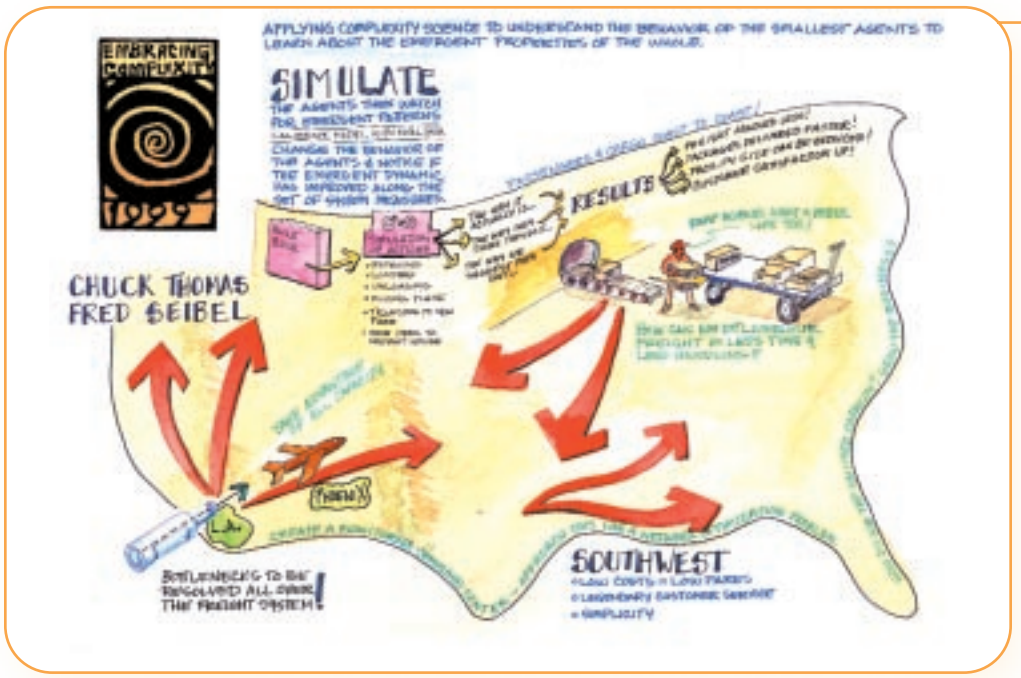
Adaptive Cargo Routing at Southwest Airlines

Chuck R. Thomas, Jr., is director of financial analysis for Southwest Airlines Company. He has served in that position for the past three years, following nine years as the head of Southwest's planning and budgeting functions. He holds a Ph.D. from the University of Texas at Arlington, where he studied accounting and finance. He currently holds a position in the Federal Aviation Administration's Collaborative Decision-Making initiative of its Free Flight Program. Current research interests include interactions among production, planning, marketing, and sales functions in mature firms; applications of complexity to task assigning; scheduling of aircraft flows to achieve aircraft maintenance objectives; the use of knowledge management methods in firms' project portfolio management; and advancements in strategic cost management particularly related to performance management without traditional budgeting.

Fred Seibel is vice president of software development at Bios Group, Inc. He received his B.S. in physics from Yale University and his Ph.D. in nuclear physics from Duke University. Dr. Seibel has over 20 years of experience in managing business and academic computer systems. Prior to joining Bios Group, he managed the software development teams supporting the Advanced X-ray Astrophysical Observatory for the Smithsonian Astrophysical Observatory. Previously, he managed a group developing interactive, simulation-based training technologies and courseware for BBN Corporation. Seibel also oversaw the design, development, and implementation of artificial intelligence-based automation systems for Merck & Company and headed the Computer Division at Princeton Plasma Physics Laboratory.



The basic concept of complexity theory, Fred Seibel explained, is to try to understand a problem by examining the behavior of the smallest elements, cells, or agents of an organism. Then, using the properties of those cells, to understand something about the emergent behavior of the organism as a whole.

What do you do when you're trying to solve a real problem? You write a computer program that consists of small modules, which captures how those individual agents or elements of the organism are behaving. Next, you run the system and execute those routines, you collect data from the aggregate behavior, and you try to see whether you can improve the emergent behavior.

Having laid out the steps to solving a problem, Fred turned the podium over to Chuck Thomas, the director of financial analysis at Southwest Airlines, to discuss the problem to be solved.

How do you alleviate bottlenecks and increase capacity in the cargo business of a major airline? By analyzing the situation through a complex adaptive systems lens, and then modeling the problem, running a simulation, and improving upon the emergent behavior. Which is just what Bios Group did, employing complexity science to improve manifesting and loading strategies and boost performance at Southwest Airlines.

Improving the Cargo Business

Southwest Airlines moves passengers and cargo from coast to coast and border to border in the domestic U.S. "The important things at Southwest," Chuck stated, "are low costs, low fares, and our people, who provide legendary customer service. We're real big on simplicity and the people side of things, and that gave us an interesting situation."

Southwest had been scrutinizing its cargo business over the past six years, and the feeling in the company was that this area of the business could be expanded. In its work with Ernst & Young, Southwest built a portfolio of improvement opportunities. These areas of improvement touched on growing the business, operational improvements, and different approaches to material and work handling.

Furthermore, one of the key aspects under examination was Southwest's cargo capacity. Southwest's operational data suggested that the airlines had approximately 7 percent (by both weight and volume) of its bin space full on any particular flight. "Which is a pretty small proportion of the flight being full," Chuck admitted. "Some of the other carriers may hold as much as 35 percent in the bellies of their aircraft."

A close inspection of work in the field revealed that there were bottlenecks all through the system. Some aircraft were scheduled to carry a large load of cargo, but lacked the bin space to accommodate this volume. In more than a few cases, the company was taking aircraft departure delays, which was a real issue for Southwest. "We're fundamentally a passenger airline," Chuck explained. "Only 2 to 3 percent of our revenue is from cargo, so to start taking flight departure delays for the cargo business is unheard of."

Another issue was that Southwest's ramp agents, the people who move the cargo, were experiencing frustration. Because these ramp agents focused on speed and efficiency, their approach to cargo was to simply "throw it on the next plane and get it out of here." One station, therefore, would ship cargo down line to another station. The ramp agents that received that freight could not understand why they had it, in addition to the rest of their workload. So they would then load the cargo onto another aircraft and send it down line to somebody else. "Obviously," Chuck said, "we had a problem that we needed to deal with."

Seeking a Threefold Solution

Southwest was determined to improve three areas. "First, we wanted to make work life better for our ramp agents," Chuck stated. "Rather than dumping cargo on other folks and getting frustrated when it was dumped back on them, we wanted to make their work life more meaningful and fulfilling."

Second, Southwest wanted to tap into its unused bin space capacity. And third, they wanted to grow the business to increase its profit base.

In a style typical of the culture at Southwest Airlines, Chuck and his team brainstormed about different ways to attack the problem. They approached senior management about tackling these issues and undertaking significant-sized projects. But when senior management gave them the go-ahead and funding, the team was unsure how to proceed.

"The initial idea was to put a focus team together in a conference room to test different ideas on how we might be able to move cargo better," Chuck said. This team would consist of subject matter experts, ramp agents, and ramp supervisors who had a good feel for best practices at the different stations. On the side, the group would also set up a temporary command center to monitor day-to-day problems with the movement of cargo and to experiment with different approaches to specific problems.

"We would have difficulties, for example, out in Phoenix with cargo coming in from LAX," Chuck stated. "So we would study that for a week or two and come up with some ideas on the best way to work in LA, so as to avoid bottlenecks in Phoenix. The general notion was to look at the local problems and see if we could devise some sort of a global solution, or a series of solutions, that would ease the bottlenecks and the frustration."

But none of the solutions seemed to fit all the problems or all the locations. "We wanted a systematic, rigorous process that would give us, with a fair degree of probability, the results we were looking for across the board," Chuck explained. "And it wasn't clear that the focus team or the command center were going to yield those results. There just weren't any big ideas that seemed to come through."

Chuck's team at Southwest had talked about bringing in network design specialists from other fields that have similar types of network problems—such as the transportation or telecommunications industries. But John Seeliger, a senior manager in Ernst & Young's consulting practice, suggested Chuck give Bios Group a call with regard to this specific cargo-routing problem.

The Nitty-Gritties

"Let's get into the nitty-gritties of what we actually did," Fred said. "Southwest came to us and asked for a rulebook that could be used to direct cargo away from 'heavy load' stations to those with lighter cargo traffic." This rulebook would sit on each freight agent's table, and he could look up in the book what he should do with freight going to a particular station. That way, Southwest hoped, freight agents could avoid some of the problems that Phoenix and LAX, for example, were experiencing.

To test the rules that were to go into this book, Bios Group created an agent-based model. This model would also be used to reproduce Southwest's current operations through simulation. Bios Group would then collect some historical data to calibrate the model. "We wanted to

have something that actually showed what Southwest was doing today, and the problems they were having. That way, we could use either the rules they generated, or the rules we might discover, to improve this model and to have some confidence that we would succeed in applying these rules to a real-world situation."

Bios Group used the following data to create this model: shipment descriptions, flight schedules, and freight logs.

A record of the freight Southwest had shipped in 1998 was provided by weight, by number of pieces, by origination and destination for each shipment, and by class of service (Next Flight Guaranteed [NFG], Rush or twenty four hour service, and Air Freight). Bios Group also had access to the flight manifests, which are instructions regarding how a particular piece of freight should reach its final destination, where it should be transferred from one flight to another, and so forth.

With regard to Southwest's flight schedules, Bios Group was privy to aircrafts' takeoff and landing times, their flight numbers, and their segments. The background data, or freight logs, showed how much of the bin space was actually available and how much was pre-loaded with baggage or mail. (Baggage and mail, Fred explained, take priority over cargo. Therefore, an assumption was built into the model that some fraction of the space needed would already be occupied.)

Freight forwarders and ramp agents were modeled into Bios Group's simulation. "So we needed to model the decisions that freight forwarders made, such as how they decided to route a package to wherever it was going," Fred added. "We also had to deal with the ramp agent, the guy who actually slugs the cargo onto the plane."

Objects in the system—namely, the shipments and the flights—were also built into the simulation. "The actions we modeled were that of a freight agent assigning a shipment to a flight," Fred commented. "We modeled loading the plane, flying the segment, unloading the plane, possibly transferring the cargo to another plane, and then moving the cargo to the freight house. So we modeled this package to all the phase transitions, if you will."

Calibrating the Data and Testing the Rules

In order to run the model, Bios Group used Southwest's actual manifests to calibrate the data. Fred and his team then ran the network for a week, moving packages from one place to another. In addition to hard data, Bios Group took some of the anecdotal information about the ramp operators and built "probabilistics" into the model. For example, one probabilistic was that an overworked ramp agent in Phoenix would just load a piece of cargo onto the next plane, without paying attention to the manifest.

"Parenthetically," Fred added, "let me remark that Southwest, as Chuck said, does things in a very simple way. The company tries to keep costs down and they're not heavily computerized. So they simply slapped a sticker on the outside of these packages, specifying the service level and its final destination. They didn't list the intermediate stops on these stickers; the manifest had them printed out, but the packages themselves didn't. There was ample opportunity, therefore, for the ramp agent to say, 'Well, I'm just going to get it out of here.'"

To test the rules embedded in the simulation, Bios Group had to generate the manifests and the ramp operations in the computer as well. Then Fred and his team ran the model in three modes: the way Southwest thought it was running its operations, the way Bios Group believed Southwest was working, and the way Bios Group thought the airlines should run its cargo-loading operations.

What was measured? How much cargo was handled at each station. (A certain amount of cargo handling is unavoidable, Fred pointed out. All cargo must be loaded and unloaded, but what can be avoided are the transfers in between.) The amount of cargo that had to be stored overnight. (For security reasons, freight stored overnight must be kept under lock and key, and then trucked back out to the aircraft in the morning.) And if the level of service for each package was met. (That is, did the NFG packages, for example, arrive as promised?)

"Right off the bat," Fred remarked, "we had some difficulties with the simulation when we flew the schedules." For starters, the manifests regularly called for loading 10,000 pounds of cargo on a flight from LAX to Phoenix. But the planes only carry 2,000 pounds. "It was clear that multiple people were manifesting cargo for a single plane,

Rush Shipment: Albuquerque to Oakland › Old f. 1

Flight	Origin	Destination	Takeoff	Landing	Route
4	HOU	DAL	7:00	7:55	102
4	DAL	ABQ	8:20	10:05	102
1547	ABQ	LAS	10:30	11:55	102
1547	LAS	SAN	12:15	13:15	102
807	SAN	OAK	14:15	15:35	91
1547	SAN	SJC	13:35	14:55	102
1406	SJC	SAN	15:15	16:30	102
1171	SAN	OAK	16:50	18:10	102
935	OAK	BUR	18:30	19:30	102
935	BUR	PHX	19:50	21:05	102
935	PHX	OKC	21:30	23:25	102

f. 2 Rush Shipment: Albuquerque to Oakland › New

Flight	Origin	Destination	Takeoff	Landing	Route
4	HOU	DAL	7:00	7:55	102
4	DAL	ABQ	8:20	10:05	102
1547	ABQ	LAS	10:30	11:55	102
1547	LAS	SAN	12:15	13:15	102
807	SAN	OAK	14:15	15:35	91
1547	SAN	SJC	13:35	14:55	102
1406	SJC	SAN	15:15	16:30	102
1171	SAN	OAK	16:50	18:10	102
935	OAK	BUR	18:30	19:30	102
935	BUR	PHX	19:50	21:05	102
935	PHX	OKC	21:30	23:25	102

or set of planes, that couldn't handle the volume. So that was an easy problem to fix," Fred added.

In the simulation, a computer-generated manifest would redirect pieces of cargo that didn't fit on the originally scheduled flight. Bios Group also allowed some of the ramp agent models to invoke the "hot potato" strategy of loading the cargo onto the next plane, despite the manifest instructions. Bios Group then compared its simulation results to the observed measures.

An "Aha!" Experience

"I'm very happy to report that we had an 'Aha!' experience," Fred commented, "and that's probably why I'm speaking to you today." Bios Group had devised an algorithm to route the cargo, rather than using the manifest. When Fred and his team ran the algorithm, they dramatically reduced the amount of cargo being transferred, as well as the amount of cargo that was stored overnight.

Why was this happening? "Because," Fred revealed, "we discovered 'gold' in the schedule."

Consider a package that is brought to the airport in Albuquerque at 9 am for rush shipment to Oakland—meaning that it must arrive in Oakland within twenty-four hours. In 1998, the employee in the freight house would have looked at the schedule and seen that there was a flight that went from Albuquerque to Las Vegas, and from Las Vegas to San Francisco. And then there was a flight from San Francisco to Oakland. (See figure 1.)

But the freight agent was ignoring the route that specific plane flew. He was overlooking the fact that the original flight—the one from Albuquerque to Las Vegas, and from Las Vegas to San Francisco—eventually flew to Oakland as well. (See figure 2.) Therefore, by leaving the cargo on the plane and letting it ride down to San Jose, back to San Francisco, and then on to Oakland, the need to transfer that cargo from one plane to another would be eliminated.

The Benefits of Same-Plane Strategy

"It's true," Fred added, "that there are some cases where transfers are inevitable. In other words, there are no same-plane routes that actually connect certain cities." But by adapting the same-plane strategy, where possible, Bios Group saw the opportunity for Southwest to reduce both cargo transfers and overnight storage.

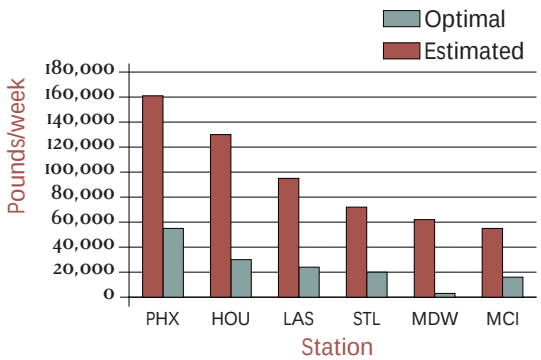
Figure 3 represents the historical data from the various Southwest stations, with regard to how much weight was transferred at each station, as well as the results Southwest could expect by adopting Bios Group's same-plane strategy. Phoenix, for example, could reduce the weight transferred at its station from 160,000 pounds per week to roughly 50,000 pounds per week. The stations are sorted by "who was feeling the most pain." Therefore, Fred pointed out, "we really had an impact on the guy who was hurting the most—Phoenix, Houston, Las Vegas, St. Louis, and so on."

Regarding the overnight transfer rate, approximately 240,000 pounds of cargo were stored overnight at Southwest, systemwide. Bios Group's optimal forecast for overnight transfer weight was just over 50,000 pounds per week. And with the same-plane strategy, the total weight handled dropped from about 3,250,000 to 2,500,000 pounds. (See figure 4a.)

Bios Group had two principal concerns: How would this same-plane strategy fare in Southwest's culture? And what impact would this strategy have on the airline's service levels? "This same-plane strategy was a bit of a problem culturally for Southwest, particularly for the ramp agents," Fred noted, "because they typically did not pay attention to things like the schedule." The same-plane approach was also counterintuitive to meeting service levels. By holding the cargo for a later plane, the ramp agents might worry that it would not arrive within the time frame promised.

But when Bios Group checked its model, it found that NFG service had actually improved. "Although we didn't go into detail to analyze this, I believe NFG improved because we weren't loading planes chock-a-block full just to get stuff off the ramp," Fred added. "By waiting for the planes that were going to the right places, we actually freed up more space for NFG packages to get there at the appointed time." While rush service did suffer by approximately 1 percent, the criterion for freight service was set at three days, which was acceptable. (See figure 4b.)

f. 3 Weight Transferred at Station



Real-World Results

"The dramatic reduction in overnight transfer will allow Southwest to cut back on our cargo storage facilities," Chuck commented, "which is a plus, because airport rent is pretty expensive." (See figure 4c.) In addition to requiring smaller overnight facilities, this reduction in overnight transfers calls for less manpower to bring cargo to the freight house at the end of the day, issue new manifests, and then transport the freight out to the airplanes again in the morning. Minimizing those wage costs is also an advantage to Southwest. And easing the burden of loading and unloading cargo is a real plus where the ramp agents are concerned.

"So what's happened?" Chuck asked. "First off, I didn't get fired for bringing scientists to Southwest Airlines—not yet, anyway. We have a low-tech, high-touch environment at Southwest, and it's pretty much heresy to talk about bringing scientists into this environment. But the folks at Bios Group have done a great job, and it's worked well."

The total weight handled by the ramp agents has been cut, thanks to the reduction in cargo transfer. Operations have become more efficient, without damaging Southwest's customer-service levels. Furthermore, by freeing up additional bin space, Southwest is able to offer more customers NFG or rush service, thereby selling customers higher service levels. "And that's a rather significant value proposition for us," Chuck added.

Southwest sent teams out to the Phoenix, Houston, Las Vegas, St. Louis, and Midway airports. These teams spent three weeks saturating each of those stations with the ins and outs of the same-plane strategy. "The teams helped the ramp and freight agents change the routing that they would normally select for the cargo, in addition to helping them with the operational side," Chuck said. "We've also had to work pretty hard with the mental side—the intuition—that says 'let's get this

cargo off the ramp,' where space is pretty tight, and 'I'll just throw it on the next plane.'"

Chuck reported that he had just received approval to roll this strategy out to twenty more airports. He also noted that Southwest is rolling out this strategy without automation support. "Because we have Y2K issues just like every other company, our systems folks have been pretty busy. So, we're not yet implementing the routing changes in our cargo point-of-sale system." Instead, Southwest's employees are working with a simple set of rules, spelled out in a three-page document, that tells them exactly how to route the cargo.

How is it working? Southwest has seen a reduction in its cargo transfer rate of 50 percent to 85 percent across its six busiest cargo stations. That translates to a decrease of roughly 15 to 20 percent in the workload for ramp agents moving cargo.

Rather than talking about this strategy solely in terms of averages, Chuck also provided specific numbers pulled from the St. Louis airport. "St. Louis is an interesting station," Chuck explained, "it has freight that's being transferred on the inbound side as well as creating transfers on the outbound side." At St. Louis, Southwest has experienced a 79 percent and 83 percent reduction in freight transfer, as measured in pieces and pounds, respectively. There has also been an 82 percent reduction in freight kept overnight.

And as Bios Group's simulation suggested, shipments on average, at all airports, are arriving earlier. "Evidently," Chuck commented, "that's because our previous routing schemes often resulted in cargo ending up where it wasn't supposed to be, which meant our ramp agents had to backtrack." In some cases, particularly NFG and rush shipments, cargo is arriving one to four hours earlier than it was with the pre-same-plane strategy.

What's more, Southwest had also been examining its material handling and overnight freight situation to see where improvements could be made. But because overnighting has been cut so dramatically, that focus group has been suspended.

In addition, with shipments arriving earlier, customers are seeing greater differences in Southwest's services levels—which has a key impact on the revenue-enhancement side.

Finally, Chuck reported, the key sponsors at Southwest are happy with the results. And now that Bios Group and Southwest have alleviated the frustration of the ramp and freight agents, the company can focus on growing the business.

An Intuitive Solution

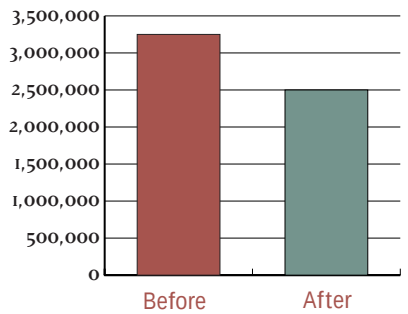
Chuck and Fred acknowledged that the same-plane strategy was an intuitive solution. So why hadn't someone at Southwest thought of it on his own?

"The truth is," Chuck remarked, "people had thought of it. They had come up with a range of possible solutions, but none of these solutions really caught on and worked their way through natural selection. We just didn't have enough data to come to a decision."

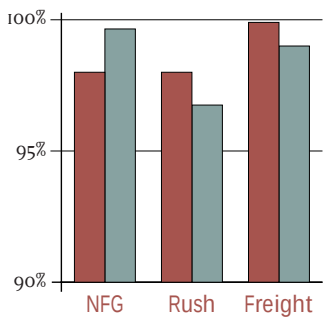
What Southwest was good at, Chuck explained, was knowing what worked at a particular station.

f. 4 The Results

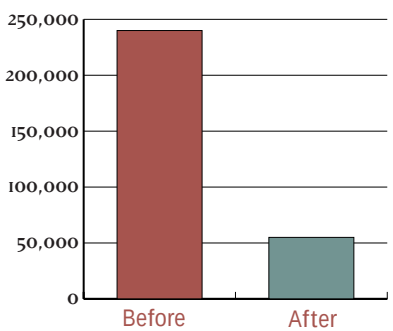
f. 4a Total Weight Handled



f. 4b % of Lots Delivered within Contract Requirements



f. 4c Overnight Transfer Weight



Bios Group's simulation provided Southwest with interconnectivity."We knew we could chase prairie dogs all day long by closing prairie dog holes. But every time you close one, two or more pop open. It was the network sense that we needed to arrive at an answer," Chuck explained.

"Well, I hate to think I'm a killer of prairie dogs," Fred remarked, "but I'm glad we could contribute to a workable solution."