kitchen to justify the difference if it is actually needed. In most cases, the kitchen does not know it is shorted until the order arrives and is inventoried. When a kitchen is out of stock of an item, many times it contacts a nearby kitchen and "bargains" for the item. Frequently, large kitchens support the needs of the smaller nearby kitchens, as they are able to respond within a lead time of a day instead of a week's lead time through the formal ordering system. CIM generally is not informed of these transshipment activities between kitchens.

CIM's role is to receive the kitchens; orders, audit them, place the adjusted orders with the appropriate regional warehouses, monitor the inventory levels at their assigned regional warehouses, place orders with Sage (a contract inventory management firm with its major warehouse located in Chicago) to replenish the regional warehouse when needed and place orders with the purchasing department for replenishment quantities when requested by the Sage warehouses. Sage is the receiving point for most factory orders. Orders are usually several months of demand.

Each regional warehouse uses a forecasting model to determine the monthly demand; demand is highly seasonal with summer months and Christmas (June, July, August and December are 30 percent above average) being peaks and the beginning of the year (January through April) being valleys. The average aircraft load factor is 65 percent for all aircraft with some flight segments approaching 100 percent.

The CIM team uses reorder point (ROP)/economic order quantity (EOQ) models with seasonal indices applied to the appropriate months. Demand during lead time plus safety stock is used to determine each item's ROP. Lead times are highly variable. One month is allowed for the purchasing department to place the order with the manufacturer. The manufacturing lead time is supplied by the manufacturer and monitored by the purchasing department. Manufacturing lead times are one to several months depending on the product and the order quantity. Inventory is received at the Sage warehouse (contractor) and then shipped to regional warehouses as ordered. One half a month's demand is provided for this lead time segment. One month of safety stock is used for each item.

The purchasing department negotiates volume discounts (price breaks) with vendors. When the purchasing department receives an item order, the purchasing department holds these regional warehouse orders until the discounted quantity associated with the price break is achieved then places the order with the manufacturer.

Flight attendants service Best Airlines' passengers. Flight attendants expect ample inventory on each flight. Kitchens are responsible for re-supplying each plane before a flight. The kitchen's performance is evaluated by flight attendants. The flight attendant completes a questionnaire after the flight segment that includes questions on inventory availability. The flight attendant occasionally requests inventory above the flight level. In some instances, the kitchen is written up for refusing to fill the order.

Stockouts and quality problems are generally noted by the flight attendants on the questionnaire. Kitchens are measured monthly by the number of stockouts and customer service level. The regional warehouse is measured by its total inventory investment. The smaller the inventory investment, the better its performance. In some cases the regional warehouse manager (CIM) refuses to accept "excess" inventory from the kitchen (e.g., china, silverware), as it will increase its inventory investment. Sage is measured by its operating expense levels -- the lower the cost to support the inventory system the better the performance. The purchasing department is measured by its cost reduction efforts (volume discounts on items) with vendors.

DISCUSSION AND APPLICATION OF THE THINKING PROCESSES

The first major step in the Thinking Process is the construction of a "Current Reality Tree," or CRT. Figure 1 illustrates a Current Reality Tree developed by the authors that represented the current state of in-flight inventory management at Best Airlines.

The CRT is, in essence, a causal flowchart of the current system state as described by the facts of the case. The CRT is constructed by first identifying the Undesirable Effects (UDEs) noted in the case and posting them near the top of the diagram. Next, those facts of the case that appear to immediately cause the UDEs are posted to the diagram and connected to the appropriate UDEs with arrows, thereby illustrating the causal relationship. Next, those causes are looked upon as effects, and then their causes are extracted from the facts of the cases and subsequently diagrammed. This process is repeated until the CRT converges upon a root cause that, once identified, can be further acted upon by the decision-makers.

Some degree of interpretation, iteration and interpolation is typically required of the creators of a Current Reality Tree, therefore slightly different CRTs may be generated from the same case by different creators. Given The Thinking Processes and Current Reality Tree are primarily intended to aid in the process of decision-making, the CRT is usually considered complete and correct when the case decision-makers agree it accurately and fully represents the relevant facts of the case. In fact, much of the benefit of The Thinking Processes is derived from the decision-makers' direct involvement in diagram development.

A Current Reality Tree is a distinct form of root cause analysis. Root cause analysis is an improvement technique originally popularized during the 20th Century's Japanese quality movement (Wilson, Dell, & Anderson, 1993). One such application at Toyota, specifically the use of "The Five Whys" – the asking and answering of "Why?" five times in succession before acknowledging the true root cause of an effect – is acknowledged within a number of works including *The Machine That Changed the World* (Womack, Jones, & Roos, 1991), a book based upon research conducted under the auspices of the Massachusetts Institute of Technology.

The Thinking Processes assumption that many effects can be traced to few causes may well have been influenced by the Pareto Principle. Nineteenth-century Italian economist Vilfredo Pareto observed that twenty percent of the Italian people owned eighty percent of Italy's wealth. Pareto developed mathematical models to predict and explain the maldistribution (Pareto, 1896). Over time, the model was employed to explain other similar "80:20" maldistributions. In 1954, Juran, based on his observations and data, adapted the concept to usage in the discipline of quality, stating that 80 percent of quality losses are effected by 20 percent of all root causes. Juran called that 20 percent of root causes "the vital few," and the rest "the trivial many." (Juran, 1954). The Pareto Principle, or "The 80:20 Rule," implies that management resources are best allocated toward modification of "the vital few" root causes.

Figure 2 represents an Evaporating Cloud, with assumptions and injections, developed by the authors for the Best Airlines case. Once the root cause has been

identified through the Current Reality Tree, the next major step in The Thinking Processes is the construction of an "Evaporating Cloud" diagram. The Evaporating Cloud diagram is, in essence, a flowcharting of the faulty and/or incomplete logic regarding the root cause. The Evaporating Cloud is constructed by first posting the identified root cause at the left of the diagram and is labeled as the system objective. Next, the two key opposing elements that are required to meet the objective are posted to the right of the objective and connected to the objective in the diagram by causal arrows. Next, to the right of each of the two requirements is placed the prerequisite condition for the requirement; each is also connected in the diagram by a causal arrow.

Refining iterations of the requirement and prerequisite statements should continue until the two prerequisite statements are in logical opposition. That logical opposition identifies the underlying and unresolved conflict that results in the sequence of undesirable causal relationships as represented in the CRT. Next, the creators of the Evaporating Cloud attempt to surface any unstated assumptions that are made regarding the four causal relationships identified in the diagram, as well as any unstated assumptions that underlie the logical opposition. Next, the creators attempt to counter these assumptions with "injection" statements. It is these injection statements that allow for a more complete understanding of the root cause/objective and the development of a more coherent future system state.

The Thinking Processes assumption that a basic conflict in logic leads to the existence and perpetuation of an undesirable system state may well have been influenced by the thinking of Kurt Lewin. Lewin, generally recognized as the father of social psychology, developed the popular change management tool known as Force Field Analysis (Lewin, 1951). Lewin believed that a current system state is held in balance by the interaction of two opposing sets of forces: driving forces that seek to promote change and restraining forces that resist change in favor of *status quo*. In order to effectively implement change, Lewin advocated the use of a Force Field Diagram, where the planned future system state is listed at the top of two columns, then the driving forces are listed in the left column and the balancing restraining forces are listed in the right column. Arrows are then drawn from each specific force toward the center of the diagram, with higher degrees of force illustrated by larger arrows. A Force Field Diagram makes visually explicit the set of counterbalancing, opposing forces maintaining the equilibrium of the current system state in order to support decision-makers toward effective change implementation. Either decreasing a restraining force or increasing a driving force can be effective in changing the current system state toward the planned future state.

CASE ANALYSIS AND SOLUTION

The analysis of the Best Airlines case that falls from The Thinking Processes can be briefly described as follows. Best Airlines' operational behaviors regarding its in-flight inventory are driven by the root cause/objective that it provides quality through both least cost and superior service. The Evaporating Cloud reveals that it has been incorrectly assumed, however, that least cost and superior service are mutually exclusive goals; i.e., that in order to provide superior service, costs must increase.

This faulty assumption, an assumption often held by Western manufacturers prior to the modern Japanese quality movement, is reflected in many of the specific actions diagrammed within the Current Reality Tree. Some actions attempt cost reduction to the exclusion of increased service; e.g., "purchasing is evaluated on its cost reduction efforts with vendors," "the regional warehouses are evaluated by inventory investment." Other actions attempt increased service to the exclusion of cost reduction; e.g., "kitchens are evaluated by the number of stockouts and customer service levels," "planes carry an average of 400 pounds of unauthorized inventory." The result is a dilemmatic, conflicting current system state that results in numerous undesirable effects. A future system state must be planned where all actions and causal relationships consider both cost reduction and increased service level in tandem.

Best Airlines management was basically pleased with the various Thinking Processes analyses with which it was presented. At the case analysis presentation stage, one Best Airlines executive stated

FIGURE 1
Current Reality Tree, Best Airlines, In-Flight Inventory

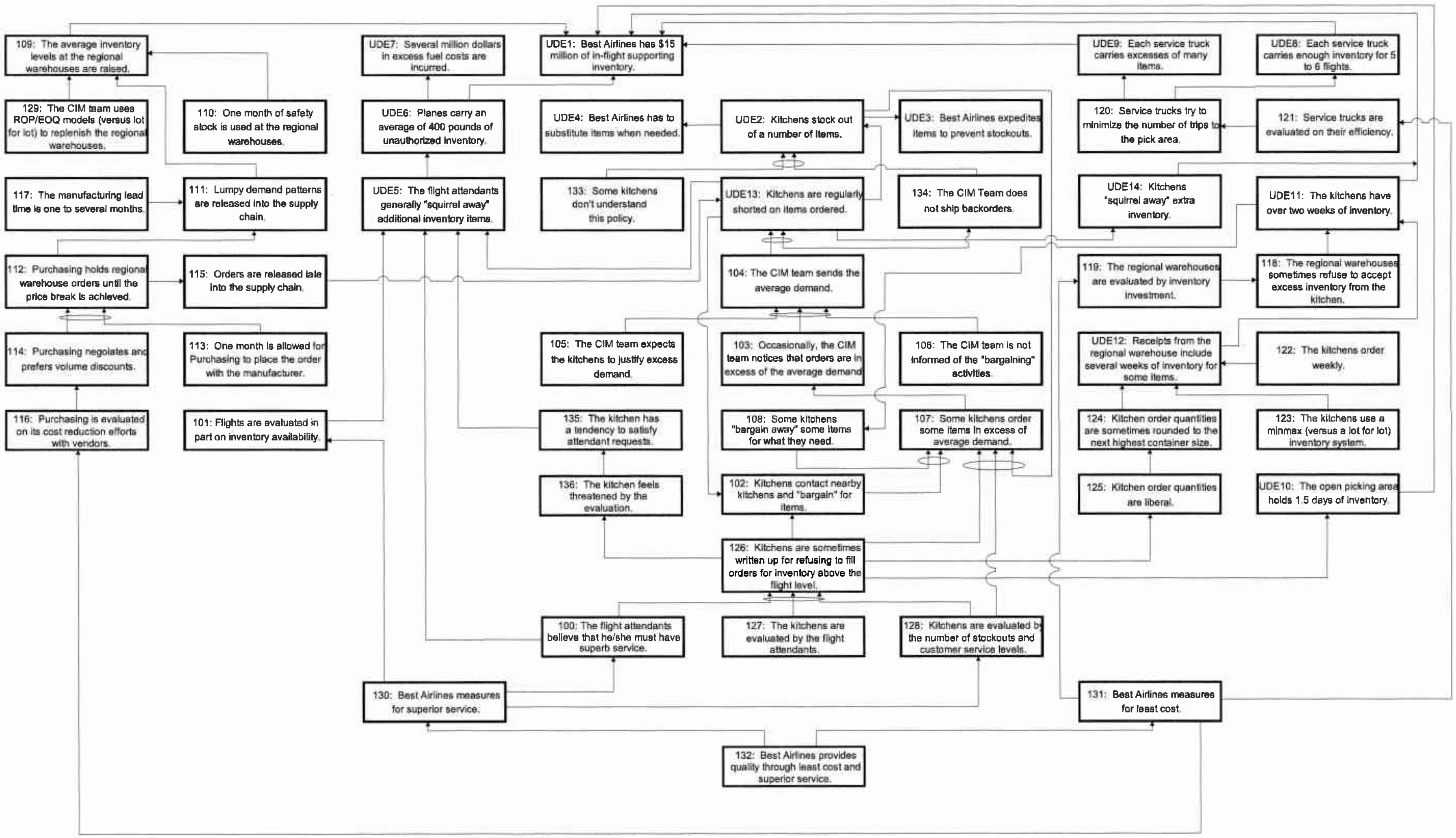
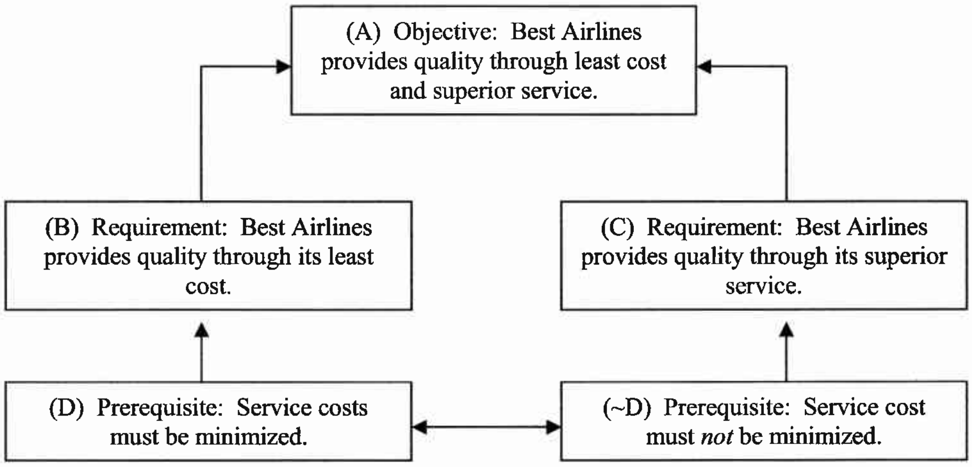


FIGURE 2

Evaporating Cloud, Best Airlines, In-Flight Inventory



(A)(B)

Assumption:	Customers require that quality includes least cost and superior service.
Injection:	Determine if target market would readily absorb higher pricing.
Assumption:	Least cost and superior service are mutually exclusive goals.
Injection:	Measure cost and service simultaneously at all cost centers.

(A)(C)

Assumption:	Customers require that quality includes superior service and least cost.
Injection:	Determine if target market would yield service for lower pricing.
Assumption:	Superior service and least cost are mutually exclusive goals.
Injection:	Measure service and cost simultaneously at all cost centers.

(B)(D)

Assumption:	Service costs must be included in least cost efforts.
Injection:	Institute incremental least cost targets in non-service cost centers that compensate for existing service costs.

(C)(~D)

Assumption:	Superior service always has higher costs.
Injection:	Implement only "high service under low cost" improvements.

(D)(~D)

Assumption:	Service costs must either be minimized or NOT minimized.
Injection:	Develop service cost control methods that control to a reasonable degree rather than enforcing minimization.

that the analysts "understood the airline's problems better than the airline did."

Typically, the final major step in The Thinking Processes is to employ the analysis and understanding captured via the Current Reality Tree and Evaporating Cloud diagramming toward the development of a causal diagram of the desirable future system state called the "Future Reality Tree." Said another way, the Future Reality Tree (FRT) is, in essence, a causal flowchart of the future system state that is now intended by the decision-makers, given their more complete understanding of the root cause/objective.

The general appearance of the Future Reality Tree is extremely similar in nature to the Current Reality Tree. The FRT is constructed by first posting the root cause/objective near the top of the diagram. Next, the effects that are desired to immediately fall from the root cause/objective, given that more complete understanding, are posted to the diagram and connected with arrows to represent the casual relationship. Next, those effects are looked upon as causes, and then their desired effects are subsequently diagrammed. This process is repeated until the FRT represents the future system state as desired by the decision-makers.

In the case of Best Airlines, management and other involved decision-makers were encouraged to construct their own FRT, and the resulting diagram served as their "solution" to the in-flight inventory problem. While confidentiality prevents presentation of the FRT solution or most other specific outcomes, it can be said that the implemented FRT solution generated in excess of a 60 percent reduction in in-flight related inventory as well as some increase in system service levels.

CONCLUSION

As this case demonstrates, The Thinking Processes can be employed as an effective and valuable tool in the diagnosis and improvement of organizational systems toward an increased competitive posture. While in this case competitive advantages in the specific areas of cost and service level were obtained, The Thinking Processes technique is not specific to any particular type of competitive advantage or organizational issue, and so can be an appropriate application toward improvement of competitive position in a wide variety of scenarios.

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Tony Polito is Assistant Professor in the department of Decision Sciences, College of Business at East Carolina University.

Kevin Watson is Assistant Professor in the department of Management, University of New Orleans.

Robert J. Vokurka is Professor of Operation Management, Texas A&M University-Corpus Christi.