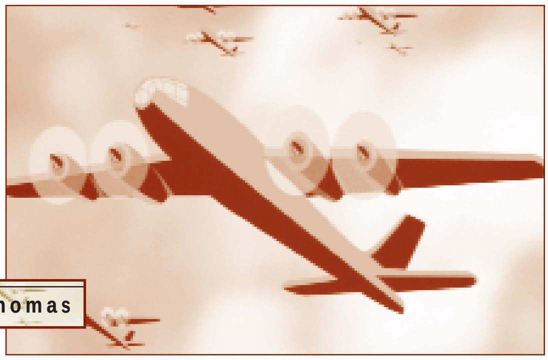
MANIFEST DESTINY:

ADAPTIVE CARGO ROUTING AT SOUTHWEST AIRLINES



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Southwest Airlines, as its passengers know, doesn't assign seating—and it never has. Admittedly, the idea was laughable when the airline first got off the ground in 1971, because Southwest was transporting only three or four people per flight. But even on its full planes today, there are no assigned seats. The company's reasoning? Speed and efficiency. Without seat assignments, Southwest can turn planes more quickly at the gates.

Dallas-based Southwest Airlines is known for many things: low fares, short-haul and high-frequency flights, legendary customer service, and—perhaps most of all—continuous innovations in efficiency. And the fifth-largest airline in the US applies this mantra of speed and efficiency not just to the transport of passengers, but to its cargo business as well.

Speedy as its cargo operations were, however, Southwest was encountering problems of congestion in some areas and excess capacity in others. With the assistance of Bios Group, located in Santa Fe, New Mexico, the airline analyzed its cargo handling system through a complex adaptive systems lens. This complexity science approach helped Southwest to make changes in its manifesting and loading strategies—a surprisingly intuitive solution that yielded dramatic results.

Re: Bin Space and Bottlenecks

Southwest had been scrutinizing its cargo business over the past six years, and the company's nagging suspicion was that this area of the business could be

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expanded. One of the key elements under examination was the airline's cargo capacity. Southwest's operational data suggested that, across the fifty-six airports it services, an average of 7 percent (by both weight and volume) of its bin space was full on any particular flight—a small percentage, considering that competitors were filling as much as 35 percent of the bellies of their aircraft.

A thorough field inspection revealed that bottlenecks existed throughout Southwest's cargo-routing and handling system. Many times, aircraft were scheduled to carry a large load of freight, but lacked the bin space to accommodate this volume. In more than a few cases, the company was taking aircraft departure delays to accommodate its cargo business—which was unheard of at Southwest, being fundamentally a passenger airline.

Furthermore, Southwest's ramp agents, the people who actually move the payload, were experiencing frustration. Focused as they were on speed, their approach to cargo was "I'll just throw it on the next plane and get it out of here." Because space on the cargo ramps is tight, and because the packages themselves specified only the final destination and not the intermediate stops, there was ample incentive and opportunity for the ramp agent to offload the cargo to someone else.

One station, therefore, would ship cargo down line to another station. The ramp agents who received that freight couldn't 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 someone else. This "hot potato" mind-set was particularly problematic at the airports that saw the heaviest cargo traffic, such as Phoenix, Houston, Las Vegas, and St. Louis.

Chasing Prairie Dogs

Southwest was determined to amend its cargo woes in three ways: by improving the work life of its ramp agents, tapping into unused bin space capacity, and growing the business and increasing its profit base.

In a style typical of the culture at Southwest Airlines, a brainstorming team was tasked with finding remedies to the cargo-routing problem. The team consisted of subject matter experts, ramp agents, and ramp supervisors who had a good feel for best practices at the different stations. In addition, the group established a temporary command center to monitor day-to-day problems with the movement of cargo and to experiment with a variety of approaches to specific problems.

Southwest's approach was likened to, as one team member described it, "chasing prairie dogs." The modus operandi of the team was to study the local problems the various stations experienced. From those local problems, the team would then extrapolate and devise a global solution, or a series of solutions, that would solve Southwest's cargo problems across the board. But as chasers of prairie dogs know, every time one prairie dog hole is closed off, another pops open.

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Southwest Airlines is known for innovations in efficiency. In order to make its cargo operation even speedier than it already was, the company adopted an idea from complexity science. Using a computer-based simulation with agents who represent decision makers, Southwest has tested the effects of simple changes in manifesting and loading strategies.

article abstract

Translation: no one solution seemed to cure all the problems at all the locations.

While Southwest excelled at knowing what worked at individual stations, what it needed was the big-picture view: network optimization. The airline considered bringing in network design specialists from other fields that experience similar network problems, such as the transportation or telecommunications industries. But, in a move that ran counter to its low-tech, high-touch culture, Southwest called on the complex adaptive systems expertise of the scientists at Bios Group.

Following the Rules

The initial solution Southwest proposed, and where it sought assistance from Bios Group, lay in the production of a simple "rulebook." This rulebook would sit on each freight agent's table and serve as a reference for directing freight away from heavily used stations to lightly loaded stations. With such a rule-book, Southwest hoped, freight agents could avoid the problems that Phoenix and Los Angeles International Airport (LAX), for example, were experiencing.

In generating this rulebook, the team relied on the rules of complexity theory: First, understand the behavior of the smallest elements, cells, or agents of an organism. Second, discover the properties of those cells that produce large-scale "emergent" behaviors in the organism.

Following these rules, the group created an agent-based model that reproduced Southwest's current operations through simulation. They collected historical data, which would calibrate the model and illustrate how Southwest was routing its cargo, as well as the problems that resulted. In this way, the team could use either the rules that were generated in the simulation or the rules they might discover, which would improve the model—and then apply those rules to a real-world situation.

Bios Group relied on data gleaned from shipment descriptions, flight schedules, and freight logs in creating this model. A record of the payload 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. (Southwest provides three levels of cargo service: "Next Flight Guaranteed,"(NFG) in which shipments are placed on the first available nonstop or direct flight out; "Priority Rush," which provides 24- to 48-hour service, depending on the distance covered; and "Freight," in which shipments are transported on a space-available basis and are not flight-specific). The team also had access to the flight manifests, which are instructions on how a particular piece of freight should reach its final destination, where it should be transferred from one flight to another, and so forth.

In addition, Bios Group was privy to Southwest's flight schedules: the airplanes' takeoff and landing times, their flight numbers, and their segments. Furthermore, they incorporated background data into the model. This background data, or the freight logs, showed how much of the bin space was actually available and how

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Figure 1

Rush Shipment: Albuquerque to Oakland—The Old Way

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

much was pre-loaded with baggage or mail. (Because baggage and mail take priority over cargo, an assumption was built into the model that some fraction of the space needed would already be occupied).

The objects in the system—namely, the shipments and the flights—were incorporated into the model. Freight forwarders and ramp agents were also modeled into the simulation, as were the actions of these agents: receiving a shipment, assigning a shipment to a flight, loading the plane, flying the segment, unloading the plane, transferring freight to the next plane, and moving cargo to the freight house.

Testing the Rules

In order to reveal manifesting strategies, the team used Southwest's actual manifests to calibrate the data. They then ran the network for a week, moving packages from one place to another. In addition to this hard data, Bios Group built anecdotal information about the ramp operators into the simulation to produce "probabilistics." (For example, one probabilistic was that an overworked ramp agent in Phoenix would simply load a piece of cargo onto the next plane without paying attention to the manifest).

To test the rules embedded in the simulation, the team generated the manifests and the ramp operations in the computer as well. The model was then run in three modes: the way Southwest thought it was handling its operations, the way Bios Group believed Southwest was working, and the way Bios Group thought the airline should run its cargo-loading operations.

What was measured?

- The amount of cargo handled at each station. A certain amount of cargo handling is unavoidable; cargo must be loaded and unloaded, but what can be avoided are the transfers in between.
- The volume of cargo that had to be stored overnight. For security reasons, freight held overnight must be kept under lock and key and then trucked back out to the aircraft in the morning.
- Whether or not the level of service for each package was met. That is, did the NFG packages, for instance, arrive as promised?

From the get-go, Bios Group experienced a few difficulties with the simulation when it 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 can only carry 2,000 pounds. It was clear that multiple people were manifesting cargo for a single plane, or set of planes, that couldn't handle the volume.

In the simulation, therefore, a computer-generated manifest redirected pieces of cargo that didn't fit on the originally scheduled flight. Bios Group also allowed some of the ramp agents in the model to invoke the "hot potato" strategy of loading the freight onto the next plane, despite the manifest instructions. Finally, Bios Group compared its simulation results to the observed measures.

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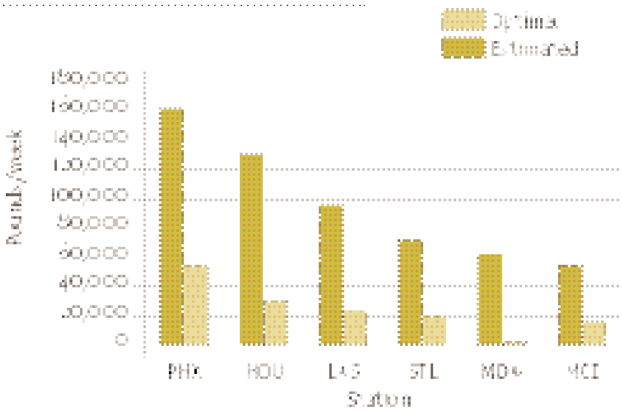
Figure 2

Weight Transferred at Station



Striking "Gold" in the Schedule

Rather than relying on the manifest alone, the team also devised an algorithm to route the cargo. When running this algorithm, the amount of cargo being transferred, as well as the amount of cargo being stored overnight, dropped dramatically. It was, as one Bios Group scientist remarked, akin to "striking gold in the schedule."

What was the "gold" that the schedule held? The flight *routes*.

Consider a package that is brought to the airport in Albuquerque at 9:00 a.m. for Priority Rush shipment to Oakland—meaning that it must arrive in Oakland within 24 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. 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.

Model Results

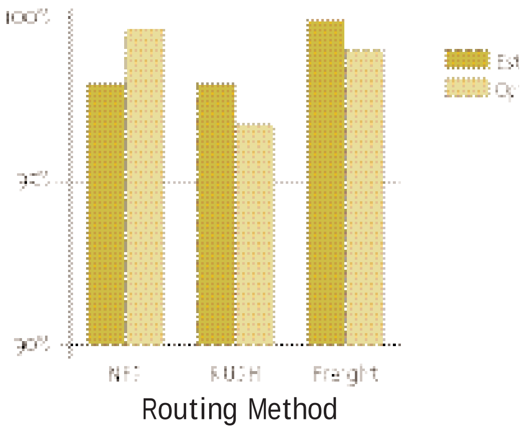
Because there are no same-plane routes that connect certain cities, some transfers are inevitable. But by adapting the same-plane strategy, where possible, Bios Group saw the opportunity for Southwest to reduce both cargo transfers and overnight storage. (See Figure 2.) For example, if Southwest were to adopt this strategy, Phoenix, which experiences the heaviest cargo traffic, could reduce the weight transferred at its station from 160,000 pounds per week to roughly 50,000 pounds per week.

System-wide, Southwest stored approximately 240,000 pounds of cargo overnight. Bios Group's optimal forecast for overnight transfer weight was just over 50,000 pounds per week. And the total weight handled dropped from about 3,250,000 pounds to 2,500,000 pounds.

While the model results were certainly promising, 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 did not jibe with the culture of speed at Southwest, especially for the ramp agents who previously had no need or incentive to consult the schedule. What's more, this same-plane approach was also counterintuitive to meeting service levels. By holding the cargo for a later plane, for instance, the ramp agents might worry that it would not arrive within the time frame promised.

Figure 3

Percentage of Lots Delivered Within Service Contract Requirements



But when Bios Group checked its model, it found that NFG service actually improved. Why? Although they didn't analyze this result in detail, the feeling was that NFG improved because the airplanes weren't being loaded, in the words of one Bios Group scientist, "chock-a-block" full. By waiting for the planes that were going to the right places, the model actually freed up more space for NFG packages and got them to their destinations by the appointed time. While Priority Rush service levels did decline by approximately 1 percent, the criterion for freight service was set at three days, which was acceptable. (See Figure 3.)

Real-World Results

To implement this same-plane strategy, Southwest sent teams out to the Phoenix, Houston, Las Vegas, St. Louis, Midway, and Kansas City airports. These teams spent three weeks saturating each of those stations with the ins and outs of the same-plane strategy—from helping the ramp and freight agents change the routing they would normally select, to fighting the intuitive response of "let's just get this cargo off the ramp."

Southwest is now rolling out this strategy to twenty more airports, without the luxury of automation support. Because Southwest has Y2K issues (much like every other company at this stage in the millennium), the company's systems personnel have not been free to automate these changes. Instead, Southwest's employees are working from the rulebook the company initially proposed: a simple set of rules, spelled out in a three-page document that tells them exactly how to route the cargo.

How is the same-plane strategy working in the real world? Southwest has seen a decline in its freight transfer rate of 50 percent to 85 percent across its six busiest cargo stations. That translates to a decrease of roughly 15 percent to 20 percent in the workload for the ramp agents moving cargo. In line with this decrease in workload, the total weight handled has also dropped, easing both the burden and the frustration of the ramp agents.

A dramatic reduction in overnight transfer has allowed Southwest to cut back on its cargo storage facilities, freeing up dollars that previously went toward renting expensive airport space. 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.

What's more, Southwest had 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.

Operations have become more efficient, without damaging Southwest's customer-service levels. As Bios Group's simulation suggested, shipments at all airports are arriving earlier. This improved efficiency is due, in part, to the elimination of offloading (when

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ramp agents simply shipped cargo down the line, regardless of its destination) and the resultant backtracking this offloading practice induced.

In some cases, particularly NFG and Priority Rush shipments, cargo is arriving one to four hours earlier than it was with Southwest's previous mode of operation. With shipments arriving earlier, customers are seeing greater differences in the airline's service levels, which has a key impact on revenue enhancement for Southwest. And by freeing up additional bin space (by waiting to load the cargo onto the appropriate planes), Southwest is able to offer more customers NFG or Priority Rush service, thereby selling customers higher service levels.

Needless to say, the key sponsors at Southwest are very pleased with the results.

An Intuitive Solution, in Hindsight

Given the networked nature of the transport system itself, coupled with the unpredictable nature of delivery capability, Southwest needed a big-picture view to solve its cargo-routing problem. Bios Group's agent-based model discovered rules of behavior, specific to the airline's manifesting and loading strategies, that could vastly improve Southwest's cargo handling operation—and recommended a solution that seems remarkably intuitive in hindsight.

And intuitive it was. In their brainstorming sessions, Southwest personnel had actually suggested the same-plane approach as a possible remedy to their cargo woes. Without a high-altitude view, however, it was unclear whether proposed solutions would correct the problem for Southwest's entire cargo-routing network, or if they would only serve to seal off, if you will, one or two prairie dog holes.

In the end, Bios Group's discovery of the same-plane strategy, combined with a simple three-page rulebook, has provided Southwest Airlines with a network-optimization solution that alleviates the frustration of its ramp and freight agents. This gives Southwest clearance to focus on steps two and three: tapping into unused bin capacity and growing the business.

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