Proceedings of the 1992 Winter Simulation Conference
ed. J. J. Swain, D. Goldsman, R. C. Crain, and J. R. Wilson

SIMULATING THE AIR MOBILITY COMMAND CHANNEL CARGO SYSTEM

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ABSTRACT

Air Mobility Command takes a businesslike approach to providing day-to-day airlift of high-priority cargo to users around the world. Analysis of the task includes a linear programming model for developing routes and assigning aircraft. Simulation analysis of the linear programming results assures a schedule that balances dual goals of efficient use of planes and timeliness of delivery. This two-phased approach has been used successfully in a number of analyses.

1 BACKGROUND

Air Mobility Command (AMC) provides air transportation of high-priority goods and personnel for customers around the world. These customers include the State Department as well as the DoD at over 200 locations. One aspect of this mission is regularly scheduled "channel" service. A channel consists of two locations that have a validated requirement for exchange of goods or personnel on a regular basis. At present there are some 435 validated channels. These channels may be serviced by commercial carriers under contract to AMC or by organic military aircraft such as the C-141, C-5, C-130, or the KC-10.

In 1991 AMC moved over 250,000 tons of cargo and 1.5 million passengers through the channel system. These numbers, though large, represent significant decreases over previous years as overseas military

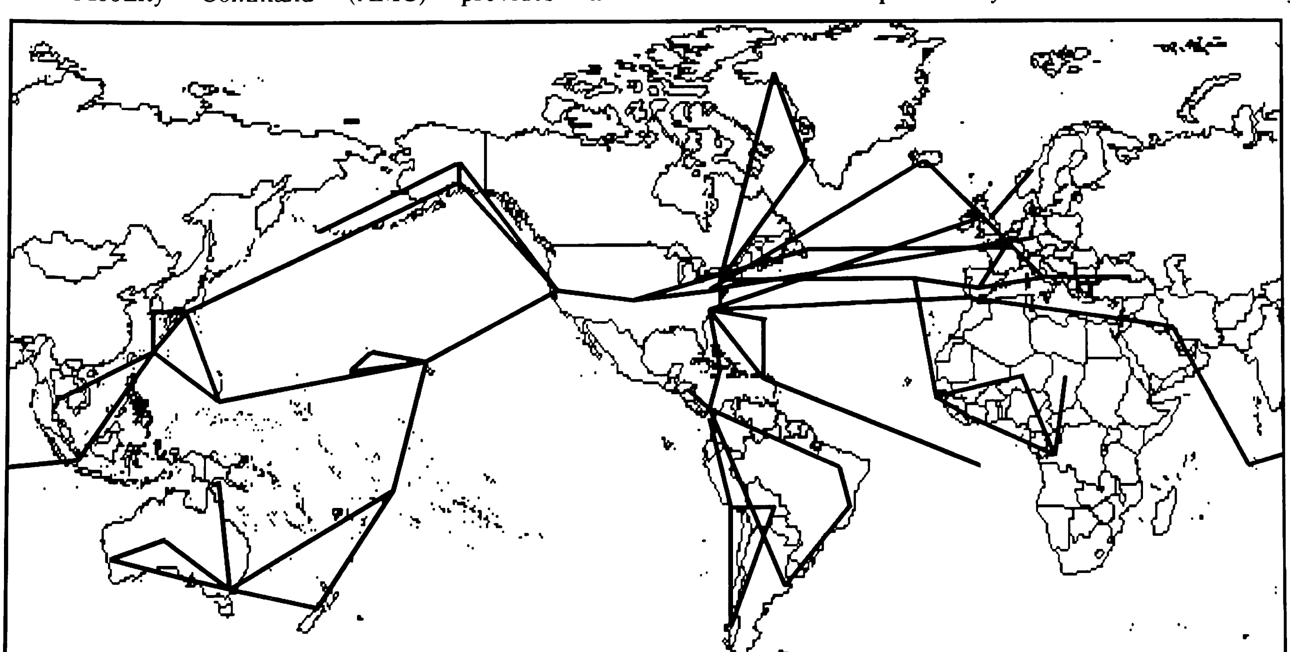

Figure 1: Air Mobility Command Channel System

forces decline. The channel system provides an important connection to these customers as well as providing valuable training to the military aircrews who fly most of the missions. Figure 1 gives some idea of the scope of the locations served by the channel system.

Channel requirements are not served by point-to-point connections, but rather are imbedded in a system of routes which serve many channels simultaneously. Efficient use of the transportation resource precludes direct connections between locations. Two of the conflicting goals are the need to fully utilize the planes and the need to serve the customers on a frequent basis to give them timely movement of goods and personnel. The simulation model described here is one tool in balancing the goals of utilization and timeliness.

2 MODEL INPUTS

The channel simulation model (CARGOSIM) is written in SIMSCRIPT II.5 as a discrete event model. The significant inputs to the model are shown in Figure 2. The route structure typically comes from a proposed schedule developed by operations personnel, or from the output of a linear prorgramming model which defines a minimum cost set of missions to move all of the channel cargo.

The linear programming model does not explicitly model timeliness of cargo delivery, however. Consequently, it may shortchange customer service to reduce costs. Additionally, the LP may find peculiar ways to route cargo which would delay cargo delivery unacceptably. CARGOSIM is used as the sanity check on the linear programming model recommendations regarding a set of missions.

Flying times for the routes can be obtained from great circle distance computations but are more typically obtained by accessing a database of previously recorded flying times. The advantage of the database is that factors such as winds and circuitous routing are implicitly accounted for.

Cargo generation is driven by the same data used in the linear programming model. The cargo generation process is modeled as a time dependent Poisson process to reflect the fact that cargo does not generate uniformly throughout the week. Cargo generation is light in the beginning of the week and peaks slightly after mid-week as shown in Figure 3.

Routes and transshipment points where cargo may be exchanged between planes are well established in the real system. Transshipments serve as a means of increasing the utilization of routes and airplanes. The linear programming solution contains routing information which specifies transshipment points for certain channels, e.g. cargo shipping from Dover, Delaware to Adana, Turkey would transship at Frankfurt, Germany. Here again, the simulation is used

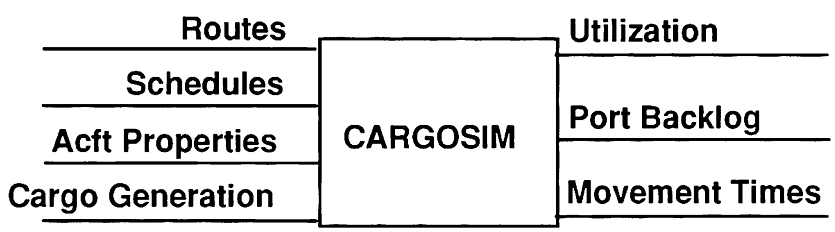

Figure 2: Model Inputs and Outputs

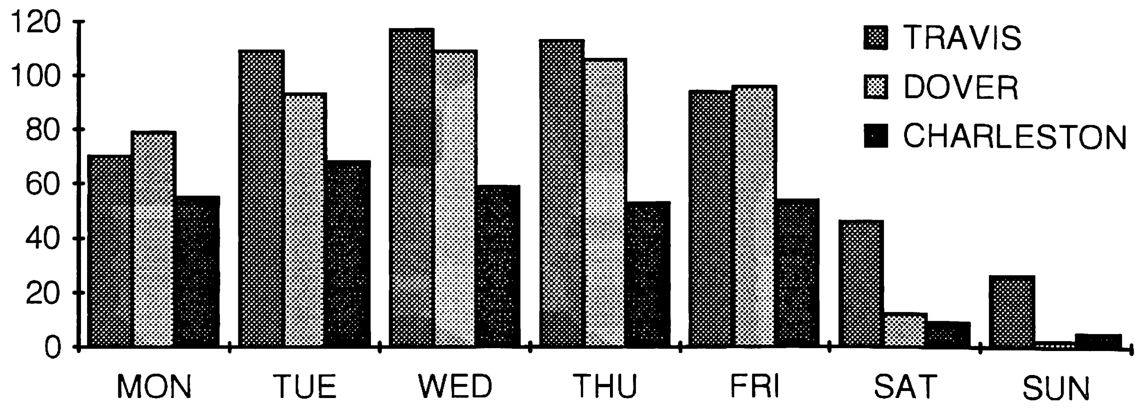

Figure 3: Cargo Generation Patterns

to test the effect of the recommendations.

Plane availability and characteristics (capacity, speed, ground time) are the final input. There are various ways of moving the planes through the system. In one version, crews are positioned at intermediate stops so that the plane can keep moving while crews are changed and minimal ground time is incurred. In the other alternative the plane and crew rest together. In this case considerably more time is expended in completing a route--a week or more in many cases. During Desert Storm when planes and crews were at a premium, decisions on staging channel missions were critical to other operations.

3 MODEL OPERATION

The model operates to keep control of two flows--planes and cargo. The flow of planes is controlled by the routes and schedules. Cargo generation is regulated by channel with a specified pattern for each pair that forms a channel. A warehouse bin is created to store the cargo for each channel.

After the model reads in the list of routes and channels, a connection is made between the two flows. Each route is given a list of all the channel pairs it can serve at each of its stops. As a plane moves along a route it simply polls this list of pairs at each stop.

4 MODEL OUTPUTS

To measure a schedule against the criteria of efficiency and customer support the model reports the utilization of the planes and routes along with cargo movement times and backlogs. A small sample of the statistical output is shown in Table 1. Dover AFB, Delaware (KDOV) is the largest of the aerial ports in the continental United States (CONUS). The channel between Dover and Frankfurt AB, Germany (EDAF) is the largest in the system in terms of tonnage. It is usually easy to obtain acceptable waiting times, travel times, and small backlogs because the flow is so heavy and steady. Although the backlog is the largest shown, 41 tons would not fill a single large airlifter like the C-5 (50-60 tons) or a B-747 (about 70 tons).

The Dover to Cairo, Egypt (HECA) channel, on the other hand, shows a waiting time of nearly eight days reflecting the fact that the load is light and the channel is driven by requirements. Until sufficient cargo builds up, no flight needs to be made. By contrast, the channel from Norfolk, VA (KNGU) to Sigonella, Italy (LICZ) is a frequency channel. There is a validated requirement to go between these two

Table 1: Illustrative Model Output

Channel Performance by Origin Destination Pair

CHANNEL NAME	Waiting Time Mean	Waiting Time Var	Travel Time Mean	Travel Time Var	Channel Backlog
KDOV-EDAF	1.56	.41	.35	.00	41
KDOV-HECA	7.74	7.01	1.25	.00	12
KNGU-LICZ	2.51	.83	1.26	.01	7
KTIK-RJTY	1.94	1.18	1.69	.56	1
KTIK-PGUA	1.59	.57	2.18	.00	0
KTIK-EDAF	2.42	2.20	.76	.15	20

Route and First Leg Utilization

1st Leg	Route	Route Description
.962	.823	KDOV EDAR HECA EDAR KDOV
.754	.438	KSUU KTIK KDOV EDAF KDOV KTIK KSUU
1.000	.763	KSUU PAED RJTY PGUA PHIK KSUU
.385	.239	KNGU LERT LICZ LEZA LICZ LERT KNGU

Aircraft Utilization by Plane Type

Aircraft Type	Utilization
C-5	.7023
C-141	.5707
C-130	.3709
DC-8	.7293
B-747	.8035

points twelve times per month regardless of the cargo tonnage. So although the tonnage is also light for this channel the waiting time is much better. The LP model and the simulation make use of the KNGU-LICZ frequency to haul other cargo headed in that direction, of course.

Tinker AFB, OK (KTIK) is a mid-continent aerial port which can accept eastbound and westbound cargo. Three channels are shown: to Yokota AB, Japan (RJTY), to Guam AB (PGUA), and to Frankfurt AB, Germany (EDAF). The relatively large travel times westbound from Tinker reflect the fact that cargo must transship at Travis AFB, CA and may also transship at Hickam AFB, HI. In this case the cargo will get off and wait for another plane to come along thus increasing travel time. The transshipment does insure better use of the airlift resource however. Eastbound cargo need not transship as often, and hence has lower travel time.

Route utilization is a time-weighted average of cargo carried divided by plane capacity over an entire route. A separate statistic is provided for average utilization on the first leg outbound. Time-weighted averaging highlights long, underutilized legs for further study. The statistics are of interest for revenue considerations since one objective is to have the planes fly full. It is much simpler to achieve good utilization over the first leg than over the entire route. One benefit of the linear programming approach to recommending routes is in improving utilization over the entire route. Hence the simulation provides separate statistics for the first leg and the entire route.

Although an extreme example is shown here, the route from Norfolk, VA to Rota Spain (LERT) and on to Sigonella (LICZ) is basically satisfying several frequency requirements. Its utilization is significantly worse than the other routes but would be poorer if the frequencies were serviced with individual routes.

A direct measure of plane utilization by type is also reported. This represents a time-weighted average over all the routes flown by a particular aircraft type. Commercial as well as military aircraft are examined. These statistics highlight underutilization of planes due to the types of routes they are assigned to. For instance, the C-5 and B-747 provide enormous capacity and tend to be used over main trunk routes in an out-and-back fashion. They typically have good utilization because of this..

Smaller aircraft fly more complicated routes where it can be difficult to achieve high utilization. They move farther out into the system and as they go they drop off cargo decreasing their load. There is typically a net outflow of cargo from CONUS which means that the planes become progressively more empty. Simulation of the linear programming recommendations helps determine whether goals for utilization of aircraft are realistic in light of cargo movement patterns.

5 SAMPLE ANALYSIS

The focus of one recent analysis was the restructuring of the European channel system after the drawdown of military forces following the Gulf War. During the war, much of what had once been American forces in Europe were transported to the Middle East. These forces were not returned to Europe after the war, but instead were brought home due to the diminished Communist threat in Europe. At that time, the current channel cargo system was still designed to supply a large standing force in Europe.

The route structures of three different proposals were compared. The first of these, RS1 (route structure #1), was the current structure designed to support large forces in Europe. The second structure, RS2, was developed by the Directorate of Operations, Cargo Management Division. The final structure, RS3, was developed within the Command Analysis Group using linear programming.

With total cost as the only measure of merit, RS3 was the clear choice with RS2 splitting the difference between RS3 and RS1. Although cost is important, the prime objective of the channel cargo system is satisfactory customer service with the most efficient airlift operations. The CARGOSIM channel simulation was used to determine the degree of service each proposal afforded.

The simulation proved all three proposals met the basic requirements of moving all of the cargo and meeting all of the validated frequencies. The first notable difference was in the utilization of the planes and the routes. RS1 proved to be the least efficient in this respect. RS2 had a high degree of first leg utilization but a lesser degree of overall route utilization. RS3 had the best overall route and plane utilization.

Table 2 shows one route utilization example of the difference between RS2 and RS3. RS3 chose to use ten total C141 missions instead of RS2's eight C141 and two C5 missions. This alone is a cost savings because the C5 is roughly two times more expensive to fly than the C141. There is more cargo for Thule than Sondestrom, therefore the linear program chose to fly this relatively short direct route to Thule more often with a C141 and save the C5 flying hours for some other better utilized route.

The best measure of merit for determining customer satisfaction is the speed of service or the length of time each piece of cargo spends in the channel system. The users of the airlift system have all agreed to a set of time standards called the Uniform Material Movement and Issue Priority System (UMMIPS) standards. These standards are the maximum acceptable time a piece of cargo should be in the channel airlift system. These standards are set to assure cargo not moving over a validated frequency still moves in a timely manner (instead of having it sit in a warehouse until enough cargo to fill a plane exists). The longer the distance or more remote the destination is, the longer the time standard.

Comparing these UMMIPS standards to the simulation output was the final task of this analysis. Summing the waiting and travel times of a specific channel pair gives a suitable number to make the UMMIPS comparison. Both RS1 and RS2 did better than or met the set standards. RS3, which up to now was the most efficient proposal, met a large percentage of the standards but failed to meet standards for some of the more remote or distant locations. Table 2 shows a comparison between RS1 and RS3. Note that RS1 meets the standard for all pairs. RS3 closely meets the standards for the first four pairs but exceeds the maximum time standard for the last pair.

The final route structure proposed and later implemented was a compromise between the Cargo Management Division proposal, RS2, and the Analysis Group proposal, RS3. This compromise proposal took into account all political constraints and UMMIPS constraints not modeled in the Analysis Group proposal. Overall the savings to the worldwide channel system was roughly 6.8 million dollars per month over the previous route structure.

6 OBSERVATIONS

Simulation of the linear programming results enhances the credibility of our analysis and frequently points out weaknesses in the routes suggested by the linear programming model. CARGOSIM looks at timeliness of delivery and takes account of the cargo generation patterns. The LP model cannot do this. The simulation also provides detailed information on channel performance, plane and route utilization, and potential backlogs that is important to decision makers.

A further modeling effort is in progress now which will connect the LP model and the simulation

Table 2: Route Structure Comparisons

Route and First Leg Utilization

	1st Leg	Route	Route Description	
RS2				
	.924	.548	KWRI BGSF BGTL KWRI	(8 times w/C141)
	.477	.245	KWRI BGTL KWRI	(2 times w/C5)
RS3				
	.962	.621	KWRI BGSF BGTL KWRI	(4 times w/C141)
	.935	.536	KWRI BGTL KWRI	(6 times w/C141)

KWRI = McGuire AFB, NJ BGSF = Sondestrom, Greenland
BGTL= Thule, Greenland

Performance for Channels Originating at KDOV

CHANNEL NAME	Waiting Time		Travel Time		UMMIPS
	RS2	RS3	RS2	RS3	
KDOV-EDAR	1.47	2.03	.52	.35	3 days
KDOV-EDAF	.98	1.56	.35	.35	3 days
KDOV-LETO	1.80	3.05	.51	.32	4 days
KDOV-LTAG	2.22	1.40	1.29	2.39	4 days
KDOV-OJAF	5.38	8.44	1.45	1.30	7 days

KDOV = Dover AFB, DE EDAR = Ramstein, Germany
EDAF = Frankfurt, Germany LETO = Madrid, Spain
LTAD = Adana, Turkey OJAF = Amman, Jordan

more directly. Part one is to develop a scheduling heuristic to accept the routes and the cargo generation pattern from the LP and convert these directly into a schedule for CARGOSIM. That scheduling process is currently done manually. Part two is to develop a mechanism to adjust schedules in response to unexpected cargo generation--much like the operators of the real system. Currently the model is capable of delaying missions when cargo generation is unexpectedly light. Ideally, the model will become adept at cancelling or adding new missions. This will enable us to test policies regarding backlogs and UMMIPS standards.

AUTHOR BIOGRAPHIES

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