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Cargo Logistics Airlift Systems Study (CLASS)

Volume 5. Summary

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Langley Research Center
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CARGO/LOGISTICS AIRLIFT SYSTEMS STUDY (CLASS)

VOLUME V – SUMMARY

JULY 1980

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Prepared under Contract No NAS1-14948 by
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for

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INTRODUCTION

The air cargo industry is presently in its infancy with the largest growth yet to come. During this future growth there will be many institutional, operational and equipment changes. To bring about these changes intelligently and effectively will require long range analysis and planning that is more advanced and more comprehensive than anything that has been done in the past. The NASA CLASS represents the initial assult on these future oriented efforts.

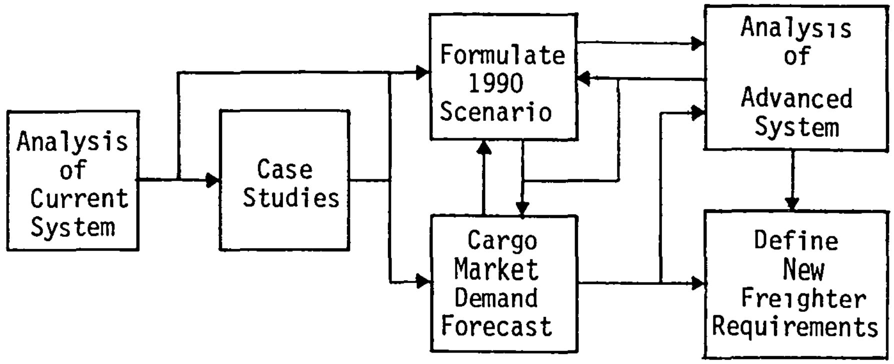
The basic Douglas CLASS was begun in June 1977 and completed in May 1978. A follow-on effort, directed to the definition of freighter aircraft requirements to the year 2008, was initiated in October of 1978 and completed in August 1979. It can be noted here that the air cargo industry was deregulated during 1977. The impact of this legislation is not reported in detail in the CLASS reports, discussions are generally maintained as written prior to the legislation. This approach was taken due to the short observation time available during the contract.

This volume of the Douglas CLASS final report briefly summarizes the 1700 pages of findings and conclusions derived during the total study as reported in the following four volumes:

- Volume I - Analysis of Current Air Cargo Systems, NASA CR158912
- Volume II - Case Study Approach and Results, NASA CR158913
- Volume III (2 Books) - Cross Impact Between the 1990 Market and the Air Physical Distribution Systems, NASA CR158914
- Volume IV - Future Requirements of Dedicated Freighter Aircraft to Year 2008, NASA CR158950

These results represent the stepping off point for the much needed coordinated future planning efforts by government agencies, the airlines, the users and the aircraft manufacturers.

The methodology utilized in the investigations is schematically shown in the following diagram. The analysis of the current system encompassed evaluations of the past and current cargo markets and on-sight surveys of airports and cargo terminals. The findings that resulted provided the basis for formulating the case study procedures, developing the future scenario, and developing the future cargo market demand.



Rather than assume a scenario, as often done, it was developed during the course of the investigations making full use of the findings derived from the case studies, the market forecasting effort and the advanced system analysis. The latter encompassed the identification and evaluation of the interrelations between system development and cargo market growth. The resulting market demand along with the future air cargo infrastructure characteristics and requirements were then utilized in developing the requirements for future freighter aircraft.

Contents of this volume are categorized under five sections. The multiplicity of subjects encompassed in each of these sections are discussed in terms of the past, present and future, thus providing a sequental view of past performance and alternatives for the future. These alternatives represent possible courses of action that have the potential to improve system effectiveness, decrease costs, and increase the air cargo market demand. These courses of action were derived with due consideration for the influencing political, economic, physical and competitive factors along with the desires and requirements of the air cargo user as identified in the case studies. It should be noted that the CLASS concentrated on all-cargo aircraft, their operation and associated infrastructure.

The Douglas Aircraft Company is pleased to acknowledge the excellent contributions made to this study by personnel of the Flying Tiger Line that participated as the subcontractor on specific study tasks. In addition, appreciation is expressed to the NASA contract monitor Lt. Col. John Vaughn, Retired, for his keen interest and support during the course of the contract.

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FINDINGS AND CONCLUSIONS

As the future unfolds it will be necessary to adjust our cargo operations and to progressively tailor its infrastructure and aircraft to the growing cargo demand as affected by changes in the total environment. From the volumes of data and results developed in the CLASS the following items were selected as appropriate signposts for directed progress.

Current Findings

- U.S. Domestic freight is dominated by the trucking industry due not only to their lower tariffs but also to level of service they provide.
- The major portion of domestic freight movement is intraregional and is carried by surface transport over average hauls of about 450 kilometers (279.7 statute miles) for trucks. Only 0.3 percent of the interregional movement is by air.
- There are large quantities of commodities moving by sea whose product value indicates that they are air eligible.
- There will be few surprises in the future products shipped by air with little change in the average warehouse density of high value bulk or processed goods. Commodities in the top 20 shipped by air will shift with a continued increase in the percent of manufactured goods making up the total freight movement. In constant dollars, the value threshold (dollars/kilogram) of air eligibility will decrease.
- While airfreight is currently a small shipment industry the airlines must cultivate large shipments on a regular basis to realize their growth expectations.
- Most of todays major airports are incompatible with wing span, fuselage length, and flotation characteristics larger than the B747F and are limited in expansion due to environmental constraints and/or land availability.
- The changes in market demand that can result from a +10 percent change in casual variables were determined as follows.

Casual Variables	Change in Market Demand (%)
GNP	22
Air Cargo Tariffs	-13
Delivery Time	-3
Cities Served	1.5
Truck Tariffs	1

- Operating at 70 to 80 percent capacity and constrained in expansion by land available, most air cargo terminals will require increased mechanization and containerization, and revised handling procedures to meet the 1990 flow levels. These improvements will also reduce the air terminal costs which are currently three times those for truck terminals.

- Due to the wide variation in package size and weight, fully automated sorting will remain uneconomical for some time into the future.

Users Desires

- Service is the prime consideration for using air cargo followed by cost. The concensus among shippers indicated that a 30 percent reduction in air tariffs would not in itself cause them to increase their use of air cargo. Similarly, ability to self load containers would not increase their use of airfreight.

- The choice between air and surface modes is made on the basis of total service. Shippers felt that the biggest airfreight problems are those associated with ground support handling (airport congestion, pickup and delivery, operational procedures, customer service, etc.) rather than the airport-to-airport segment.

- Mode choice should consider the cost/benefit tradeoffs in the framework of the shipper's total production system. The analysis must consider both the qualatative and quantitative factors since the former can identify potential benefits that are becoming increasingly important in todays competitive markets.

- Shippers consider door-to-door single carrier responsibility, single tariffs, and intermodal capability to be necessary elements in the future transportation system. The number of forwarders will decrease and the survivors will increase their scope of operation to provide worldwide forwarding services. Shippers were in favor of the airlines performing this service.

- There is need for the airlines and forwarders to educate shippers on the total distribution concept in a manner that does not appear self-serving.

Near Future - The 80's

- The future development of the air cargo industry, its operations, infrastructure and equipment could be more seriously handicapped by institutional road blocks than by technology.

- The average annual compounded growth rates for the all-cargo aircraft portions of the air cargo market are forecast to be 8.6 percent for U.S. Domestic, 7.9 percent for U.S. International and 12 percent for the Foreign market during the period 1978 through 2008. The combined growth rate for the three markets is 10.7 percent.

- The U.S. Domestic air cargo demand will have its largest growth in the South and Southwest. The largest international growth will occur in the underdeveloped regions, primarily South America, West-Central Africa, parts of the Middle East, and the Far East including mainland China. Foreign airlines will capture the major portion of the growth in these regions.

- While fuel cost and availability will be among the determining factors in future air cargo system growth their impact on intermodal competitiveness cannot be viewed in isolation but must be considered relative to concurrent changes in technology, wages and the availability and cost of money, and the relative intensities of these costs within the respective modes.

- As we proceed toward the turn of the century the competitiveness of air will increase relative to trucks and ships but decrease relative to rail.

- Construction of new metropolitan airports during the 80's is unlikely. Many major hubs will encounter runway saturation although this can be delayed by the installation of advanced air traffic control systems.

- There will be a proliferation of curfews and operators will encounter increasing airside delays due to flow control and night operating restrictions.

- System congestion may be relieved by increasing the number of direct flights; developing many small hubs in preference to a few super hubs; establishing cargo operations at general aviation airports, utilizing surplus military bases and/or through joint use of military airports.

- Customer loaded containers (CLC's) and/or off airport consolidation is the most effective means of increasing airport terminal productivity and decreasing costs.

- A point of diminishing returns on manpower reduction is reached once the terminals' functional operations are mechanized, however, additional mechanization will increase terminal capacity.

- Multiple level storage and queuing, utilizing current technology and elevating transport vehicles, combined with 90 percent CLC's and a reduction of the average import storage time from 3 to 1½ days, can reduce manpower and terminal equipment costs by 65 and 35 percent respectively.

- The progressive development of terminals and aircraft will culminate in mechanized 2.4x2.4x6 meter (8x8x20 foot) M2 container terminals. Encompassing computerized document management these terminals will be cost effective on a weight flow basis.

- The growing use of containers and intermodal operations will stimulate new container designs, including modular configurations for inter and intraline transfer, that eliminate the slave pallet and in addition provide 30 percent reductions in cost and tare weight compared to current maritime intermodal containers.

- The increased volume and selectivity of shipments associated with the growing market demand will facilitate increasing container volumetric utilization from the current average 54 percent to 85 to 90 percent and will also increase aircraft load factors from current 65 to 70 percent. The latter can reduce direct operating cost (DOC) by at least 7 percent.

- The hub-spoke concept has the potential to substantially reduce, or eliminate, the current backhaul problems in international operations. Acceptance of this concept would place increased emphasis on larger aircraft and all-cargo airports, however, these approaches will be handicapped by institutional barriers.

- Future terminal and on-board aircraft systems will provide intermixed handling of air and maritime containers with a substantial reduction in loading manpower.

- Improvements in ground handling operations and equipment combined with increasing fuel cost will substantially reduce the importance of indirect operating costs (IOC) as an element of the total operating cost (TOC) thus placing increasing emphasis on aircraft technology and utilization.

- The investment related components (depreciation and insurance) of the aircraft DOC have the potential to offset the cost reductions realized from advanced technology.

- A modified air cargo system incorporating improved mechanized terminals with reduced storage time; 90 percent shipper-loaded containers; and an advanced technology freighter operating at 70 percent load factor and with improved airport compatibility; could realize a 21 to 24 percent reduction in tariffs and a four percent increase in airline profits after 10 years of operation. At the end of this period the new freighter would be handling about 45 percent of the cargo market demand.

- The reductions in TOC achieved by infrastructure improvements utilizing 1980 technology are as important as the reductions achievable with 1990 aircraft technology.

- The future trend will be toward tariff stability while improving the return on investment and increasing profit. Incentive tariffs will be employed to increase CLC's, container/volumetric utilization, and aircraft load factors.

- In the absence of new, more efficient, derivative aircraft the number of current, small narrow-body aircraft (DC-9F, B737F) could increase 20 percent before phasing out in the early 80's. The number of large narrow-body aircraft (DC-8F, B707F) could increase 60 percent reaching a maximum in the mid 80's, however, a portion of this demand is being met by DC-10 and B747 combi-aircraft. The number of large wide-body aircraft (B747F, DC-10F) could increase to 400 units by 1992 with fleet operations (trips) increasing at an average annual rate of about 7 percent.

- The combined development of short and long range, 3219 and 7025 kilometers (2000 and 4365 statute miles) respectively, improved technology derivative cargo aircraft would be economically desirable for the post 1985 time period. With payloads in the range of 91 to 149.7 tonnes (100 to 165 tons) these derivative aircraft would increase the airline return on investment (ROI) four percentage points and reduce the airlines required investment 20 percent relative to a comparable fleet of current aircraft. 386 of these aircraft would be reqired by 1998. The number of current wide-bodies would increase to about 150 units before beginning to be replaced by the derivatives in late 80's.

- In the presence of two or more aircraft manufacturers a considerable number of passenger versions of the derivative aircraft would have to be sold to realize a reasonable ROI for the manufacturers, a necessary condition to the initiation of a dedicated freighter program for the post-1995 time period.

- The exterior dimensions of the conventionally configured 149.7 tonne (165 ton) payload aircraft are near the limiting values compatible with current hub airports. However, these larger derivative aircraft could contain the fleet average annual frequency growth to 4 percent compared to 6.4 percent for the fleet of current aircraft.

Far Future - The 90's and Beyond

- The lower investment related costs of the derivative aircraft tended to negate the cost benefits of the 1990 technology in the dedicated freighter. This behavior, in combination with the lack of a passenger version, forced the preferred dedicated freighter to smaller payloads in order to increase the production run and thus reduce the unit price.

- With one manufacturer the economically preferred long range, 68 tonne (75 ton) payload dedicated freighter was clearly desirable increasing the airline ROI four percentage points and reducing the airline investment by 18 percent compared to the reference fleet of current and derivative aircraft. However, for the more realistic case of two manufacturers these economic improvements were reduced by a factor of four thus placing the dedicated freighter in a position of questionable economic value.

- Based upon two manufacturers each realizing a 15 percent ROI, the economically preferred dedicated freighter program for the post 1995 time period was a combination of short and long range aircraft having payloads of 45.4 tonne (50 ton) and 68.0 tonne (75 ton) respectively. The value of this program was considered marginal since it increased the airline ROI only two percentage points and decreased their investment by 7 percent relative to the reference fleet of current and derivative aircraft. Increasing the payload size resulted in a further degradation of the airline economics.

- The number of economically preferred 45.4 and 68.0 tonne (50 ton and 75 ton) payload dedicated freighters increased to 949 short range and 623 long range units by the year 2008. The result was a fleet annual frequency growth rate of 12.6 percent, nearly twice that of the reference fleet of current and derivative aircraft. This increase in operations is considered a disadvantage since it could provide a serious conflict with projected airport capacities.

- Following introduction of the dedicated freighters in 1995 the number of derivatives would remain at about 248 units until the late 90's when they would begin being replaced.

- With a cargo market demand less than forecast the derivative and dedicated aircraft would be less competitive against the current wide-bodies and the undesirable economic effects would be greater with the dedicated freighter in the fleet.

- Considering the economic performance of the dedicated freighter program it is clear that manufacturers would be reluctant to initiate its development (in preference to a program of continued improvement of the derivative aircraft) unless stimulated by the civil passenger or military airlift sectors and/or by partial subsidy of the research, development and testing (RD&T) costs.

- Fifty percent subsidy of the RD&T costs for the dedicated freighter program could increase the resulting airline ROI by 5 percentage points and decrease the airline investment 30 percent. Such subsidy would make the dedicated freighter program economically feasible for payloads well above the aircraft size limitations imposed by major existing airports.

- The analysis of RD&T subsidy indicated that the underlying economics may have sufficient latitude to accommodate some degradations in weight and/or performance imposed by military requirements when compared to a commercial freighter without subsidy.

- Although not economically sized, competitive economic analysis of non-conventional aircraft configurations showed that a 235.8 tonne (260 ton) payload Spanloader (minimum size to be competitive with conventional configurations) and a 149.7 tonne (165 ton) payload M=0.7 Propfan have the potential to economically compete with the reference fleet of current and derivative aircraft. Although both configurations encompass characteristics that could conflict with airport/airways operations they should be given further consideration for the post 1995 time period. The M=0.8 Propfan and the laminar flow control (LFC) aircraft were considered economically undesirable based upon the configurations evaluated.

- Economic analysis substantiated the conclusion that bigger aircraft are not necessarily better. While small payload dedicated freighter aircraft can be economically preferred over large payloads they pose operational problems such as large increases in frequency. On the other hand, large payloads offer operational advantages but at possible economic penalty to the airlines in spite of their reduced trip cost.

- There are many issues remaining to be resolved before the viability and preferred size of a post 1995 dedicated freighter aircraft can be established. Among the more prominent of these issues are airport capacity limitations and operational restrictions, institutional barriers, and fuel availability.

Section 1

THE AIR CARGO INDUSTRY

There are many factors, in and out of the cargo system, which have inter-reacted to bring the industry to the level of development it is at today. The results are evidenced in patterns of movement, commodities shipped, operations performed, and inter-modal competition, that exist under an umbrella of political and economic regulations and agreements.

Airfreight and Its Movement

The pattern of united States industrial growth has been such that in nearly every instance the growth of supporting industries has occurred in close proximity to major industrial centers. The result is that the major portion of domestic freight movement is intraregional, reference Figure 1-1, and is handled by surface transport over average hauls of about 450 kilometers (279.7 statute miles) for trucks and 850 kilometers (528.3 statue miles) for rail. A relatively small portion, 0.3 percent, of the interregional movement is handled by air. The distribution of this airfreight in 1976 is shown in Figure 1-1 with the prior four year growth presented in Figure 1-2. In spite of this pattern of movement air cargo managed to grow at an average annual compounded rate of 12.5 percent between the years 1963 and 1976.

During 1976 ten city-pairs accounted for 20 percent of the total domestic airfreight of 4.2 billion tonne-kilometers (2.9 billion short ton-statute miles). With the exception of CHI-NYC the yearly variations of flow over these routes, identified in parenthesis, are shown in Figure 1-3. Over the period of 1973 to 1976 the flow between these city pairs has either declined or remained constant with no consistant pattern apparent. It is evident, therefore, that the realized growth occurred over the lower activity routes and through the additon of new services. While there was no correlation between capacity offered and airfreight carried between the top 10 city-pairs when considered

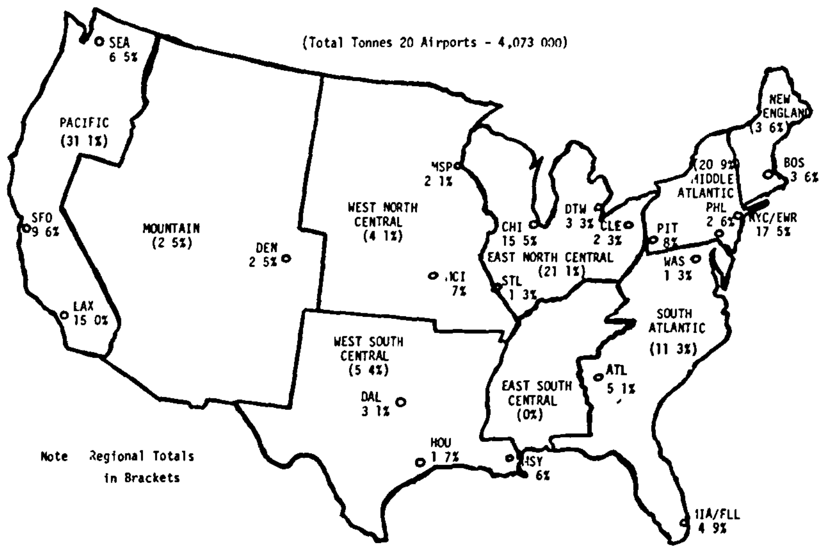


Figure 1-1. Percentage Distribution of Airfreight Activity, 1976

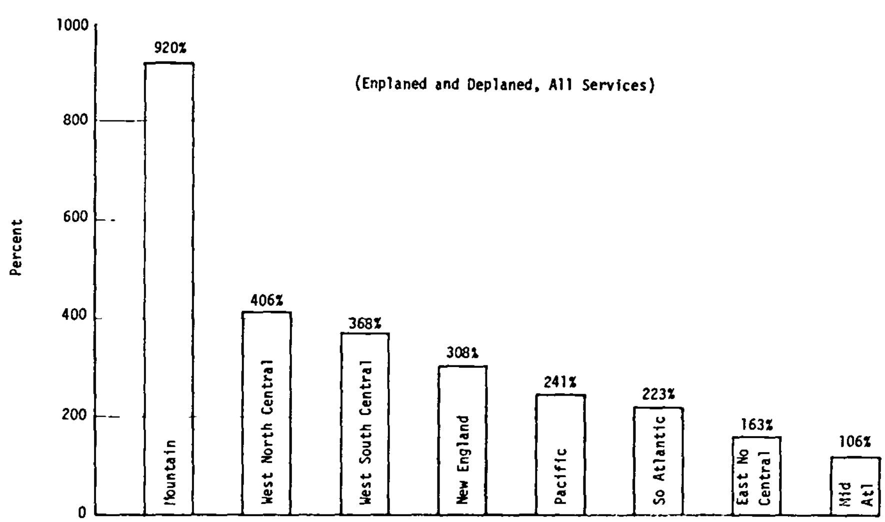


Figure 1-2. Percentage Change in Domestic Airfreight Activity, 1972-1976

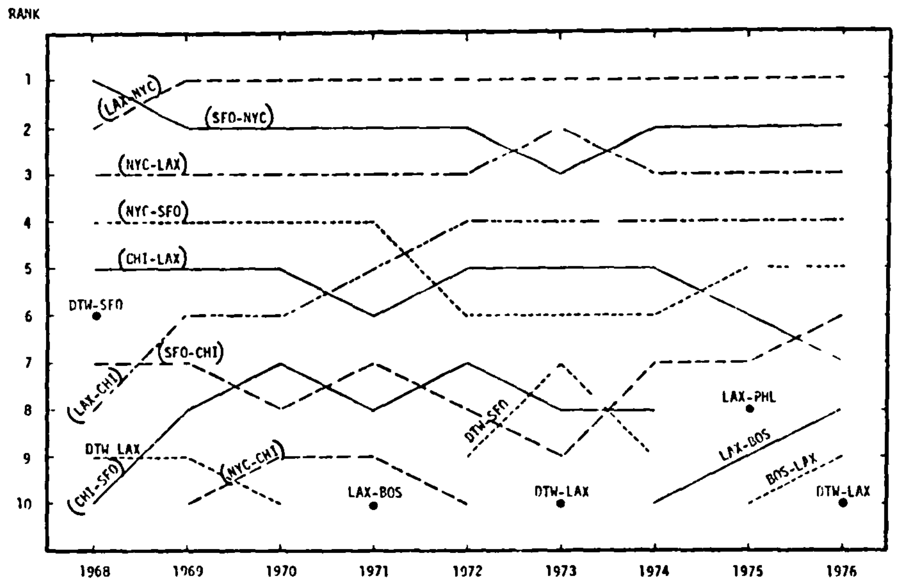


Figure 1-3. Ten Top Domestic City-Pairs (Ranked by Tonne-Kilometers)

individually, such correlation did occur when based upon the combined totals as illustrated in Figure 1-4. It is surmized, therefore, that short range trend lines are not a singly major factor in the allocation of capacity.

The types of commodities shipped by air within the U.S. has remained relatively constant as illustrated by the variation in the top ten commodities shown in Table 1-1. For 1972 twenty, four-digit SIC commodity classes (out of over 2500 classes) accounted for 85 percent of the air freight. Considering the nature of the top ten commodities it is not surprising that market demand has seasonal patterns with the largest decline occurring between the fourth and first quarters.

Air cargo has been characterized as a small shipment industry with 75 percent of the total shipments weighing less than 90 kilograms (198 pounds). A limited number of shipments exceed the 4500 kilograms (9912 pounds) defined as small by the Interstate Commerce Commission (ICC). While the small shipment market is large, 4.8 million shipments per day in 1974, it does result in a very uneven work load at the terminals. In one example this load varied between 4000 and 17 000 shipments per month over a year's time. A portion of the total

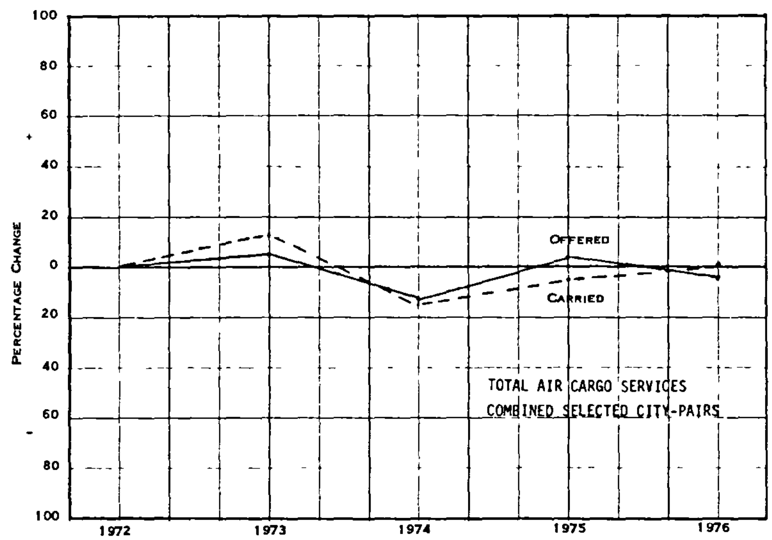


Figure 1-4. Percent Change in Capacity Offered and Quantity Carried

TABLE 1-1.
TOP TEN COMMODITIES

Commodity	Rank by Year				
	1955	1965	1970	1971	1975
Machinery Parts and Equipment	1	1	3	3	1
Cut Flowers, Horticulture	2	7	6	5	3
Electrical Products	3	5	1	2	4
Wearing Apparel	4	3	2	1	5
Printed Matter	5	4	4	4	2
Auto Parts and Accessories	6	2	5	6	6
Aircraft Parts	7	-	10	-	8
General Hardware	8	9	-	-	-
Advertising Display Matter	9	-	-	-	-
Photographic Film	10	-	-	-	-
Metal Products	-	10	-	10	-
Phonograph Reco ds, Tapes, Records	-	-	8	7	-
Fresh Produce	-	6	-	8	9

problem is relieved by the forwarders who often consolidate shipments prior to terminal handling. In 1975 these forwarders, including United Parcel Service (UPS), accounted for about 43 percent of the airfreight transported between the top 10 city-pairs.

The distribution of world airfreight movement during 1976 is shown in Figure 1-5. The European region originates, by a small margin, the greatest

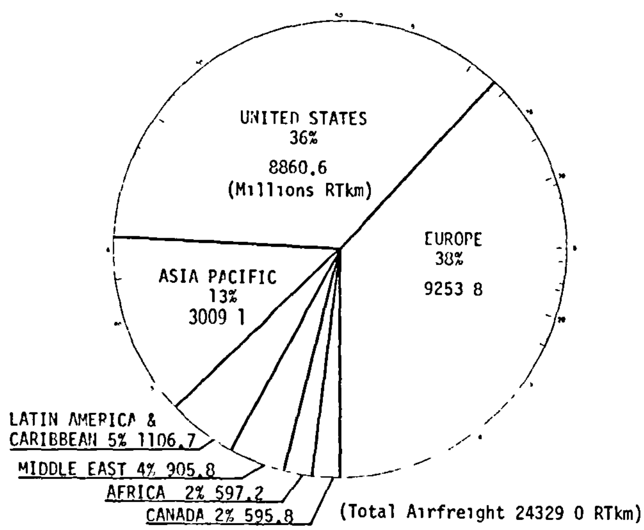


Figure 1-5. Percentage Distribution of World Airfreight by Originating Region, 1976

quantity of combined scheduled and non-scheduled freight with the U.S. in second place followed by the Asia Pacific region. During the five year period 1972-1976 the Africa, Middle East and Asia Pacific regions had the greatest growth. Also in terms of growth the top ranking countries, in order, were the United States, USSR, United Kingdom, France, Germany, Japan, Netherlands, Canada, Lebanon and Italy.

Although the United States is the top originator of scheduled airfreight the scheduled foreign airlines have been increasing their share of the total market. Between the years 1963 and 1976 the U.S. International market has grown at an average compounded annual rate of about 14 percent while the combined growth of 44 of the major foreign airlines has increased about 19 percent per year. During 1976 these foreign airlines carried 56 percent of the combined U.S. Domestic, U.S. International and Foreign markets.

Forty percent of U.S. dollar exports were flown to the Western Bloc countries with 30 percent moving to the Asian area. In 1976 the portions moving by air were 23 percent by value and 0.3 percent by weight to Europe and 17 percent by value and 0.1 percent by weight to Asia. On the other hand, 40 percent of U.S. imports came from Asia and 25 percent from European Bloc. Air shipments were 11 percent by value, 0.2 percent by weight, from Asia and 21 percent by value, 0.8 percent by weight, from Europe. These values give evidence to the fact that there exists a large potential for air penetration in international trade.

The air penetration potential was investigated with detailed analysis of the trade between the U.S. and sixteen of its major trading partners. In this analysis screened sea volumes were derived by excluding low-value bulk commodities. The resulting screened sea tonnes, the potential for air shipment, amounted to about 10 percent of the total sea movement. Results are illustrated for ten specific routes in Table 1-2. With the exception of exports to Germany and the United Kingdom air shipments were all less than 10 percent of even the screened tonnes. Similar behavior can be noted in sea trade routes around the world indicating a broad base of potential future airfreight.

As we proceed into the future there will not be any big surprises in the commodities that will be shipped by air. As in the past, there will be shifts in and out of the top 20 commodities and a continued increase in the percent of manufactured goods. Origin patterns of the latter will change due to the growth of developing regions and the search for cheaper labor. New products will enter the market and some will disappear with an overall trend toward minaturization and compactness, however, these changes will not be apparent at the five digit SITC code level. There will be little change in the average warehouse density of air cargo high value bulk or processed goods. Reductions in air tariffs relative to other modes and continuing inflation will lower the value threshold (dollars/kilogram) of air eligibility in constant dollars.

TABLE 1-2.

SELECTED U.S. INTERNATIONAL AIRFREIGHT MARKETS

Selected Markets	Total Air Tonnes	Screened Sea Tonnes	Total Sea Tonnes	Air % of Screened Sea	Air % of Total Sea
NYC to Germany	30 272	199 853	241 005	15 1	11 1
Germany to NYC	26 386	570 442	655 852	4 6	3 9
NYC to UK	34 542	262 604	498 183	13 2	6 5
UK to NYC	21 910	500 176	882 362	4 4	2 4
NYC to Brazil	9 927	138 223	153 317	7 2	6 1
Brazil to NYC	10 354	214 413	254 584	4 8	4 1
LAX to Japan	9 047	714 930	2 324 730	1 2	0 4
Japan to LAX	22 948	2 408 832	2 426 708	1 0	1 0
LAX to Indonesia	512	34 264	53 949	1 5	1 0
Indonesia to LAX	67	10 165	13 310 442	0 7	-
	165 965	5 080 902	20 801 132	3 3	0 8

Refined minerals will become eligible back-haul freight for select regions and market characteristics.

The U.S. Domestic air cargo market will have its largest growth in the South and Southwest portions of the country. Concerns for energy, environment and labor will see the creation and re-location of industries in these areas that can effectively utilize airfreight as part of their total production process. The largest international growth will occur in the developing regions of the world, primarily South America, West-Central Africa, Middle East and the Far East including mainland China. Growth in the encompassed countries will result in ever changing patterns in the types of commodities exported and imported depending upon the regions state of development. A key to achieving high growth in these emerging markets may be through the application of total distribution cost concepts backed up by aggressive educational/sales efforts by the airlines. In all regions the industry must cultivate high volume shipments that occur on a regular basis.

Air Eligibility

The decision to use or not to use a particular mode to ship a particular product at a particular point in time is a function of the product and market characteristics and the decision process employed by a particular shipper or consignee. In the past, these factors have interacted to facilitate segregation of air cargo into three basic categories, namely, emergency, perishable, and divertible. Emergency freight consists of products that are shipped by air due to the opportunity cost, such as lost sales due to delayed delivery, associated with a particular market/distribution situation and/or physical considerations. As an example, the central point inventoring of repair parts that is employed by manufacturers in many areas of the U.S. and/or the world. In such cases air cargo is a planned element of the distribution system yet is often identified as emergency use of air. Perishable freight is made up of products that are realistically shipped by the fastest available mode due to physical and/or demand perishability. Divertible freight is that which is shipped by a variety of modes depending upon its economic and physical properties and the demand for the product.

The importance of the respective product and market characteristics differ with the type of freight; not all the criteria are considered in all cases. The applicability of the respective characteristics within each of the through-freight categories is illustrated in Table 1-3. As the importance of the shipment decreases, emergency to divertible, the number of criteria pertinent to decision process, increases.

The product characteristics identified in Table 1-3 can well serve as indicators of air freight's potential to fulfill a company's distribution needs. The importance of each criterian must be determined on the basis of the shipper's or consignee's unique situation and method of evaluation.

Physical perishability. - If product deterioration enroute to the assigned market occurs more rapidly than the surface transportation can be performed then air cargo is a logical choice provided market conditions allow a sufficient margin to cover the added cost of air transport. However, there are cases where it may be more economical to ship by a slower mode and accept partial perishability.

TABLE 1-3.

AIR ELIGIBILITY CRITERIA

	Type of Freight		
	Emergency	Perishable	Divertible
Product Characteristics	Physical Perishability Transit Environment Weight, Size Volume Lead Time	Value/Weight Ratio Density	Product Range Production Process
Market Characteristics	Opportunity Cost Value Life-Cycle Stage Market Location Demand Perishability	Demand Variability Mark-ups	Dispersed Demand
Mode Choice	Fastest Available	Fastest - If Market Conditions Allow Margin Sufficient to Cover Cost	Mode Giving Lowest Total Cost of Distribution

Transit environment. - Air freight provides a superior environment and the reduced transit time decreases the exposure to the risks of damage and theft.

Weight, size, and volume. - Vehicle compatibility is highly dependent upon the transport mode. Airfreight is often restrictive relative to weight, size, volume, although the wide-body aircraft are helping to relieve this situation.

Lead time. - Allowable values must be established by either the shipper and/or consignee on the basis of the considered market. This is a pertinent consideration to improving air cargo service.

Value-to-weight ratio. - The higher the value per pound of a product the more likely it will be shipped by air as evidenced in Figure 1-6. However, financial management and intangible benefits of air cargo are becoming increasingly important, making air distribution profitable at decreasing value-to-weight ratios.

Density. - Surface modes discriminate more against lighter products than do the airlines. The density break for air occurs at 142.7 kilograms per cubic meter (9 pounds per cubic foot), lower density products are charged this weight break rate to compensate for the volume occupied.

Product range. - Selection of a limited number of items for air shipment, out of a wide product design range, decreases the costs associated with fluctuations in demand and the capital tied up in high levels of inventories.

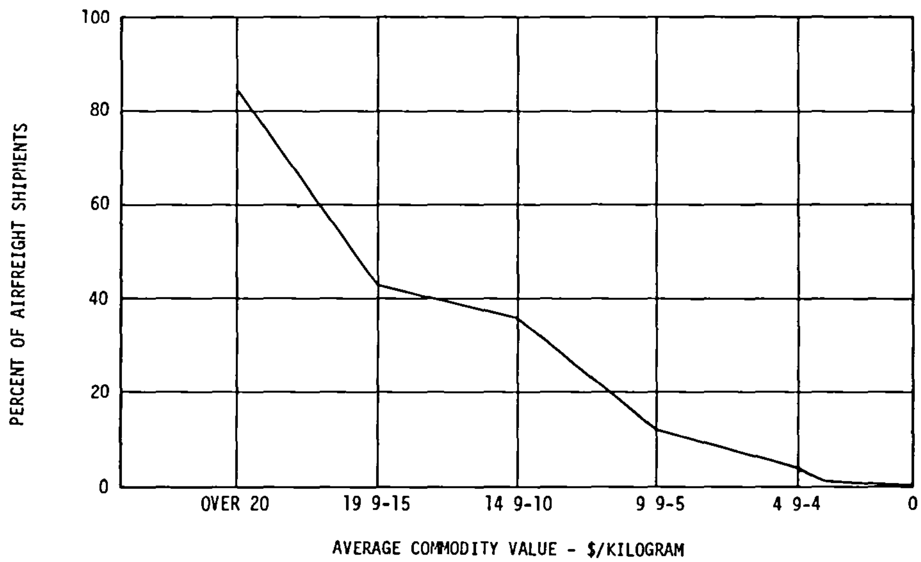


Figure 1-6. Commodity Value in U.S. Air Trade to the Far East

Production process. - Products having long production lead times or those employing the batch process are less likely to be shipped by air. Products produced at rates compatible with demand are potential candidates for diversion to air transport.

The preceding commodity characteristics must be considered in the light of the market environment in order to realistically evaluate the economics of air cargo versus surface transport. The following market characteristics are highly determinant in deciding whether air cargo will provide marketing and/or distribution advantages sufficient to offset the cost.

Opportunity cost value. - Opportinity cost is equivalent to the profit that could be derived from a specific market if the right products were available at the right time and in the desired quantity.

Life cycle stage. - Related to the risks involved in putting new products on the market or in putting existing products into new markets.

New product introduction. - Where timely opportunity to introduce new or different products offset the additional transportation cost of air over surface. In these cases time is of the essance and air freight tariffs are a secondary consideration.

Market location. - Air transport might be favored where significant barriers to surface transport exists or where the circuity of surface transportation causes undesired time delays.

Demand perishability. - Related to products which are time sensitive from the standpoint of demand. The fastest mode of transport is desired provided the market conditions can accommodate a sufficient margin to cover the cost of that mode.

Demand variability. - In markets where demand is volatile the air mode can be used to meet either greater or less than the expected demand with a resulting reduction of risk associated with large inventories.

Markups. - There are products for which the markup depends on the market situation resulting in a possible trade-off between risk and profit. In these markets slow transportation can maximize profit at the risk of market change while airfreight could take expeditious advantage of the market situation.

Dispersed demand. - Air transport could be favored where production and consumption are dispersed and/or when the production process takes place in two or more widely separated locations.

Air cargo is not always the most expensive mode of transport. The preceding criteria are most important where the air rates are higher and the mode choice should consider the total distribution cost in the framework of the shipper's total production system. In such cases the product and market criteria initially serve to qualitatively indicate a product's applicability to air transport. Once the cost benefit analysis is underway these criteria serve to identify factors and considerations to be included in the analysis. In the majority of cases, the product and market characteristics are quantifiable to the level required for decision. However, there are cases when the conditions prevent quantification with the result that pertinent qualitative factors are also ignored. This procedure may lead to erroneous conclusions since it appears that qualitative analysis can identify potential benefits that are becoming increasingly important in today's competitive markets.

Political and Economic Factors

Airfreight markets and the air cargo industry are effected by international agreements along with economic and non-economic regulations. Often the resulting requirements represent institutional road blocks to such things as efficient aircraft utilization and the acceptance of large aircraft, interline gauge changes, network and frequency changes, and reductions in customs processing time. Table 1-4, elaborated upon in the paragraphs that follow,

TABLE 1-4.
THE EFFECT OF ECONOMIC AND POLITICAL FACTORS

	Airfreight Market						Future Airfreight System[3]										
	Market			Nature of Demand[1/2]													
	Domestic	U.S. International	Foreign	Emergency	Perishable	Divertible	Volume	Commodities	Airports and/or Terminals	Ground Equipment	Aircraft	Network	Operations	Capacity	Economics	Entry	Rates
International Agreements																	
Bermuda II		X	X						D	IN	IN	D		IN	DOC[4]	IN	
Tariffs		X	X		II	I	+	D									
Quotas		X	X	III	II	I	+	D									
Voluntary Quotas		X	X		II	I	+	D									
Non-Economic Regulations																	
Curfews and Night Flight Rules	X	X	X	I	II	III	-		D			D	D	D	DOC/IOC[5]		IN IN
Noise	X	X	X	III	II	I			D	D	D	IN	D		DOC/IOC		
Air Pollution	X	X	X	III	II	I	-		D	D	D	IN	D		DOC/IOC		IN
Hazardous Materials	X	X	X														
Economic Regulations																	
International Tariff		X	X														D
International Economic		X	X													D	D
Domestic Market Entry	X															D	
Domestic Price	X																D
Horizontal Mergers	X															D	
Vertical Mergers	X								D						IOC	D	IN
Civil Reserve Air Fleet	X	X				I		+	D	D	D	IN	IN	D	DOC		IN

1 The nature of demand classifications, reference Air Eligibility section
2 I - largest effect, II - next largest effect, III - smallest effect
3 D - direct effect, I_N - indirect effect
4 DOC - direct operating costs
5 IOC - indirect operating costs

summarizes the impact of a representative portion of the factors that are considered in the body of the CLASS report.

Of the international agreements in effect the Bermuda II Agreement (July 23, 1977) between the U.S. and U.K. may well serve as a model for forthcoming future agreements between other nations and the U.S. The result could be a promotion of foreign flag at the expense of American flag airlines with a subsequent decrease in the capacity serving some routes. While the limitations imposed on Fifth Freedom rights will decrease the load factors of U.S. carriers between foreign countries the increased number of change of gauge points allowed will facilitate better aircraft utilization.

The impact of tariffs and quotas is to decrease the supply of the effected commodity with a resulting increase in price and a decrease in demand. Divertable commodities are the most sensitive to the ensuing elasticities of demand followed by perishable and emergency freight. Continuation of the current trend to reduce world trade barriers will increase the airfreight market demand while the formation of economic blocks (e.g., European Economic Community, Arab League) will stimulate intrabloc while decreasing interbloc trade. Although tariffs and quotas are on the decline, trade restrictions on high-value consumer goods are on the increase. This results in the export of "top of the line" items thus increasing the value per pound and increasing the volume of air eligible commodities.

Non-economic regulations have a profound effect on the ability of the air cargo industry to provide desired services. Among these regulations are the curfews and night flight rules being imposed by airports both here and abroad. Air cargo flights are time sensitive preferring to leave late in the evening and arrive early the next morning. The proliferation of restrictions on night operations both in the U.S. and abroad will restrict overnight domestic service and the flight windows for international service. In addition, the city enforcing the curfew pays a price in service with a subsequent reduction in economic activity that permeates throughout the community.

Noise abatement and air pollution programs greatly increase airline expenses, especially those requiring the retrofitting of aircraft. Such is the case for the Civil Aeronautics Board (CAB) FAR 36 and the International Civil Air Organization (ICAO) CAN 5 which set maximum acceptable aircraft noise levels. These regulations require modification, compatible with the following timetable, of all jet aircraft having a maximum takeoff weight of 34 000 kilograms (74 900 pounds) or greater.

Aircraft not powered by JT-8D engines, 100% by 1985

Aircraft powered by JT-8D engines, 100% by 1983

In addition, environmental impact studies are required (CAB SFAR 27) when adding origins and destinations or when changing operations at an airport.

Hazardous material regulations are established by the Department of Transportation (DOT) CFR Title 49 for all transport modes. In the past these requirements have been poorly understood and, in some cases, poorly enforced. In the future these DOT requirements will be rewritten and more widely understood. The enforcement of the International Air Transport Association's regulations for foreign service will gradually improve.

Economic regulations are established by a variety of agencies and in total define the commercial environment in which airlines operate. The International Air Transport Association (IATA) was established primarily to set tariffs on international routes. These tariffs depend upon the unanimous approval of all IATA members and the cognizant aeronautical agency of each of the affected member nations. The resulting rates are not always followed since membership is not mandatory and because rebating is widespread in the international air cargo industry.

The International Civil Aviation Organization (ICAO), now a special agency of the United Nations, in part has responsibility for the economic aspects of international air transport. The functional ability of this organization is seriously handicapped by the fact that the reporting of airline operational statistics is not mandatory.

Since deregulation of U.S. Domestic air cargo anyone who can establish capability and worthiness can establish an air freight business. Although rates are still filed they need not be approved and the CAB acts only in cases of possible rate discrimination. However, in the case of mergers government approval is still required. Depending on the type of merger, a vertical between airlines or a horizontal between competing modes, a multiplicity of government agencies can be involved. Of equal concern to the industry must be the CAB's elimination of reporting requirements that accompanied deregulation. This action, unless picked up by other government and/or private agencies, will leave the air cargo industry without the means to moniter its domestic performance and for the airlines to evaluate their efficiency within the industry. The lack of knowledge of cargo and traffic movement will seriously handicap advance planning efforts thus stimulating deficient service and poor utilization of equipment. The result could be a further exaggeration of the resource utilization problem already solidly established in surface transportation.

The Civil Reserve Air Fleet (CRAF) is an integral part of the National Transportation Plan's standby programs and procedures for emergencies. Established by Executive Order No. 10999 in 1952, the plan requires the Office of Emergency Transportation of the Department of Commerce to allocate to the Department of Defense (DOD) specific aircraft, with designated capabilities, for use in direct support of the military airlift needs. The DOD, working with the nation's airlines, arranges for a contractual release of the CRAF aircraft for emergency service. To help develop the program, military airlift contracts are awarded only to those civil airlines that are members of CRAF.

Competitive Modes

At the present time air cargo's primary competition on land is the truck and, of course, the container ship at sea. Due to developments in technology and changes in the social and economic environments the competitive positions of all modes will undoubtedly change in the future. It is essential, therefore, to clarify future developments in the respective modes and to understand the possible effects of such changes upon the mode's potential competitiveness.

The trucking industry has been continuously increasing its share of domestic intercity freight movement reaching a level of 33 percent of the total in 1975. Comparable values for rail and air were 51 percent and 0.25 percent respectively with the balance handled by the sea mode. Although the air share was small its growth rate exceeded that for trucking as shown in Figure 1-7, note scale change. Except for the clothing and data processing products where shippers rely heavily on airfreight, trucking predominates in the transport of manufactured goods. In addition trucks reduced the rail and air shares of produce movement as illustrated in Figure 1-8. The data shown

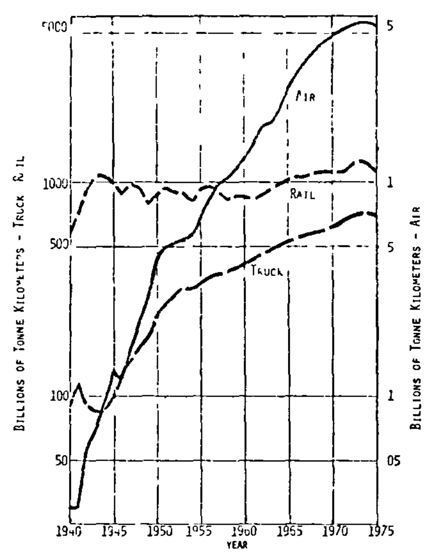


Figure 1-7. Volumes by Mode

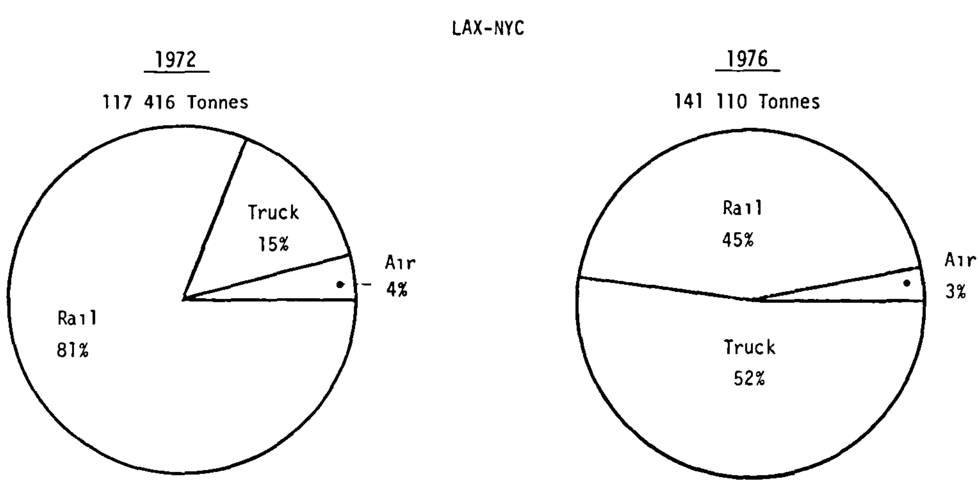


Figure 1-8. Fresh Fruits and Vegetables, 1972 to 1976

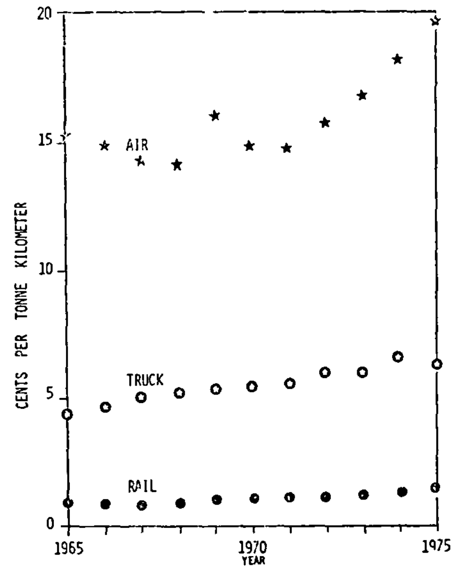


Figure 1-9. Revenue per Tonne-Kilometer

in Figure 1-9, based upon total revenue and movement, illustrates the fact that such mode shifts are not due to cost alone. CLASS investigations indicate that service from the standpoints of containerization, loading and unloading on a door-to-door basis, and pick-up to delivery time, often predominate in the mode decision process. Airfreight has the advantage in transit time being 1/2 to 1/5 of motor and 1/3 to 1/6 of rail domestically, and 1/11 to 1/27 of ocean travel time internationally.

The structure of class and commodity rates underlying the transportation revenues is a very involved subject reaching an ultimate with the rail mode that has 43 trillion commodity rates on file with the Interstate Commerce Commission (ICC). In order to develop a basic understanding of the relative rate structures of the air, surface, and sea modes, six commodity classes and seven weight breaks were investigated for ten domestic and twelve international origin-destinations.

The weight breaks at which transportation tariffs show significant declines vary with mode occurring at 225, 445 and 2270 kilograms (496, 980 and 5000 pounds) for air; at 225 and 9080 kilograms (496 and 20 000 pounds) for truck; and at 4540 kilograms (10 000 pounds) for rail. For the cases investigated the air tariffs range from 10 percent to 734 percent higher than the comparable truck tariffs. Rail tariffs range between 41 percent lower to 558 percent higher than truck tariffs. In international traffic the air tariffs as a percent of ocean tariffs fall at every rate break since ocean tariffs are constant per kilogram. While some air tariffs are over 1400 percent greater than ocean tariffs there are many origin-destinations and commodities where air tariffs are less than ocean tariffs for small shipments, 45 kilograms (99 pounds). However, for clothing shipments between Rio de Janeiro and New York the air tariffs are 79 percent to 59 percent lower than sea tariffs over the full range of weight breaks.

If air cargo is to substantially grow in the future it must begin capturing high volume shipments on a regular basis. A necessary, but not sufficient, condition for this expansion is a reduction in the air carriers total operating costs and a subsequent lowering of air tariffs relative to truck, rail and container ship tariffs. To acquire a better understanding of how these objectives could be achieved, the operating costs of air and the competing modes were first segregated into the line haul, terminal and pick-up and delivery (PU and D), and then into the capital, fuel, maintenance and labor components. Comparisons with the surface modes were based upon a DC-8-63F for air, a single 12.2 meter (40 foot) trailer for trucking, and 12.2 meter trailers loaded on a 70-car mixed train and a 35-car through train for rail.

When adjustments were made for shipment density and route circuity the difference in total cost to ship 907 kilograms (2000 pounds) over 1979 kilometers (1230 statute miles) by air compared to the cost by surface was reduced between 16 and 30 percent, depending on the mode considered. The resulting air cost was 82 percent higher than truck, 102 percent higher than a 70-car train, and 149 percent higher than a 35-car train. These results indicate a substantially different competitive position for air when viewed relative to prior expectations.

The relative importance of the three total cost elements, line haul, terminal and PU and D, to intermodal competitiveness is illustrated in Figure 1-10. These percentage figures indicate that line haul costs for air are a smaller percentage of the total cost, and hence of lesser importance,

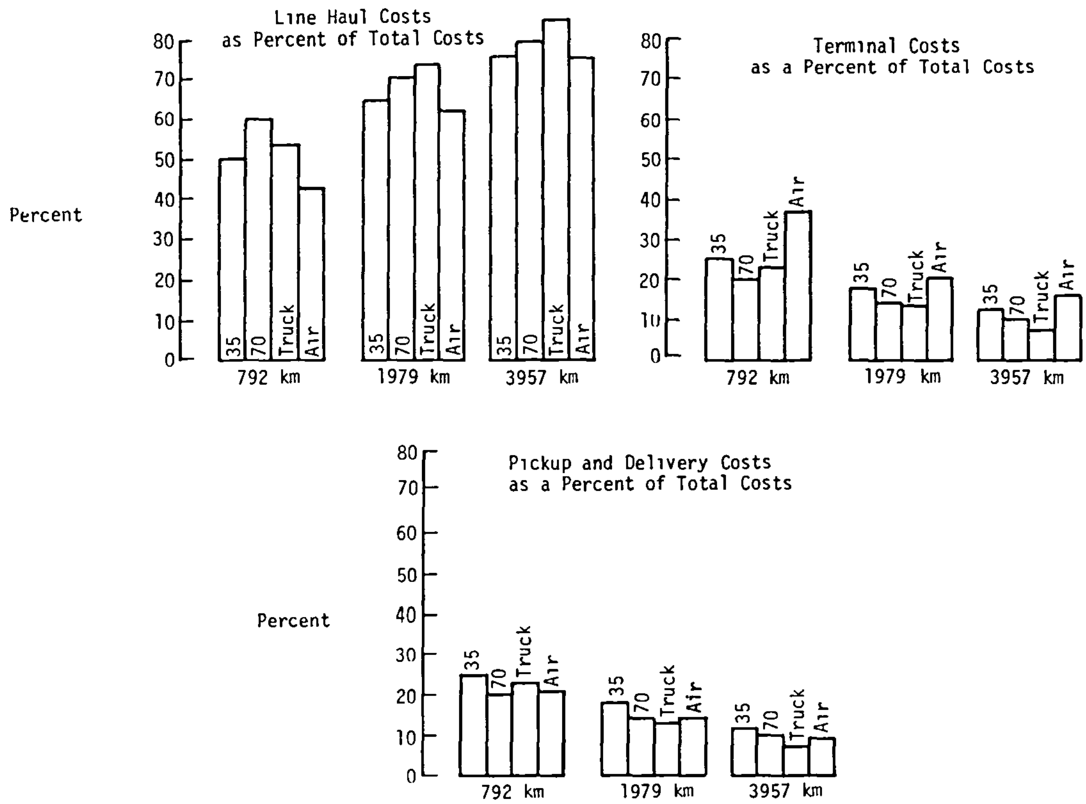


Figure 1-10. Percentage of Total Costs

than for other modes. This result, along with the relatively high importance of terminal costs to air competitiveness, was not expected when the analysis was begun. However, to understand the reduction of the intermodel cost gap (discussed in the preceding paragraph) requires knowledge of the components that make up the cost elements of Figure 1-10.

The line haul cost for airfreight is 42 percent to 126 percent greater than the surface modes due primarily to the fuel component as illustrated in the following table. The high fuel cost of rail is due to payload density and route circuity adjustments and the inclusion of truck movement between the truck and rail terminals. Air excells in two areas, labor compared to trucks and maintenance compared to rail.

RATIO OF LINE HAUL COSTS

907 Kilograms 1979 Kilometers	Total	Fuel	Labor	Captial	Maintenance
Air/Truck	1.42	4.68	0.44	2.91	1.67
Air/Train					
70-car	1.66	3.53	1.47	1.67	0.85
35-car	2.26	4.38	1.43	3.61	0.96

A component breakdown of line haul costs for the respective modes is presented below.

COMPONENTS OF LINE HAUL COSTS

907 Kilograms 1979 Kilometers	Percent of Line Haul Cost			
	Fuel	Labor	Capital	Maintenance
Air	28	19	41	13
Truck	8	61	20	11
Rail				
70-car	13	22	40	25
35-car	14	30	25	31

The predominating components are capital costs for air and labor costs for trucking. In the case of rail the highest cost varies between labor, capital and maintenance, however, rail is burdened by high maintenance costs when compared to either air or truck.

Results of the intermodal comparisons indicated that terminal costs are surprisingly high compared to truck terminal costs.

RATIO OF TERMINAL COSTS

907 Kilograms	Total	Labor	Capital
Air/Truck	3.24	3.16	4.86

The 386 percent higher capital cost is partially explained by the higher airport land values and greater terminal mechanization. The higher labor costs can be explained in terms of air terminal peaking, level of service and current operational procedures. The component breakdown of terminal costs are comparable for the air and truck modes with 5 to 8 percent for capital and the remainder for labor. These data substantuate the finding that if the air mode is to improve its competitive position the air terminal costs must be reduced with no penalty to service. The increased importance of this cost reduction at shorter ranges is illustrated in Figure 1-10. Air terminal costs increase from 20 to 37 percent of total costs when the range decreases from 1979 to 972 kilometers (1230 to 490 statute miles) while the comparable trucking costs go from 13 to 22 percent.

The last element of total cost to consider is PU and D. As for the terminal operations the cost for PU and D of 907 kilograms (2000 pounds) of freight is 85 percent higher for air than for truck. Air has 43 percent greater labor costs and 65 percent greater maintenance costs. The most important cost component is labor which accounts for 50 to 60 percent of PU and D costs for air or trucks.

The combined results of Figure 1-10 and the preceding discussions indicate that line haul capital and fuel costs be at the top of the list of potential improvements followed by terminal costs. If the air terminal and PU and D costs were reduced to the level for truck transport then the cost differential between air and truck freight would be comparable to the current cost differential between truck and rail. Considering line haul costs, the availability and cost of fuel will be among the determining factors in the future growth of the air cargo industry. However, assuming the availability problem is solved, the impact of fuel price on intermodal competitiveness cannot be viewed in isolation but must be considered relative to such factors as technological improvements, spiraling wages, and the availability and cost of money. The potential to reduce fuel consumption through advances in materials, vehicle design, and propulsion efficiency is greatest for the air mode. The labor intensiveness of the line haul cost is less for air than for either rail or trucks. And finally, inflation, interest rates, and capital availability will serve to increase the value of time, time in the warehouses and in transit. Relative to the latter, while rail speeds are expected to gradually increase, air and highway speeds will remain about as they are. However, air can improve its situation by reducing PU and D time relative to the other modes. In view of these anticipated trends it is concluded that air cargo will improve its competitive position relative to trucking but will begin to lose ground relative to rail as we move into the late 80's. A contributing factor in the latter will be a growing interest in rail electrification, containerization and truck on flat-car.

The line haul cost differential between air and ocean transport was examined over two routes, New York to the U.K. and U.K. to Japan. The Douglas DC-8-63F and the Boeing 747-100F were compared to a 1250 Twenty-foot Equivalent Unit (TEU) container ship on the N.Y-U.K. route and with a 2500 TEU container ship between the U.K. and Japan. Consideration was given to cargo density and route circuity based upon deep-sea procedures.

The ratios of air to container ship costs are presented in the table below. With adjustments for freight density and circuity the total cost of shipping 907 kilograms (2000 pounds) by air is 2.1 to 3.8 times that by ship over the routes considered.

RATIO OF LINE HAUL COSTS

907 Kilograms	Total	Fuel	Labor	Capital	Maint.	Insurance Landing Fees Port Charges	Route
DC-8/1250 TEU	2.7	7.6	1.7	2.0	13.7	1.1	U.S.-U.K.
B747/1250 TEU	2.1	5.1	0.9	2.1	10.4	0.7	U.S.-U.K.
DC-8/2500 TEU	3.8	3.9	5.0	2.5	19.5	2.7	U.K.-Japan
B747-2500 TEU	3.5	3.2	3.1	3.2	17.8	2.2	U.K.-Japan

The decrease in fuel ratios for U.K.-Japan compared to U.S.-U.K. is due to the large surface circuity connected with passage through the Panama Canal. The large increase in the labor ratios for the U.K.-Japan route are mostly due to the high stevedoring cost in New York. Similarly, the greater ratios for insurance, handling fees and port charges are due primarily to the high port charges in New York.

Breaking the line haul costs into its components, as shown below, indicates that capital costs are predominating for the B747 and the container ships. On the other hand, the DC-8 substitutes fuel for capital. Deep sea shipping is generally more capital intensive than the airfreight industry. The increased importance of fuel for the 2500 TEU ship, long voyage, is due to the length of voyage where fuel accounts for over 60 percent of the daily operating costs including capital.

COMPONENTS OF LINE HAUL COSTS

970 Kilograms	Percent of Line Haul Costs					
	Fuel	Labor	Capital	Maint.	Insurance Landing Fees Port Charges	Routes
DC-8-63F	32	21	27	14	6	U.S.-U.K. and
B747-100F	28	14	38	14	6	U.K.-Japan
1250 TEU	11	33	37	3	16	U.S.-U.K.
2500 TEU	31	16	42	3	9	U.K.-Japan

On short voyages, the labor costs, including stevedoring, are most important as illustrated by the 1250 TEU cost breakdown. In a similar manner container ships are more port charge intensive than aircraft are landing fee intensive.

The intensities of fuel, labor and capital are remarkably similar for the B747 and the 2500 TEU ship. As these costs increase in the future the cost competitiveness of these vehicles will remain relatively constant for long voyages. On the other hand the competitiveness of the B747 to the 1250 TEU ship will vary from the current situation with the realized improvement or degradation dependent upon the relative increases of fuel and labor costs. As in the case of ground transport, the increasing value of time will intensify the advantage of air cargo since, in consideration for fuel, the line haul speed of containerships will tend to decrease, not increase. In addition there will be essentially no reduction in their PU and D time.

Section 2

USERS VIEW OF AIR CARGO

A primary objective of the CLASS was to consider the users views during the analysis and in outlining future courses of action. To achieve this objective the case study research task was conducted to identify the current and future factors that determine the use of airfreight, to obtain the users view of the present air cargo system, and to understand the shippers desires and requirements for the future. The approach taken was designed to minimize self-reported reactions to suggested future airfreight concepts. If such concepts appear better at the moment they usually solicit opinions which have no relation to the respondent's future behavior. The acquisition of data, and subsequent analyses, were therefore directed toward understanding the shipper's needs and motivations and out of that to draw inferences for the future.

The case study research was conducted in two phases. The first phase consisted of in-depth, taped, interviews with 34 users and non-users of air cargo which included manufacturing, distribution, agricultural and professional firms plus airlines and forwarders. The large-scale mail survey performed in the second phase provided a statistical list of the hypothesis and issues examined in the depth interviews. The mail survey form contained 56 closed-ended questions and 16 statistical and demographic questions. 551 transportation and distribution executives answered these questions using the Likert scale. The following discussion delineates the integrated findings derived from the depth interviews and the mail survey.

Organization of the Distribution Function

The organization of the distribution function was examined because it can affect how and why mode choice decisions are made. Results show that in the majority of cases the distribution function interacts informally with upper management in Finance, Marketing and Production. Although not formally involved in developing broad objectives, the distribution function is aware and sensitive to the needs of the other functions. This is evidenced by the data of Figure 2-1 since system analysis considers the collective needs of all involved functions.

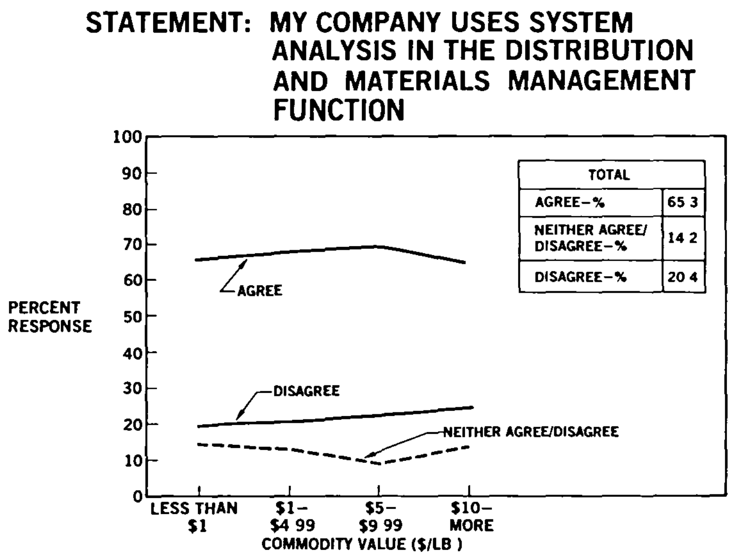


Figure 2-1. Distribution

Decentralization can present a handicap to the decision process. Although results indicate an almost even division between centralized and decentralized firms there is a definite trend toward greater centralization as shown in Figure 2-2. Manufacturers, especially of high value products, tend to be decentralized in operation and mode decision making. However, centralization does not necessarily mean that one department has the responsibility for all distribution decisions. Traffic managers at each plant location can make day-to-day mode selections based upon advise from the staff distribution executives.

Mode Choice Decision-Making

It was quite evident that most firms currently employ airfreight on an urgency, "emergency" basis as illustrated by the mail survey results given in

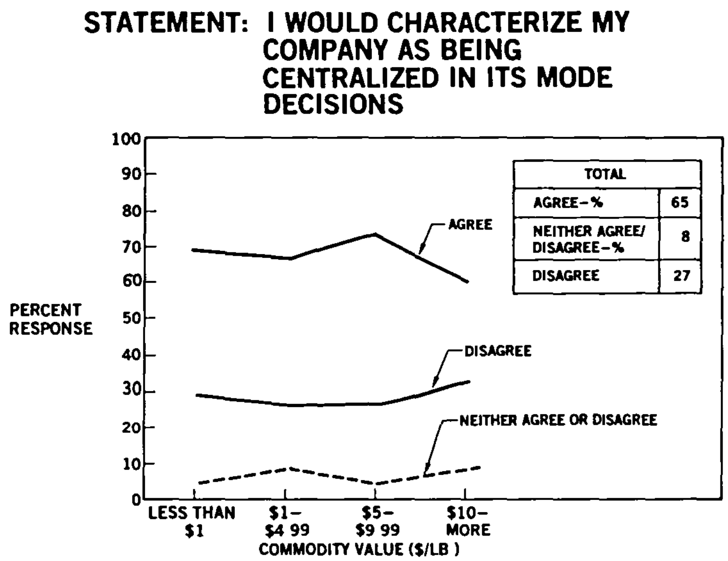


Figure 2-2. Centralized Decisions

TABLE 2-1.

REASONS FOR USING AIRFREIGHT

Reason	Direction of Shipment	
	Outbound	Inbound
1 Urgency - %	47 7	60 4
o Breakdowns		
o Deadlines		
o Backorders		
o Speed in Transit		
2 Competition %	21 4	12 9
o Customer Service		
o Increase Competitiveness		
3 Service %	12 1	12 8
o Time Reliability		
o Less Loss/Damage		
o Limited Handling		
o Tracing		
4 Cost %	7 2	8 4
o TDC		
o Cash Flow		
o Cheaper than Alternatives		
o High Product Value		
5 Other %	11 6	5 5
Total - %	100 0	100 0

Table 2-1. The situations identified under urgency apply to most industries, exceptions being the shipment of perishables and high value per pound products. However, it must be emphasized that the terms urgency, "emergency", are generic with the specific meaning varying widely as discussed in Section 1. In spite of the predominance of emergency applications airfreight is often viewed as a tool that used routinely can give the shipper a competitive edge when considered in the framework of total service with consideration for the cost/benefit trade-offs. Heavier airfreight users, firms dominent in their field, and high value per pound producers, reference Figure 2-3, are predominent among the firms that

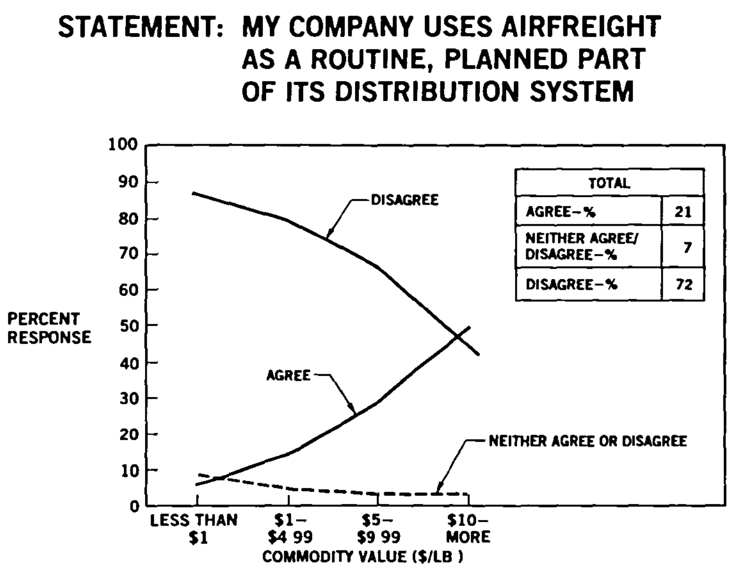


Figure 2-3. Planned Airfreight Use

use airfreight as a routine, planned part of their distribution system. Low value product producers were generally satisfied with surface transport as illustraed in Figure 2-4, using airfreight on an emergency basis, Figure 2-5, for competitive reasons.

Since the consignee bares the brunt of the economic impact of the market oriented circumstances surrounding the use of airfreight, it appears logical that the consignee should make the mode choice. While this perspective was strongly condoned in the depth interviews it was refuted by the mail survey

STATEMENT: MY FIRM CAN ALMOST ALWAYS SATISFY ITS CUSTOMER SERVICE OBJECTIVES BY USING SURFACE TRANSPORTATION

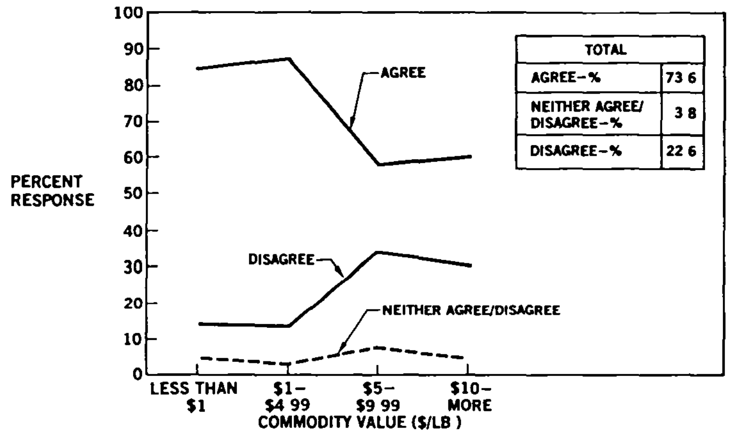


Figure 2-4. Customer Service

STATEMENT: MY COMPANY USES AIRFREIGHT ON AN UNPLANNED, EMERGENCY BASIS ONLY

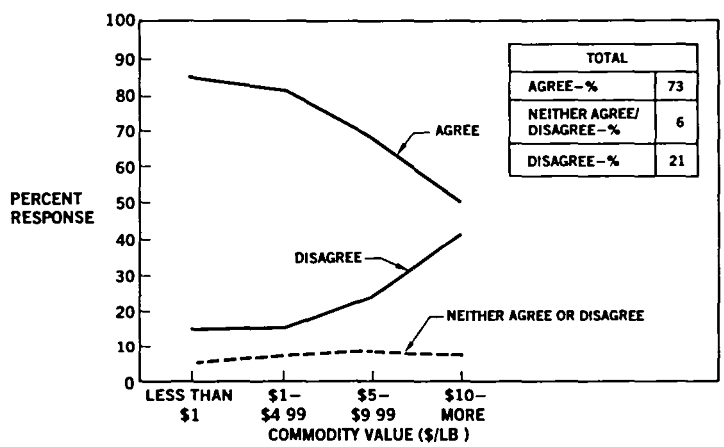


Figure 2-5. Unplanned Airfreight Use

which showed the consignee to be less influential than the shipping firm unless that firm was the consignee. The greater influence of the shipper is especially true for heavy airfreight users where the mode decision apparently becomes routine and the consignor assumes more of the responsibility.

Although rational cost/benefit tradeoffs are employed in mode choice, the research results indicate that the formal use of total distribution cost (TDC) technique is not widespread. This is substantiated by the fact that while inventory carrying cost (ICC), a pertinent element in TDC, is used in evaluating a company's distribution system it is not necessarily important in mode choice as illustrated in Figure 2-6. A major barrier to formal use of TDC is

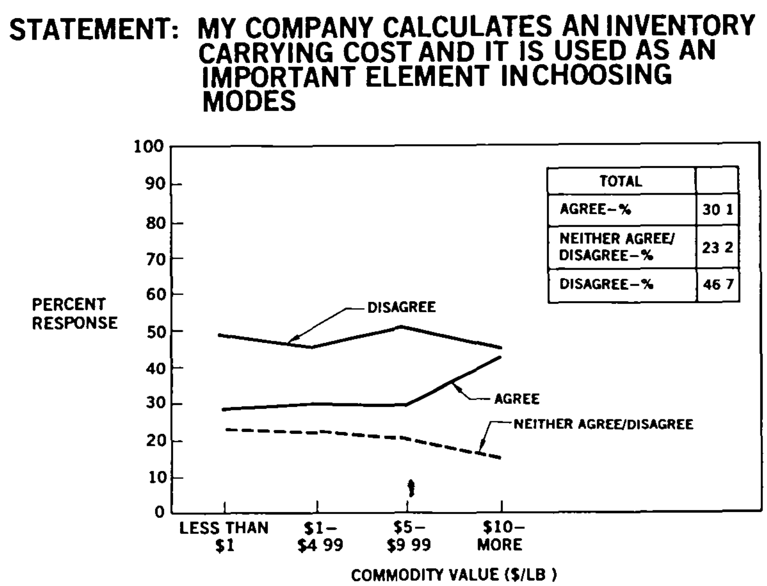


Figure 2-6. Inventory Cost

the previously discussed, limited organizational role of the transportation manager coupled with the fact that his performance is not primarily measured against budget as illustrated in Figure 2-7. In many cases the TDC inputs required are not compatible with the accounting procedures in use thus making the potential benefits marginal relative to the cost of implementation. Decentralization presents a potential obstacle to the effective use of TDC because its viability is dependent upon the higher quality and totality of

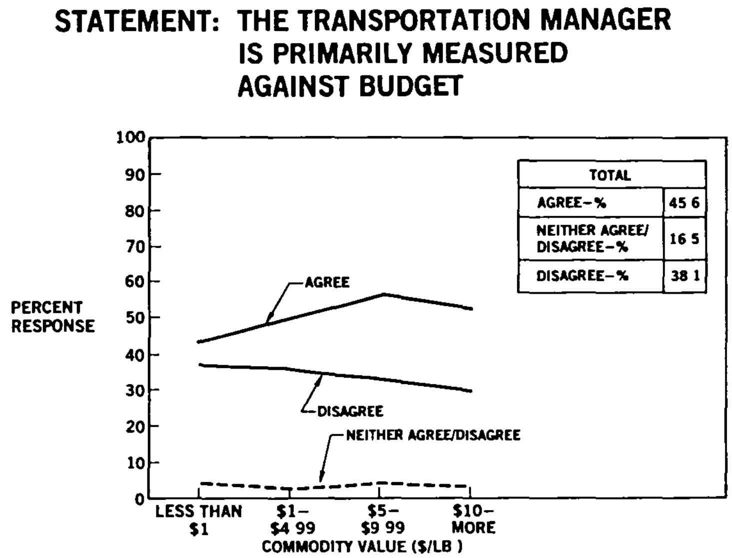


Figure 2-7. Transportation Managers

information that may be difficult to obtain in a decentralized environment. Both the airlines and forwarders feel there is a need for educating the shipper on the TDC concept but also agree that such efforts have been relatively unsuccessful in the past because they appeared self-serving.

Todays Airfreight System

Since urgency, competition, and service are the dominent reasons for using airfreight today, it can be concluded that service in general is the primary factor in airfreight use. This service accounts for the popularity of the forwarder illustrated in Table 2-2. Forwarders are preferred for their PU and D capabilities, door-to-door possession, reliability and documentation. In contrast, the airlines are often seen as being unresponsive to the shippers or forwarders needs with sales personnel lacking product knowledge. The airlines are viewed as being primarily concerned with airport-to-airport operations and large volumes of freight. Shippers felt that the biggest airfreight problems are those associated with ground support and handling (airport congestion, PU and D, operational procedures, etc.) rather than the airport-to-airport segment. Other problems cited relate to the tracing of freight, and

TABLE 2-2.

USE OF FORWARDERS

STATEMENT: WHEN MY COMPANY SHIPS BY AIR, AN AIRFREIGHT FORWARDER USUALLY HANDLES THE SHIPMENT

PRODUCT	AGREE (%)	DISAGREE (%)
ELECTRONICS	58 3	25 0
MACHINERY	52 2	24 6
CHEMICALS	62 5	16 7
DRUGS	63 2	24 6
CLOTHING	81 0	14 3
FOOD	56 1	34 1
PAPER	37 5	62 5
PRINT MATERIAL	73 3	6 7
ADV AND SAMPLES	68 6	17 1
TOYS	83 4	8 3
MISCELLANEOUS	64 8	20 5

BASE 549 TRANSPORTATION EXECUTIVES

the lack of lift to and from appropriate cities. On the positive side, airfreight is generally considered to be more reliable than truck service. However, if firms can be competitive in the market place using surface transport, that mode will prevail. Many firms have their own truck fleets to better meet their transportation needs.

Results indicate that shippers are not greatly concerned with the type of aircraft or where the containers are carried in the aircraft. Their concern is with quality of service for the price charged. Regarding service, a large majority indicated that having the ability to self-load containers would not increase their use of airfreight. Only one-third indicated that overnight (next day) delivery was mandatory.

The Future Airfreight System

The shippers view of the future airfreight system is described in cautious terms especially with regard to equipment needs. In general, the shippers future planning efforts, beyond five years, do not adequately consider the interrelations between their anticipated future distribution needs and the potential developments in transportation systems.

Forwarders were unanimous in advocating improved communications in, what they view as, their partnership relations with the airlines. They also expect to see their number decrease and the possibility of conglomerates made up of steamship lines, truckers, and airlines getting into the forwarding business. On the other hand, the airlines expect to educate the shipper on their door-to-door capability. Their success, however, will be dependent on reaching the appropriate decision-makers.

The shipper desires improved service above all and in this respect they are in favor of intermodality. Most shippers felt that intermodal capability will be a vital element of the future transportation system. They view intermodality in terms of single carrier responsibility with airfreight as a partner in a fully integrated transportation system. Such system satisfies the need for efficient door-to-door service while realizing single carrier responsibility. Shippers were in favor of airlines providing the door-to-door service as illustrated in Figure 2-8. They also saw the possibility of the conglomerate

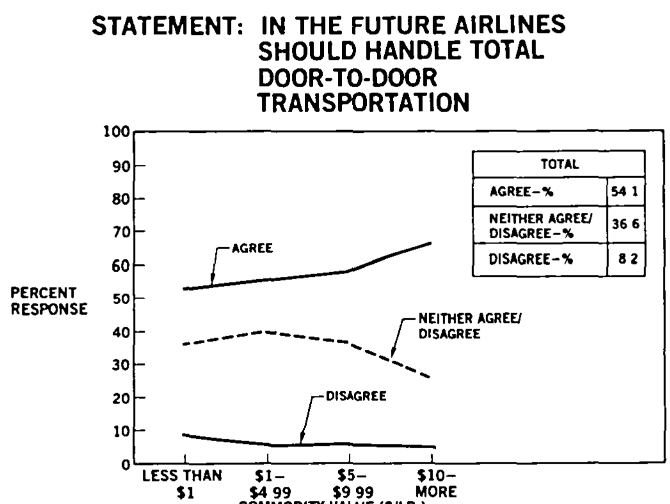


Figure 2-8. Door-To-Door Transportation

multimode groups suggested by the forwarders. These groups were visualized as providing worldwide forwarding services, including unbiased TDC analysis to the shippers. Some shippers hypothesized the demise of the combination carriers on the basis that passenger and shipper needs cannot be adequately satisfied on the same aircraft, schedules and routes.

One aspect of an intermodal system would be the increased use of containers. While the forwarders favored the 8x8 container the airlines expressed mixed feelings, pointing out such problems as aircraft weight and balance and the tare penalties occurring on weight limited flights. It was pointed out that while containerization offers service advantages, such as security, these are currently realized by forwarders and large shippers not by the small shipper.

Shippers had mixed opinions regarding the impact of deregulation on service and rates. On the whole it is seen as having negligible positive effects on the airfreight industry. Many felt deregulation would accelerate the separation of passenger and cargo services. Since deregulation will allow forwarders to acquire aircraft fleets, the forwarders postulated a resulting decrease in the differences between them and the airlines.

As shown in Figure 2-9 shippers were generally unresponsive to a 30 percent

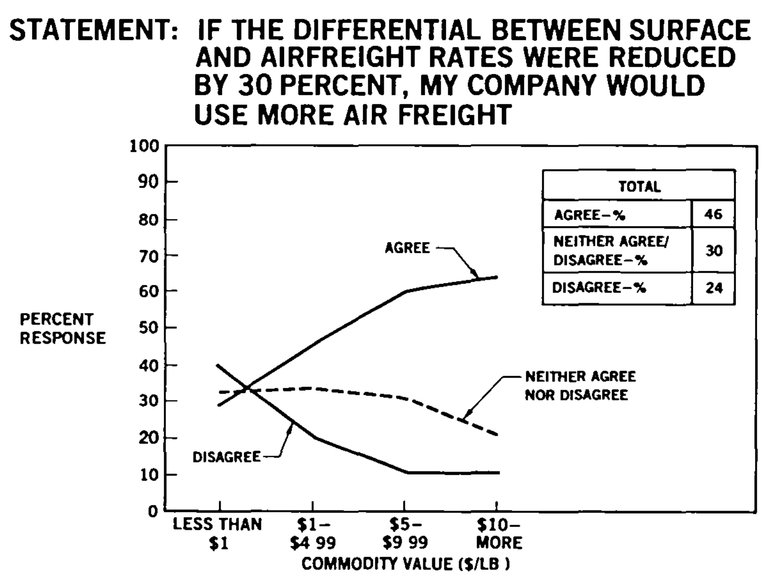


Figure 2-9. Airfreight Rates

rate reduction with interest being substantially greater for heavy airfreight users and higher value per pound producers. Some felt that a 60 to 70 percent reduction would be required to substantially stimulate planned, volume shipments. Regardless of their activity level, shippers want to know a single door-to-door price. They, therefore, foresee one combined tariff that will be computerized and stored by a central source with most documentation performed by data processing.

There was the general opinion that there is a definite need for more economical aircraft of different sizes assigned to different markets. There was no concensus as to the type or performance of these aircraft because shippers are not concerned with aircraft, per se, put with services provided and rates charged.

Section 3

THE AIR CARGO INFRASTRUCTURE

In achieving future industry growth the importance of the direct support infrastructure will become increasingly evident and unless given proper attention can seriously curtail the growth that will be realized. In this respect the airport, cargo terminals, and route networks were considered in the CLASS as being principal infrastructure elements having cross impacts with the cargo market and aircraft. Containerization was also addressed in depth recognizing that it is categorically linked with the aircraft, the cargo terminal, the surface transport system, the shipper and consignee, and the cargo being moved.

Airports

An airport complex is composed of two basic elements, the airside and landside, which collectively establish its operational capacity. On the airside the complex must be capable of efficiently handling varying sizes and number of aircraft and on the landside to effect time-phased transfer of cargo and passengers between aircraft and between the air and surface vehicles. Over the long run a balance between the airside and landside capacities must be achieved within the framework of the changing social, political, physical and economic environments. A task of the CLASS was to determine the current and future compatibility between the resulting airport capacities and the air cargo system requirements.

Detailed, on site, surveys in combination with published information were used to assess the impact of the airport elements on the total air cargo system. Surveys were conducted at LAX, JFK, ATL, ORD and DTW because these installations were considered as having problems and objectives typical of a majority of major air cargo centers. The forecast growth in air cargo flow through these airports as developed by the respective airport authorities, is shown in Figure 3-1. This growth, if realized, will exaggerate already existing problems. As an example, all five surveyed airports already have landside congestion, and

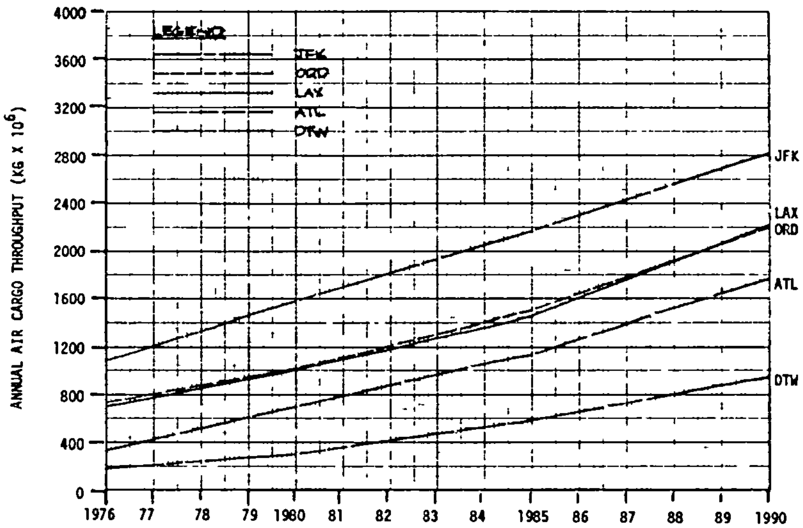


Figure 3-1. Air Cargo Forecast for Domestic Airports

environmental restrictions on operations and/or expansion. Ramp conditions limit the size and/or number of cargo aircraft that can be simultaneously loaded or unloaded at all but the Atlanta airport. Three of the five airports have runway congestion and/or some form of flow control. Congestion delays are already a very serious problem with the scheduled airlines. To illustrate, between 1968 and 1973 the increase in direct operating costs (DOC) due to airport delays (takeoff, landing and gateing) were twice the average airline earnings. Such deficiencies will become untenable in the light of further increases in fuel prices and decreasing availability.

Listed below are airports anticipated to be congested by 1990 for the reasons noted. Airports having the five highest levels of current all-cargo flights are designated by circles and appear on all three listings. Four of the airports, designated by the solid triangles, anticipated to have runway congestion already have flow control, while four of the remaining, designated by open triangles, are expected to have such controls by 1990. Some relief of the flow control problem can be expected from the advanced air traffic control (ATC) systems under development by the FAA. The 1987 system is expected to increase runway capacity up to 17 percent for intersecting runways and up to 35 percent for parallel runways. The gain for intersecting runways is less due to alternating departures and arrivals.

Runway Congestion	Apron/Gate Congestion	Ground Access Congestion
o ORD ▲	LGA	o LAX
LGA ▲	DCA	o JFK
o JFK ▲	o ORD	LGA
DCA ▲	BOS	BOS
BOS △	o SFO	o SFO
o SFO △	o JFK	MIA
o PHL △	o LAX	o ORD
DEN	CLE	CLE
ATL △	o PHL	o PHL
o LAX	DEN	DTW

Additional relief for runway congestion could be achieved with larger aircraft thereby reducing the frequency of required flights. However, in some cases this may lead to a reduced market due to the accompanying reduction in service. In addition, runway/runway, runway/taxiway spacing combined with pavement width and strength limit the size of aircraft that can operate at most of todays major airports to dimensions not much longer than the current B-747. The current ultimate constraint on wing span is the separation standard used in airport design. FAA standards specify 73 meters (240 feet) as the maximum span for future Group 4 airports. The maximum allowable tread width is 15.2 meters (40 feet). There is the additional requirement that all new aircraft must meet the noise standards of FAR Part 36 and the comparable ICAO CAN 5 discussed in Section 1.

All-cargo operations are fortunate in the sense that they want to occur during the hours when total operations are lowest as illustrated by Figures 3-2 and 3-3. However, night operations are seriously curtailed by the curfews invoked at domestic and foreign airports, a trend that is expected to increase in the future. The operational windows for international flights are greatly reduced when both the origin and destination airports have curfews. Such restrictions impact world-wide schedules and lead to scheduling problems, reduction in capacity offered and decreased aircraft utilization. At many airports night operations are further restricted by constraints on approach and departure procedures, use of reverse thrust, engine run-up, and on taxiing.

All large hub airports encounter problems directly related to aprons and gates and many have landside access problems. At some airports gate slots are already full during peak hours thereby prohibiting the expansion of operations

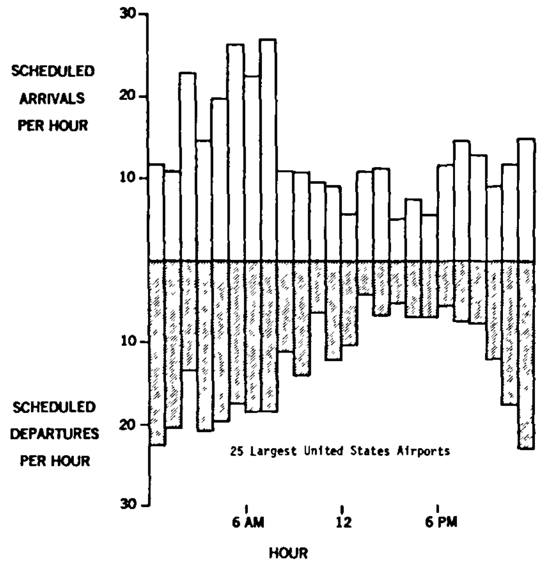


Figure 3-2. Total Scheduled All-Cargo Operations by Hour

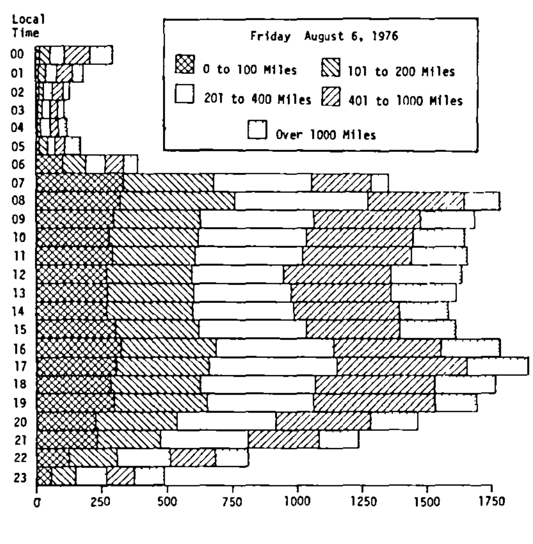


Figure 3-3. U.S. Total Top 100 Airports Scheduled Operations by Hour

even if the airport quotas are increased. At other airports the apron/gate layouts are such that they cannot accommodate a large wingspan aircraft unless the adjacent gate positions are empty or are occupied by a small aircraft. The current situation is therefore limiting, placing restrictions on the number and/or size of aircraft that can be accommodated by the current airport system. The improvements to be realized between now and 1990 are also limiting. At airports where expansion is possible, and provided environmental approval is obtained, it appears unlikely that the new aprons and gates will be designed for aircraft significantly larger than the current B-747. There will also be installations where the height (vertical tail) and/or length of aircraft will be limited by the manditory clearance established by a 7:1 slope originating at the centerline of instrumented runways. Any expansion of aprons and terminals must be such as to relieve or prevent landside congestion keeping in mind that cargo moves into and out of the airport during the hours of peak passenger traffic and coincident with the local rush hour traffic.

Although the FAA has identified the need for at least 10 new metropolitan airports it is unlikely that there will be any such construction until the 1990's. Over this same period expansions will be limited to terminals and runway extensions at a few major hub airports. Whether the airport is new or expanding, development will be constrained by environmental requirements along with capital and land availability. For at least the next decade the air cargo industry must operate within the framework of a domestic airport system that is not significantly improved over today's airports. Operators will encounter increasing airside delays and congestion that could exaggerate the fuel problems. Unless counterveiling action is taken the growth in air cargo will be handicapped by the retardation of new flights from the growing number of congested airports. A partial solution to this problem would be to increase the number of direct flights between uncongested airports instead of transferring at the congested hub airports. The problem would also be reduced if the airlines spread their transfer operations over many smaller hubs rather than a few superhubs. Such reduction and spreading of transfer traffic will reduce the need for a super-large aircraft but will increase the need for a slightly above average aircraft size.

All cargo operations could be established at general aviation airports, at surplus military bases or by joint use of military airports. Each choice has a unique set of social, political, physical, technical and economic considerations that must be resolved based upon location. Among these considerations is the time and distance to the area's center of commerce, surface transport available, and the transfer of belly cargo (currently about 54 percent of the world air cargo movement) to and from the passenger airport. In the case of a new dedicated cargo airport it is doubtful that revenues would be adequate to pay operating expenses plus debt retirement. However, whether for mixed or dedicated operations the design of new, or the modification of existing, airports must be closely coordinated with the aircraft industries design studies of future derivative and new aircraft.

Terminals, Ground Handling and Containers

The cargo terminal is the element in the air cargo system which controls and directs cargo movement and accomplishes interline transfers and the interchange between air and surface modes. In itself the terminal is a complex man-machine system operating within the airport environment and effecting and affected by the interfacing system elements. To assess these cross impacts and establish an interface with the 1990 scenario, on-site observations, statistical surveys, and analysis were conducted of 20 terminals located at the five study airports and operated by seven different airlines.

Results of the terminal analysis revealed a wide variation in productivity as illustrated in Figure 3-4. This performance is due to operational procedures as affected by cargo flow direction, quantity, and selectivity; air and surface vehicle scheduling; facility and equipment capabilities; personnel performance and costs; plus government constraints. Most of the main hub terminals are operating at 70 to 80 percent capacity and nearly all are limited in physical expansion by airport restrictions and/or the availability of adjoining land. These terminals cannot meet the forecast cargo flow levels for 1990 at current levels of mechanization and handling procedures.

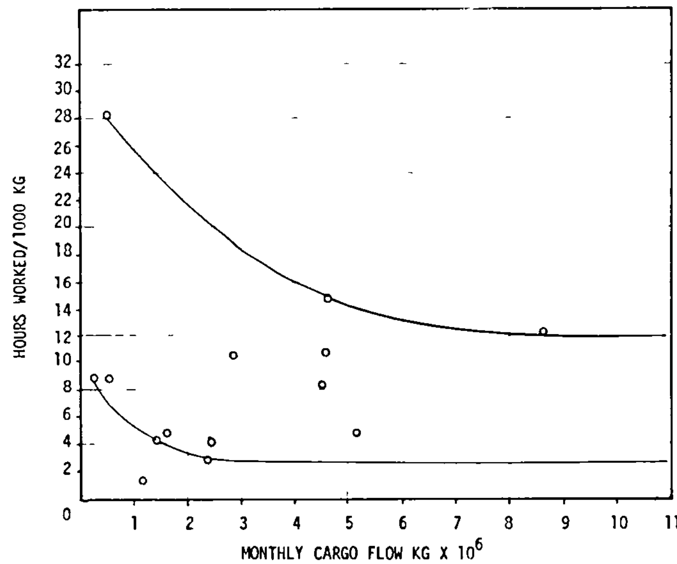


Figure 3-4. Monthly Cargo Flow Variations

To meet the 1990 flow levels with available terminals will require the productivity levels achievable with increased mechanization, containerization, and revised handling procedures. These revisions also provide an opportunity for reducing the indirect operating costs (IOC). The productivity per manhour for various types of cargo terminal processing equipment and operations is shown in Figure 3-5. The least productive operations are buildup/breakdown while the most productive are those performed by the elevating transfer vehicle (ETV), Figure 3-6, and the transporter. The close proximity of the latter shows that the level of diminishing returns on manpower reduction is reached once the terminal's functional operations are mechanized. However, further mechanization can increase capacity for a given floor area. Although not shown in Figure 3-5, conveyers may be an aid to buildup/breakdown, however, the large variations in size and types of freight tendered by the shipper present a severe handicap to complete automated sorting. Conveyers on-board the aircraft, such as the proprietory, automatic latching concept shown in Figure 3-7, can reduce the loading manpower by as much as 500 percent. Both the terminal and aircraft handling systems are achievable with current technology, provide for intermixed handling of air and maritime containers, and eliminate the current 440 kilogram (969 pounds) slave pallet currently required for handling maritime containers onboard the aircraft.

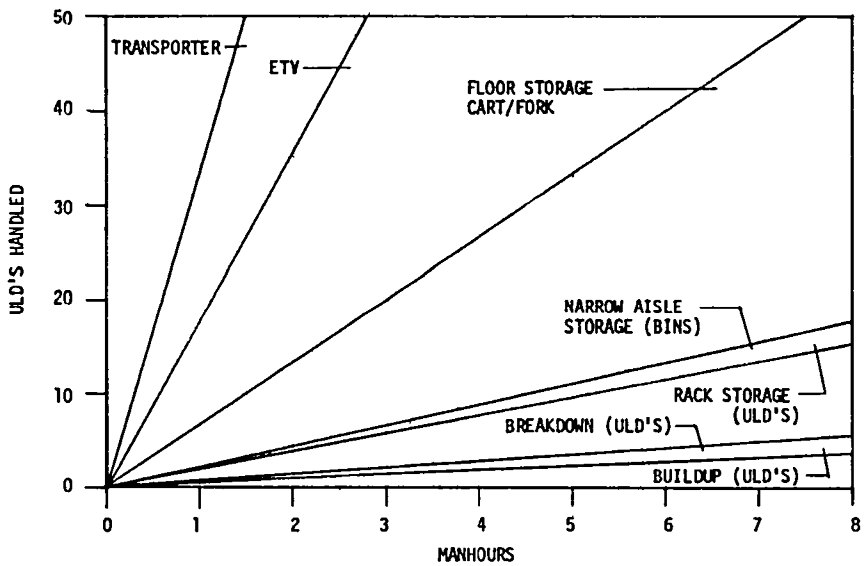


Figure 3-5. Functional Productivity Per Man

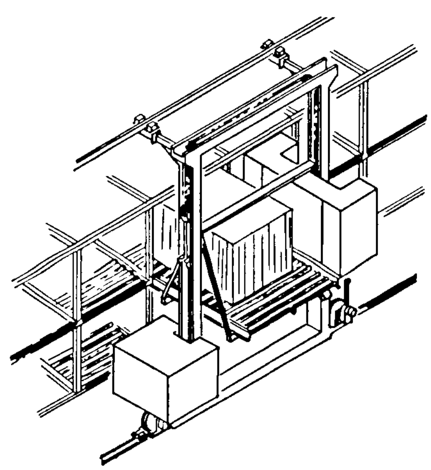


Figure 3-6. High Mechanization Elevating Transfer Vehicle

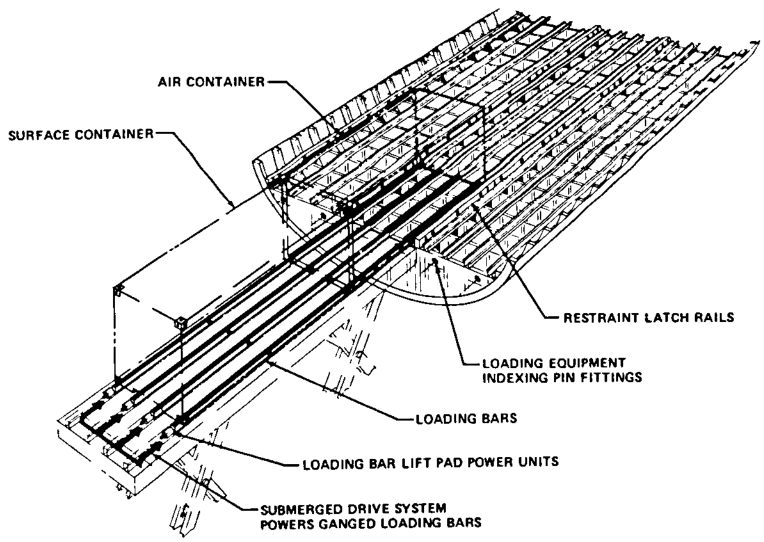


Figure 3-7. Loading-Bar Concept for Handling Air and Surface Containers

The floor area requirements associated with the mechanized functions exercised in buildup, breakdown, temporary shortage, and staging of unit load devices (ULD's) no larger than 2.4x2.4x3.2 meters (8x8x10 feet) type M containers are presented in Figure 3-8. As mechanization increases the required floor

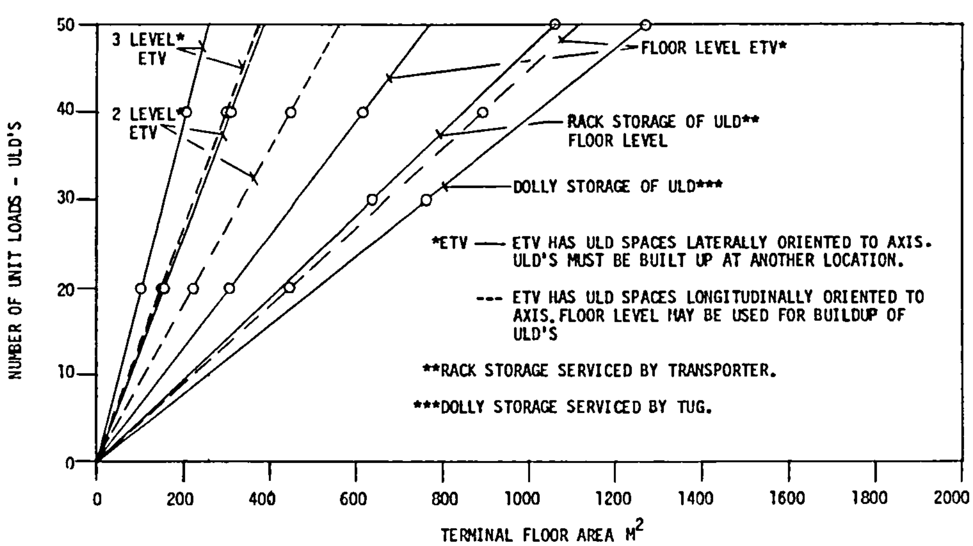


Figure 3-8. Area Requirements for Buildup, Breakdown and Staging

area decreases and/or the number of ULD's handled increases. Triple-level ETV stacking with longitudinally oriented space for ULD buildup or breakdown reduce the required floor area 70 percent compared to the dolly system. Such area reductions are extremely important to international terminals where the average import storage interval is about three days. It is unlikely that this storage can be reduced below 1.5 days without the institution of preclearance procedures through international agreements. However, decreasing import storage from 3 to 1.5 days in a mechanized bulk terminal will increase the processible flow capacity by 22 percent.

Terminal surveys have consistantly shown poor utilization of ULD volume due to time of tender, inadequate buildup techniques, and cargo selectivity. However, model tests and computer analysis has shown that cube utilizations (sum of cargo piece volumes ÷ ULD interior volume) up to 90 percent are practically achievable as shown in Figure 3-9. It is expected that revisions

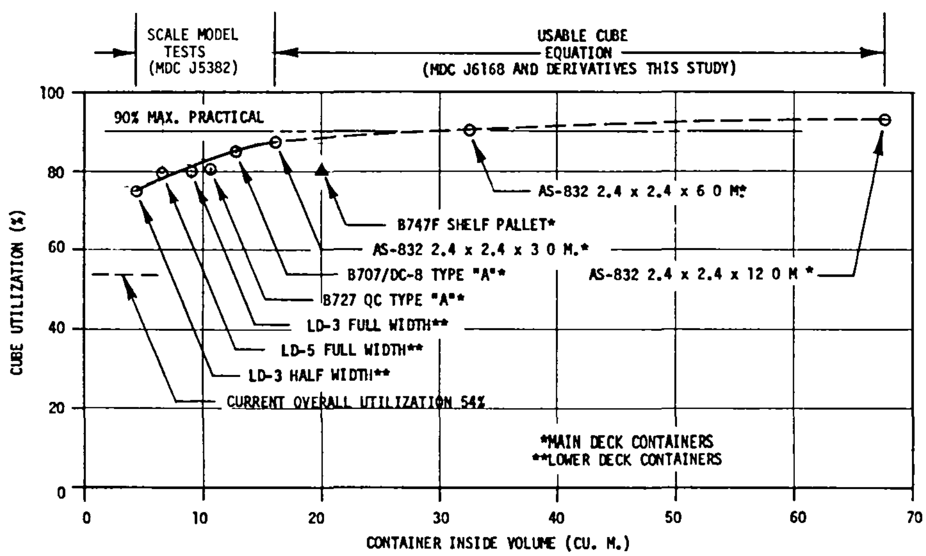
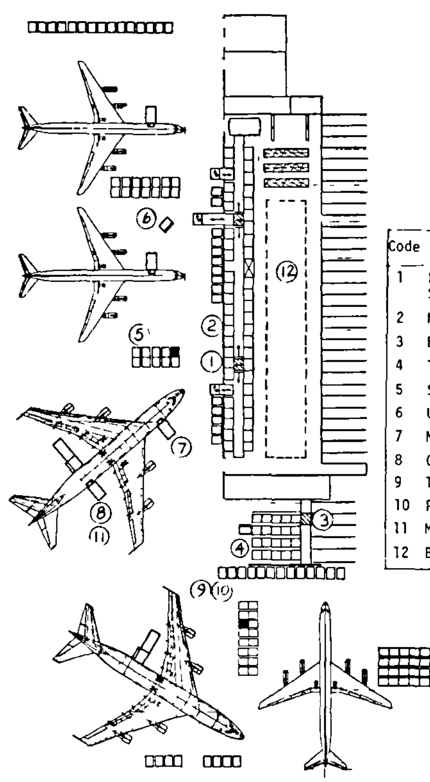


Figure 3-9. Achievable Maximum Cube Utilization

in ULD loading combined with increased availability and selectivity of pieces associated with the growing cargo market will make these levels of cube utilization achievable by 1990. Availability and selectivity can be enhanced by tariff structures that make allowances for a deferred level of service at lower rates thus maintaining a cargo backlog for opportunity fill-in. Increasing the mean cube utilization from the current 54 percent to 90 percent can reduce the number of ULD's handled by approximately 10 percent, a favorable contribution to making the existing terminal fit the future cargo flow. The resulting increase in loaded densities will have the added benefit of increasing revenues, decreasing the tare weight/cargo weight ratio, and increasing the airlift energy efficiency. However, consideration must also be given to the resulting increased loads on the aircraft floor, fuselage shell, and upon the payload design density for new aircraft.

A bulk terminal incorporating the preceding mechanization and operational changes is illustrated in Figure 3-10. It is anticipated that such terminal



Code	Description
1	Elevating Transfer Vehicles and Scales
2	Multilevel Cellular Storage
3	Bypass-Transfer Vehicles
4	Transfer Convey
5	Staging/Storage Racks
6	ULD Transporters
7	Main Deck Loaders
8	Container Pallet Loaders
9	Tugs
10	Pallet Dollies
11	Mobile Conveyors
12	Bulk Processing

Figure 3-10. 50 Percent Bulk Terminal High Mechanization

will encompass computerized documentation management to include billing; cargo routing, scheduling, and tracing to minimize interline transfer; flight scheduling; aircraft loading; storage scheduling; and customs documentation and clearance. Areas are provided for both bulk and customer loaded container (CLC) processing. The latter is of great benefit because CLC's eliminate the area and manpower intensive buildup and breakdown functions, they rapidly improve productivity even with low mechanization. The impact of CLC's on terminal and personnel costs are shown in Figure 3-11. Going from the current

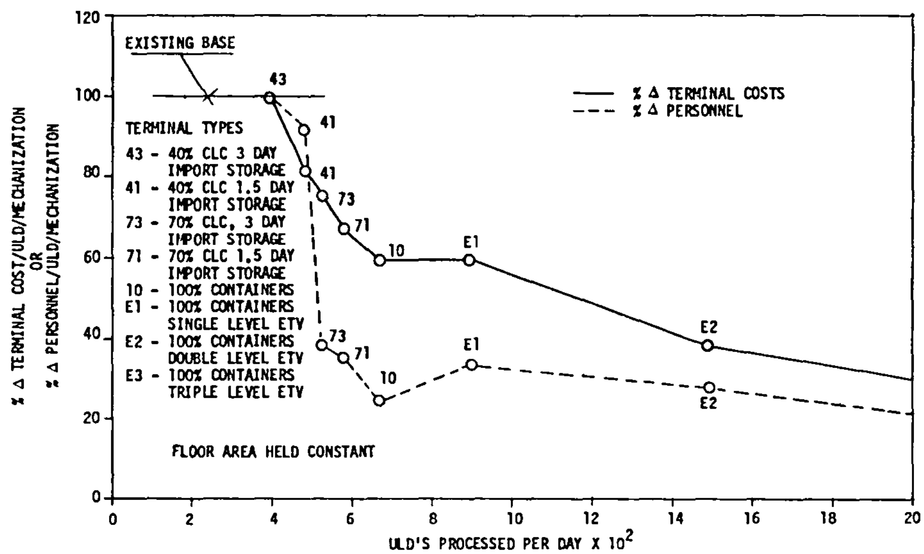
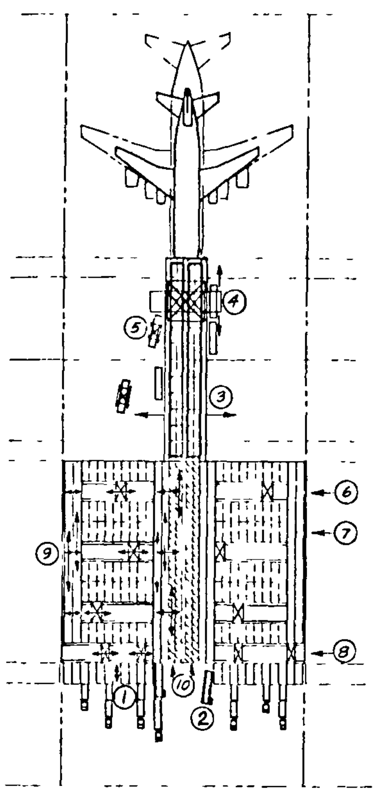


Figure 3-11. Operational Cost and Personnel Variation for All-Cargo Carrier

40 percent CLC's to 70 percent reduces personnel and terminal costs by 60 and 25 percent respectively. Reducing import storage from 3 to 1.5 days and eliminating bulk flow through the terminals provides additional 5 percent and 10 percent reductions in personnel and terminal costs respectively. The 100 percent container flow can be achieved through offsite bulk processing and CLC's. The latter shifts buildup/breakdown functions to the forwarders/shippers that must be compensated for by incentive tariffs. Although offsite processing by the airlines could require some increase in personnel and some duplication of equipment it moves the area intensive functions to lower cost land leaving the high cost airport area free for staging and aircraft loading and unloading. It also can reduce the landside truck traffic by a factor of 10 or more.

The adoption of mechanization will be achieved progressively and consistant with the growth in market demand, level of transfer operations, and the quantity of CLC's. As we move out into the future the quantity of CLC's will increase to 90 percent of the total air cargo flow by 1990. At that point in time the bulk processing area, reference Figure 3-10, will have nearly disappeared. This progressive development of terminals will culminate in the mechanized 2.4x2.4x6 meter (8x8x20 foot) M2 container terminal, illustrated in Figure 3-12, to serve



Code	Description
1	Truck Docks
2	Mobile Loaders
3	Aircraft Loading Dock and Positioning Carriage
4	Overhead Crane on Loading Dock
5	Straddle Lifts
6	Stacker Elevators
7	Multilevel Cellular Storage
8	Transfer Cars
9	Transfer Conveyors
10	Staging/Destaging Conveyors

Figure 3-12. High-Mechanization M-2 Container Terminal

the post 1995 dedicated air cargo aircraft. Although more costly than highly mechanized versions of present terminals, these M2 terminals will also be considerably more productive and as a consequence cost competitive on a cargo weight flow basis as shown in Figure 3-13. Although currently frowned upon by the U.S. airlines, additional savings can be realized through the use of joint terminals. As an example, the use of a single terminal by three airlines

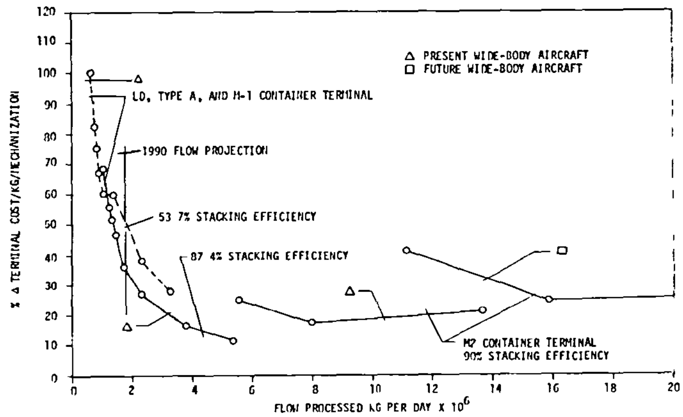


Figure 3-13. All-Cargo Flow/Cost Variation

would reduce container handling costs and the land area required by 50 percent compared to each airline operating its own terminal.

Until the advent of the dedicated cargo aircraft, designed to be compatible with industry preferred containers, terminals will continue to be handicapped by the large variety of ULD's designed for belly operations and to fit cargo aircraft derived from their passenger counterparts. Although containers have the advantages of better cube utilization and improved security, the pallet will continue to be used by some airlines on weight limited flights, ranges greater than about 6000 kilometers (3729 statute miles), where the three to four times less tare weight is a major concern. As the air cargo service improves and intermodel operations, such as air bridges, expand, the air transport of maritime containers will increase in frequency in spite of the 2.7 to 2.4 times greater tare weights compared to the comparable 6 and 12 meter (20 and 40 foot) air containers.

As the air cargo system expands attention will be directed to improving the compatibility of containers not only with air operations and terminals but also with shippers and consignees and with the intermediate surface transport links. Additional certification requirements will be imposed on design and construction which, when met, will allow the resulting sealed, tamper-proof containers to cross all common borders of participating countries without being opened for customs inspections. Advances in material and manufacturing techniques will result in 30 percent reductions in tare weight and manufacturing cost of intermodal containers. One such concept, shown in Figure 3-14, is currently being developed by the McDonnell Douglas Corporation. The growing

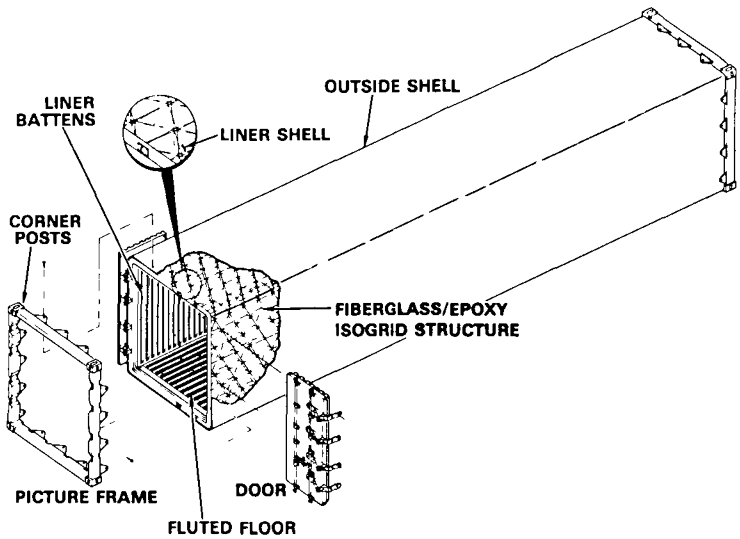


Figure 3-14. MDAC 40-Foot Isogrid Intermodal Container

use of containers, a necessary approach to assure efficient intermodal operations, will stimulate the development of unique, hybrid container designs that are compromises between security and weight. Included in these designes will be modular configurations directed to reducing inter and intraline transfer operations while maintaining load integrity.

Air Networks

The route network with its associated origins and destinations combines with operational frequency to provide the necessary service to meet the growing air cargo market demand. The following discussion addresses possible future changes in this service postulated to occur due to potential variations in international economics and institutional patterns.

The network formed by the worldwide scheduled all-cargo airport-pairs for August 1978 is shown in Figure 3-15. The greatest change in this network will

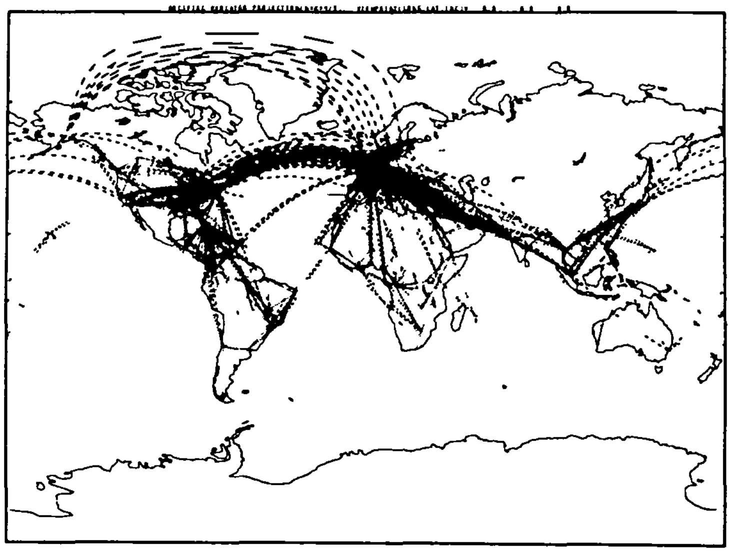


Figure 3-15. Scheduled All-Cargo Airport - Pairs, OAG August 1978

occur in U.S. Domestic routes where the impact of deregulation will materialize over the next 3 to 5 years. During this period the expansion of existing and the entry of new airlines, both cargo and communter, will provide a proliferation of the number of cities served. The result will be a 15 percent increase in cities served at stage lengths less than 3000 kilometers (1865 statute miles). To avoid an increase in the air traffic at already congested major domestic hubs there will be a diffusion and an increase in the number of transfer hubs thus reducing the need for very large aircraft to handle inter-hub traffic. Such changes in the air network have the potential to affect changes in domestic commerce including a shift in the location of some activities. As an example, the shift from distributed to central warehousing.

Due to international agreements potential changes in the international network are less apparent. In the event there is a revision of the approach to such factors as frequency, routing, gauge change, and Fifth Freedom cargo throughput in multilateral agreements, there should be an accompanying increase in cargo flow over ranges less than 5000 kilometers (3100 statute miles). Changes in the principles of such agreements will facilitate network revisions employing the hub-spoke and itinerary routing concepts.

In the hub-spoke concept cargo is delivered to the hub by surface mode or by short-haul aircraft, is consolidated, and proceeds to the destination hub aboard a larger, long range, cargo aircraft. This approach has the potential, as illustrated in Figure 3-16, to substantially reduce, or eliminate, the

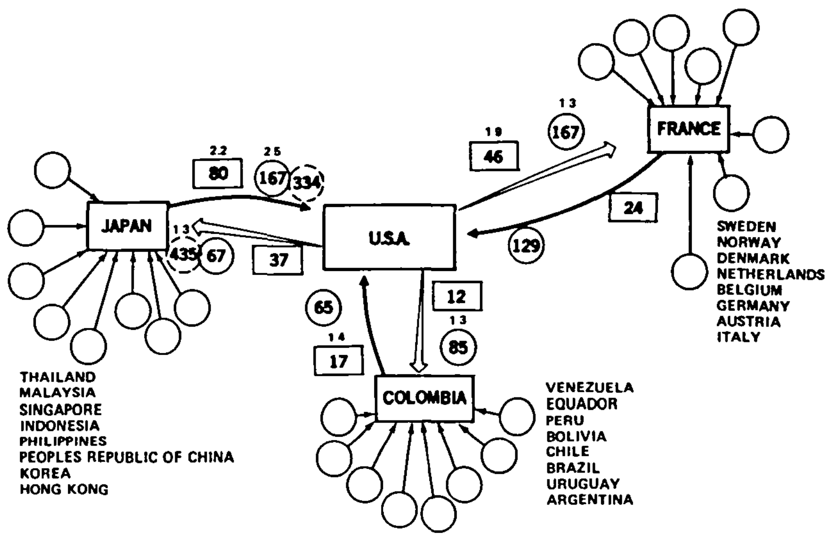


Figure 3-16. Hub Concept - Backhaul Balance (1000 Tonnes)

backhaul problem so prevelent in current international operations. In this example the hub cities, New York, San Francisco, Paris, Bogota, and Tokyo, are fed by spokes to the surrounding countries noted in the figure. The quantities of air cargo that moved between hub countries during 1976 are given in the boxes and show the imbalance in exports to France and Colombia, and in imports from Japan. When the spoke flows are added, given in the solid circles, the imbalance with France is greatly reduced and reversed in the case of Colombia. In the case of Japan, combining the hub and spoke flows exaggerated the 1976 imbalance. However, based upon the 1990 forecast cargo flows, dashed circles, the imbalance with Japan was shifted to the export side. These data indicate that air cargo sales efforts working in unison with implementation of the hub-spoke operations could do much to relieve back-haul problems in the future. Acceptance of the hub-spoke concept in international operations would tend to shift emphasis to larger aircraft and to all-cargo airports. However, dedicated airports, being separated from passenger operations, would give rise to difficulties in the transfer of belly-pit cargo.

Section 4

SYSTEM SERVICE, ECONOMICS AND MARKET DEMAND

The air cargo industry grew substantially over the six years prior to 1976 with revenue tonne-kilometers increasing at average annual rates of 5 percent domestically, 9 percent internationally and 14 percent in the foreign markets, while tariffs (rates) declined 1.6 percent in real terms. However, with todays perspective this industry appears to be in its infancy with the largest growth yet to come. To bring about this growth and the required system changes intelligently and effectively will require advanced and comprehensive planning. This section, therefore, examines a key element of this planning effort, the relation between system service, economics and cargo market demand as affected by the infrastructure and the transporting aircraft.

Rate and Service Elasticity

An elasticisty model was developed and exercised to examine the relationship between market demand and air cargo rates for all-cargo operations. Application of this model over the period 1968 to 1976 provided the results shown in Figure 4-1. Except for the oil embargo years, 1974 and 1975, the model estimated demands were very close to the Civil Aeronautics Board (CAB) actuals. As Gross National Product (GNP) increased the demand, revenue tonne-kilometers (RTK), increased and was accompanied by a steady decrease in real airfreight rates. Since 1973 the real domestic airfreight rates have behaved erratically thus contributing to some of the variations in demand. The slopes of the GNP and yield scales show that market demand has been more influenced by GNP and much less significantly by changes in air cargo yield/service. This supports the common thesis that past market demand has been relatively inelastic with respect to air cargo rates.

Utilizing the model the question of elasticities was investigated in detail. Results showed GNP to be the most important influencing factor with a demand

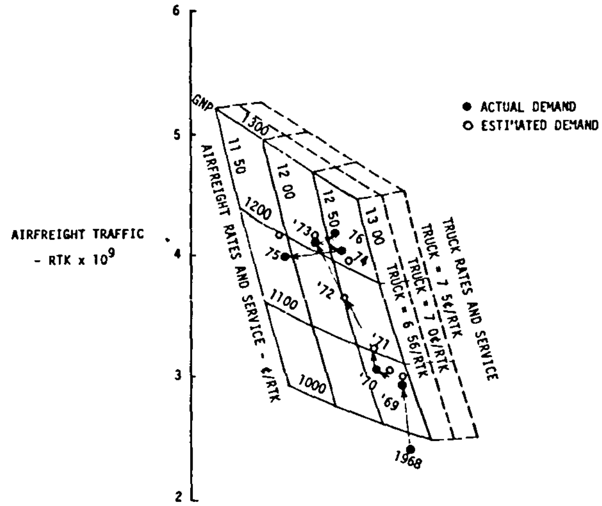


Figure 4-1. Cargo Flow as a Function of Gross National Product, Airfreight Rates and Service

elasticity of +2.2 for all-cargo operations. The next most significant factor was the air rate with an elasticity coefficient of -1.3 followed by truck tariffs with a coefficient of +0.1.

Due to the lack of data, a research technique known as Conjoint measurement was employed to produce utility measures of air cargo service. Figure 4-2 presents the results of a commercial market research study with the ordinate being a normalized measure of relative utility. As delivery time and tariffs increase the utility of air decreases. Delivery time is based upon shipping at the close of business and shows that a noon delivery, 19 hours later, is worth only 60 percent of a 9:00 a.m. delivery. In terms of elasticity these data provide a coefficient of -3 percent thus supporting the marketing philosophy that overnight delivery of airfreight is a differentiated product.

As the number of destinations (cities served) increase the utility of air transport increases, however, the effect is considerably less than for either tariffs or time (Figure 4-2). These data indicate a demand coefficient of +1.5 associated with increased destinations. This value along with those discussed above are presented in order of importance in the following listing.

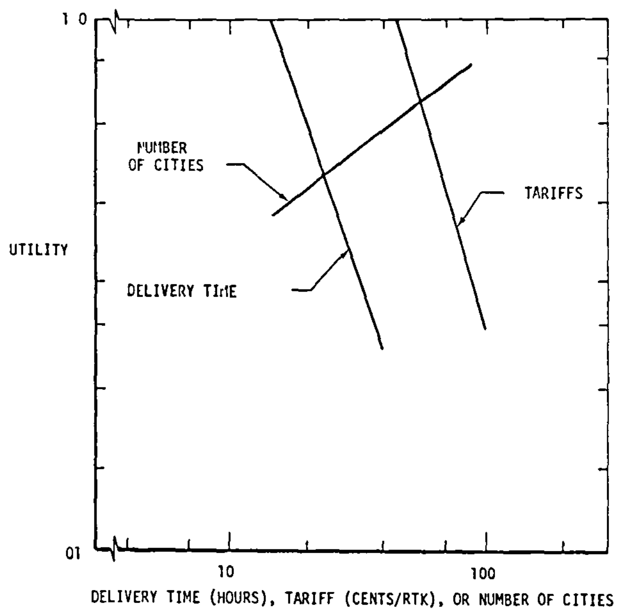


Figure 4-2. Relative Utility of Delivery Time, Tariff and Number of Cities

Values shown provide the percentage change in demand resulting from a +10 percent change in the causal variables.

Causal Variables	Change in Market Demand (%)
GNP	22
Air Cargo Tariffs	-13
Delivery Time	-3
Cities Served	1.5
Truck Tariffs	1

System Economics

Between the years 1972 to 1974 the CAB conducted an in-depth investigation, Domestic Airfreight Rate Investigation (DAFRI), of the cost elements associated with air cargo operations. Although the resulting multielement rate structure is no longer applicable under deregulation, the work represents the most comprehensive study of capacity and noncapacity causative cost factors with a major achievement being the definition of noncapacity terminal costs. The resulting rate structures, updated to 1977, were employed to perform detailed analysis of the elements of total operating cost (TOC) and their relation to short- and long-term rate making.

Despite the growth of the air cargo market and a cost structure that has exhibited increasing returns to scale, cargo carriers have not been able to achieve the consistant profits necessary to induce the capital investments required to serve future growth. Profits can be increased through reductions in the indirect (IOC) and direct operating costs (DOC). Encompassed within the former are the costs associated with the terminal which can amount to 28 to 83 percent of the total revenue depending upon the range flown. Terminal improvements provide the added incentive of avoiding the terminal saturation discussed in Section 3 and illustrated by the domestic terminal data of Figure 4-3. Even

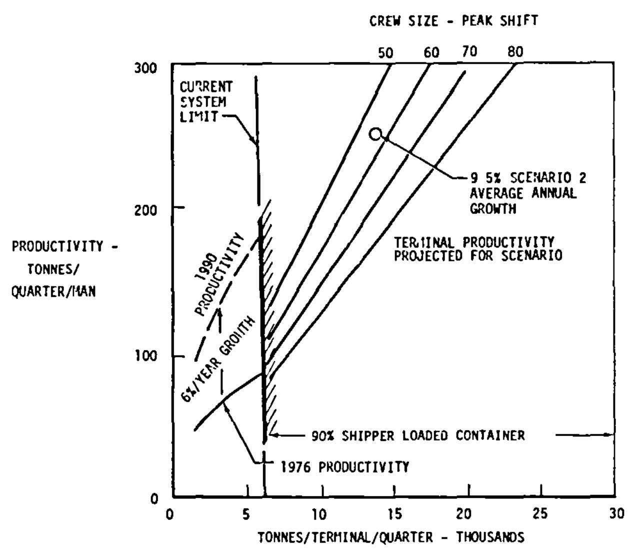


Figure 4-3. U.S. Domestic Terminal Productivity vs Tonnes

if the 6 percent annual improvement in productivity realized over the past six years continues until 1990 the terminal capacity associated with the current bulk processing approach will fall far short of the capacity required to meet the forecast 9.5 percent average annual domestic market growth. However, by going to 90 percent shipper loaded containers and vertical storage the necessary throughput capacity would be achieved with no increase in terminal area and would provide a 23 percent reduction in IOC. This saving is primarily due to manpower, the gain due to technically improved handling equipment, such as elevating transport vehicles (ETV), is much smaller providing an additional 6 percent reduction in IOC.

The improvement in returns to scale realized in the past is forecast to continue as illustrated in Figure 4-4. This improvement when applied to the

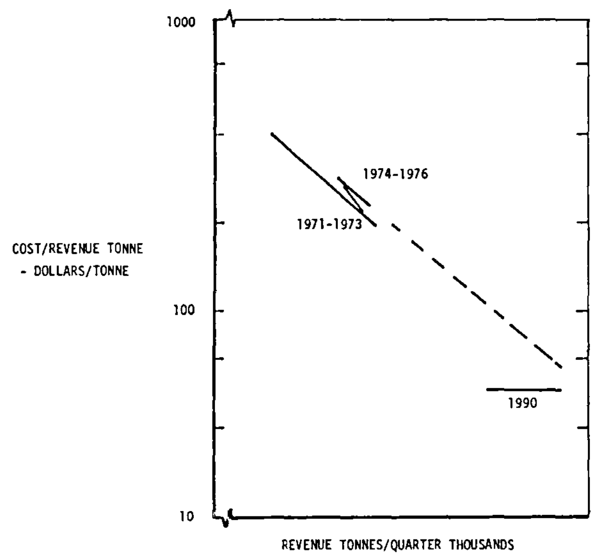


Figure 4-4. Indirect Operating Cost vs Revenue Tonne

areas of sales promotion and corporate staff provides a 15 percent reduction in IOC. Very few people must be added in the sales and management staffs to accommodate a large increase in revenue tonnes.

As these and other infrastructure developments are implemented there will be a shift in the relative importance of the respective elements making up the total tariff. This behavior is illustrated by the results shown below.

Year	Percent 1976	1990
Direct Operating Cost (DOC)	57	69
Indirect Operating Cost (IOC)	39	24
Profit (Before Taxes)	4	8
Tariff	100	100

Increases in the price of fuel above the 48 cents per liter (181 cents per U.S. gallon) forecast for 1994, will exaggerate the difference between DOC and IOC. The increasing importance of DOC will force increased emphasis on aeronautical technology and design on the one hand and improved aircraft utilization (scheduling) on the other.

As discussed in Section 1, Competitive Modes, the air cargo industry is capital intensive, a fact partially responsible for the cargo industries poor profit picture. The reason for this becomes evident when the cost factors for scheduled all-cargo service are grouped according to their relationship to the system as illustrated by the 1976 data below.

Flight Related Costs	49%
Payload Related Costs	33%
Investment Related Costs	13%
Management Related Costs	5%
Total Operating Cost	100%

The investment related costs, 13 percent in 1976, can be expected to become even more significant with the potential to affect the types, size and number of aircraft desired by the industry. This is illustrated in Figure 4-5 which compares a new, military/commercial cargo aircraft to the current B747-200. While the new aircraft shows a fuel consumption improvement of about 4 percent its DOC is 10 percent greater due to the increased cost of depreciation associated with the more expensive new aircraft. Factors affecting depreciation include aircraft price, utilization, useful life, and payload. Price is the more powerful of these factors and is directly related to the number of aircraft produced as illustrated in Figure 4-5. The importance of increasing the production run and of decreasing development and production costs to achieving an economically viable aircraft program cannot be overemphasized. The reduced fuel costs achieved with a new aircraft can be more than offset by the accompanying increases in depreciation and insurance.

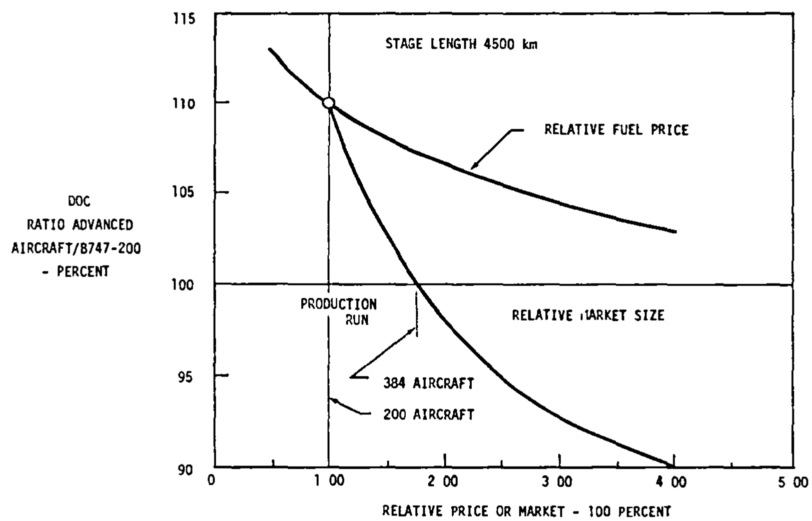


Figure 4-5. Relative Direct Operating Cost vs Relative Fuel Price and Advanced Aircraft Market Size

The effect of an advanced technology, dedicated cargo aircraft on fleet economics was determined on the basis of a 154 tonne (169.7 ton) payload aircraft entering service in 1990. Over a 10 year period this aircraft could capture at least 45 percent of the cargo market and would have a fuel consumption 29 percent below that of the B747-200. Values of DOC were first derived using the standard modified ATA method and based on a production of 200 aircraft. The resulting costs were then adjusted by factors to relate the calculated values to real world values. These adjustment factors were determined on the basis of actual airline experience in operating the B747-200. Except for the depreciation and insurance elements the adjustments were small. The resulting reduction in DOC of the advanced technology aircraft compared to the B747-200 varied between 23 and 13 percent as respectively determined by the ATA and adjustment methods of computation.

Perturbing the DOC analysis showed that one of the largest benefits occurring to the 1990 system could be realized by increasing the average aircraft load factor from the current 65 percent to 70 percent. This could be realized through improved cube utilization (54 to 85 percent) and aircraft loading as discussed in the preceding section. This change alone would provide a 7 percent reduction in DOC without additional investment.

It is anticipated that a coordinated effort will occur between the FAA, airport authorities, the airlines and the aircraft manufacturers in the integration of new technology and intermodal capabilities. The resulting aircraft/airport compatibility improvements in operations will provide an additional 4 percent reduction in IOC. Additional reductions in IOC can be realized, as previously discussed, through the increase in CLC's, 23 percent; improved terminal mechanization and handling procedures, 6 percent; and through economies of scale relative to management and sales staffs, 15 percent. Terminal reductions were based upon the data of Section 3.

In total, the proceeding future changes can result in a 20 to 30 percent reduction in DOC and a 48 percent reduction in IOC as noted in the first two columns of Table 4-1. Translating these values into fleet reductions in the

TABLE 4-1.

POTENTIAL COST AND TARIFF REDUCTIONS

Year Possible	Improvements	Percent Reductions			
		DOC	IOC	TOC	Tariffs
1978-1985					
	Increased Aircraft Load Factor (65-70%)	7		4	4
	Shipper-loaded Containers (90%)		23	10	9
	Reduced Terminal Storage (3-1 5 days) with Vertical Storage and Improved Handling Equipment		6	2	2
	Sub Total			16	15
1985-2000					
	Improved Aircraft/Airport Compatibility		4	1	1
	Economy of Scale (Avg Annual Total Cargo Market Growth of 10 7%)		15	6	6
	Advanced Technology Dedicated Freighter	13-23		7-12	3-6
	Sub Total			14-19	10-13
	Increased Airline Profit				-4
	Totals	20-30	48	30-35	21-24

1990 to 2000 operating environment, with adjustments for the profit element and the fact that the advanced aircraft make up less than half the fleet, results in the TOC and tariff reductions presented in columns three and four. Combining the potential tariff reductions with a 4 percent increase in profit to stabilize airline earnings results in a potential net tariff reduction of 21 to 24 percent. Attention is called to the fact that changes possible in the pre-1985 period can be achieved with currently available technology yet produce potential tariff reductions as great as those achievable in the 1985 to 2000 period with advanced technology. Because advanced freighter concepts will make up only a part of the total fleet for many years following their introduction only 3 to 6 percent of the tariff reduction is traceable directly to these advanced freighters.

It is quite likely that a portion of the tariff reduction identified in Table 4-1 will be absorbed for increased profits and/or incentive tariffs directed toward increasing customer-loaded containers, productivity, container volumetric utilization, and aircraft load factors. Such incentives will be stimulated by the innovative challenges of the new domestic entrants under deregulation.

In the light of the potential cost reductions to be derived through system changes, the direct and indirect operating costs were investigated from the standpoints of "by-product" (belly pit) and "joint cost" (all-cargo) costing approaches. The cost criteria used was the minimum the operator would be willing to accept over the short and long run respectively. Results showed the range of "rational" tariffs to vary by a factor greater than 6, based upon a bulk shipment of 1000 kilograms (2203 pounds) and 49 pieces over 4500 kilometers (2797 statute miles). These data illustrate the thinking underlying the reduced belly cargo rates offered by some combination carriers since deregulation. For the all cargo carrier, tariffs must be sufficient to recover all costs (flight, payload, investment and management related) while the combination carriers can rationalize some degree of marginal costing in the light of their passenger revenues.

In general, there has been little evidence of aggressive tariff reductions aimed at increasing the cargo market. At best a partial explanation of this behavior can be seen in the industries perception of rate elasticity. Based upon an equity ratio of 45 percent and an interest rate of 8.5 percent the current market would favor price increases over decreases at price elasticities less than -1.33. Since individual industry members preceive elasticities less than one there is no temptation to reduce prices but rather to increase them in an attempt to maximize profits to provide adequate returns or to facilitate further growth. Long run rate making behavior will be even more conservative because volume-inducing rate reductions will be made only in highly elastic markets, price elasticities greater than -3. Therefore, in the future there will be a strong general tendency in the industry toward tariff stability with increased profits and improved return on investment (ROI).

Cargo Market Demand

The air cargo market forecast to the year 2008 was developed in two phases. The first phase developed the baseline total scheduled airfreight market forecast based upon a sound background of current and past operations, including regional traffic flows (city-pair and country-pair) for the U.S. Domestic, U.S. International, and 44 Foreign carrier markets. Econometric behavioral equations were developed for each market considering GNP growth, inflation, currency rates, and inter-model price ratios. Compounded annual growth rates of 9.5, 8.3 and 14.3 percent were derived for the U.S. Domestic, U.S. International and Foreign markets respectively. The higher growth rate of the foreign market is due to the anticipated increased trade with and between the currently underdeveloped regions of the world. The larger portion of this trade will be captured by foreign airlines.

The second phase developed the forecast for the all-cargo portion of the market. In this phase the baseline forecast was modified to account for system induced growth and the mail and express components of the cargo market. System induced growth was based upon the system changes and elasticities discussed earlier in this section. Additional changes considered included the market impact induced by the improved service provided through increasing the number of cities served and reducing the average import storage time from three to 1½ days. With the exception of the impact of increased airline profit, the induced growth factors were all positive ranging from a plus 1.3 percent due to aircraft-airport compatibility to 11 percent for achieving 90 percent shipper loaded containers.

One of the more important factors affecting the sizing of future air freighters is the expected market share to be carried in these all-cargo aircraft. For the three markets combined, the weighted all-cargo share was forecast to increase from 44 percent in 1978 to 60 percent by the year 2000. This 16 percent increase was considered a viable change over the 22 year period. The resulting forecasts for each of the three markets are presented in Figure 4-6. The associated average annual compound growth rates for the

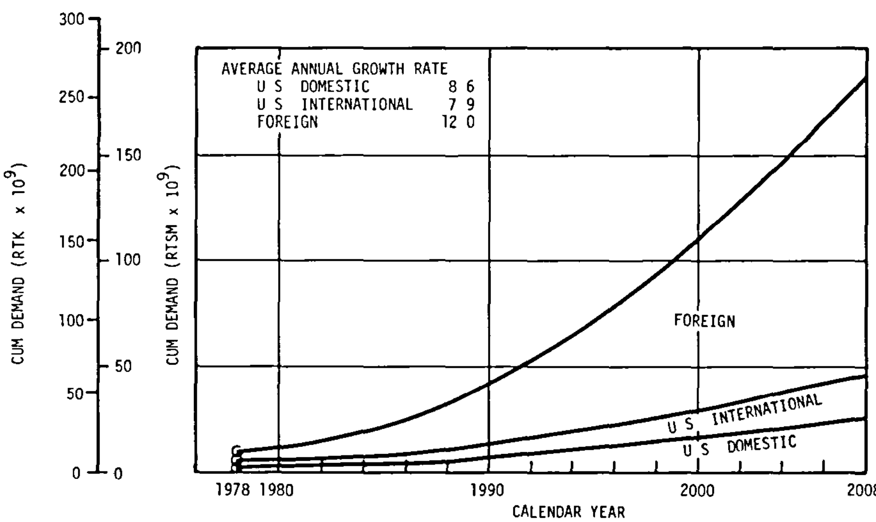


Figure 4-6. Air Cargo Market Demand Forecast for All-Cargo Aircraft

period 1978 to 2008 are 8.6 percent for U.S. Domestic, 7.9 percent for U.S. International, and 12 percent for the Foreign market. The average annual compound growth rate for all three markets combined is 10.7 percent. To realize this growth will require a concentrated sales effort by the air cargo industry conducted in an atmosphere of providing service and meeting the needs of the shipper. Any meaningfull expansion of the air cargo share of the total world freight movement will require the cultivation of high volume shipments on a regular basis as already pointed out in the preceding sections.

Section 5

FUTURE AIR CARGO AIRCRAFT

The final task of the CLASS directed attention to the Future Requirements of Dedicated Freighter Aircraft to Year 2008. Recognizing that a lower direct operating cost is not a sufficient criterian upon which to base a decision regarding the selection of a specific aircraft design, investigations also considered the interrelations with the system infrastructure, institutional barriers, and system economics. Among the economic parameters considered were the airline investment required, the accompanying levels of cash flow and operating income, and the return on investment to the airlines and aircraft manufacturers. These parameters along with fleet mix and aircraft characteristics were evaluated using the Douglas Future Requirements and Advanced Market Evaluation (FRAME) simulation program outlined in Figure 5-1. The input model

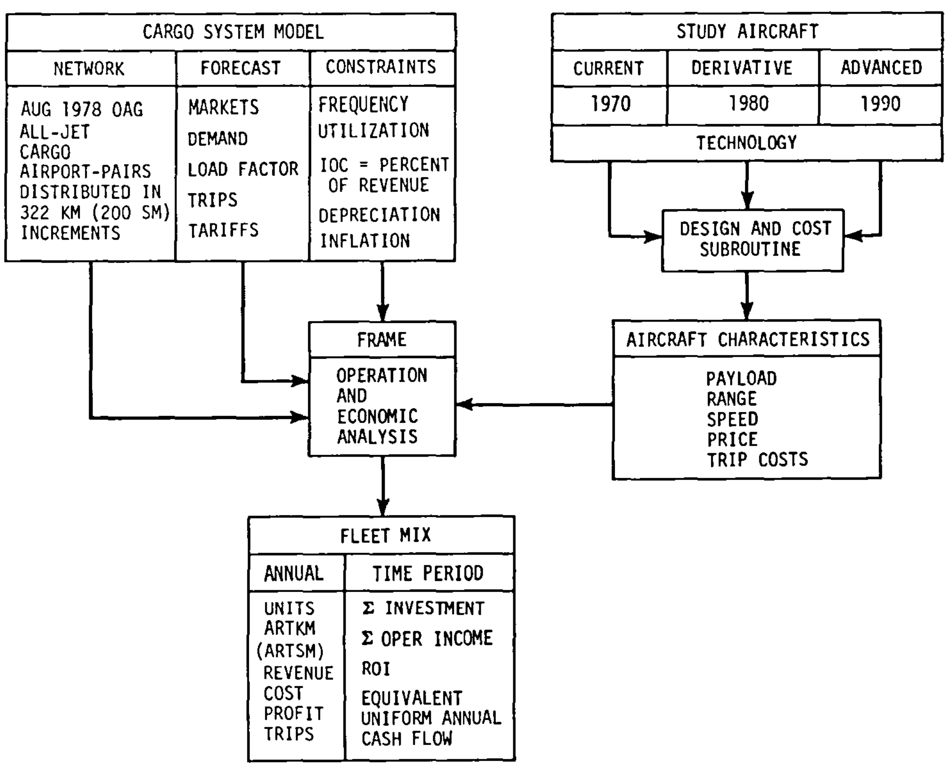


Figure 5-1. Future Requirements and Aircraft Market Evaluation - FRAME

encompassed the world air cargo network shown in Figure 3-15, forecast network characteristic and constraints, and the all-cargo market demand presented in Figure 4-6.

Simulation of the world air cargo network provided the means for competitively determining the fleet of current type aircraft to the year 1992. Subsequently this fleet competed with the new derivative configurations projected to enter airline service in 1985 thus defining the fleet of current and derivative aircraft to compete with the new dedicated freighters to become operational in 1995. Results of these competitive fleet analysis provide solutions based upon the optimum use of available aircraft operating over the world air cargo network and upon the forecast market demand and system variables. However, one must bear in mind that exterior forces acting in the future environment could cause the airlines to deviate from the aircraft acquisition and disposal sequences noted herein. The results do provide a viable guide to preferred action.

Current Aircraft 1978-1992

Analysis of the current aircraft fleet considered fifteen generic types of all-cargo jet aircraft which fell into three distinct size categories. Averaging the capabilities and characteristics within each of these categories lead to the identification of the three representative models defined in the following table.

REPRESENTATIVE AIRCRAFT CHARACTERISTICS

Model	Types Represented	Design Range- KM (SM)	Design Payload- Tonnes(Tons)	Cruise Speed- M
A1	Small Narrow-Bodies (7 Types)	3806 (2356)	14.2 (15.6)	0.78
A2	Large Narrow-Bodies (5 Types)	5149 (3200)	42.9 (47.3)	0.80
A3	Wide-Bodies (3 Types)	7023 (4364)	94.7 (104.5)	0.85

The analysis of current aircraft was extended out to the year 1992 based upon the most effective fleet utilization of the three representative aircraft. If available either as new and/or as re-engined passenger aircraft conversions, the number of A1 and A2 units could increase 20 and 60 percent respectively as shown in Figure 5-2. The A1 phases out in the early 80's and the A2's reach

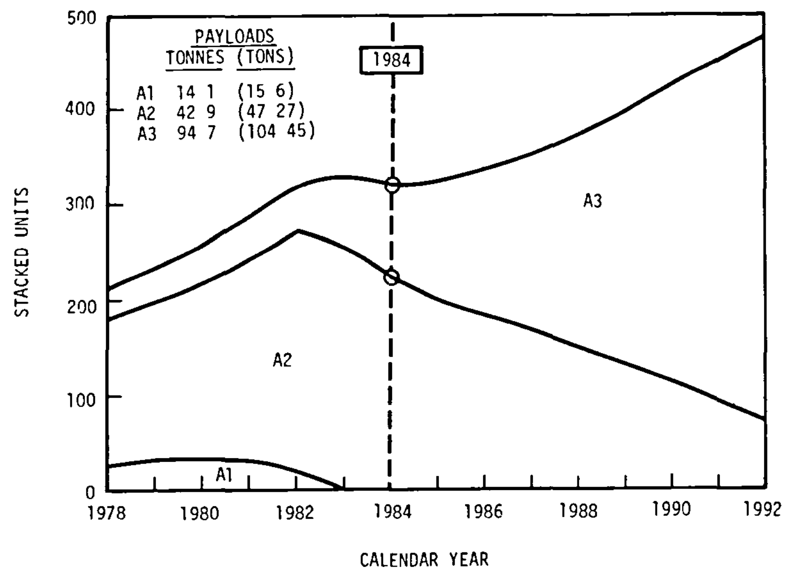


Figure 5-2. Fleet Mix 1978-1992 Reference Fleet

a maximum in the mid-80's. As the market demand grows the large narrow-bodies replace the small narrow-bodies and are in turn replaced by the wide-bodies. In the international market DC-10 and B747 combi aircraft (cargo and passengers on main deck) are being substituted for the A2's and are thus contributing to the market growth. In the absence of new more efficient aircraft, the number of A3's could increase to nearly 400 units by 1992. In spite of the shift to larger payload aircraft the cargo market demand is sufficient to result in a continuing increase in fleet departures (trips) amounting to an average annual growth rate of about 7 percent.

1980 and 1990 Technology

Based upon the cargo market demand and the reduction in aircraft research, development and testing (RD&T) cost due to component carryover and the added production of passenger versions, it was concluded that the 1985 generation aircraft would develop as derivatives of contemporary configurations. Selection of technology developments applicable to these aircraft considered 1980 availability and the limitations imposed by the derivative approach. These 1980 developments were viewed as an interim step toward achieving the 1990 level of technology which will encompass composites in primary structure, adhesive bonding, energy efficient engines, improved airport/aircraft compatibility, active flight control, and improved aircraft systems. The incremental changes to aircraft design parameters resulting with the 1980 and 1990 levels of development are presented below based upon the respective values for contemporary wide-body A3 aircraft.

IMPACT OF TECHNOLOGY DEVELOPMENTS

	Incremental Changes Relative To Current Aircraft									
Design Parameters	ΔW_{P+N}	ΔW_{STRU}	$\Delta L/D$	ΔSFC	ΔW_{ENG}	ΔW_{FURN}	Mgr. Cost		Maint. Cost	
							A/C	Eng.	A/C	Eng.
Derivative 1980 Tech	-8%	-11.2%	+4%	-8%	-2%		-1%			
Dedicated 1990 Tech	-24%	-32%	+11%	-13%	-4%	-9.5%	-14%	+7.2%	-2%	-5%

Derivative Aircraft 1984-1998

To define the size, fleet operations, and economics, of the derivative aircraft a range of parametric models were each competitively evaluated in fleet operations against the reference fleet of representative A2 and A3 aircraft. Payload size was varied between 22.7 and 181.4 tonnes (25 and 200 tons) for design ranges of 3219, 5150, and 7025 kilometers (2000, 3200 and 4365 statute miles). Economic evaluations were based upon a manufacturer's break-even point of 200 units. This was a viable approach since the derivative aircraft would undoubtedly be produced in passenger versions which would substantially increase the production run.

Results of the economic analysis of the derivative aircraft are presented in Figure 5-3. These data define the economic worth of the preferred models

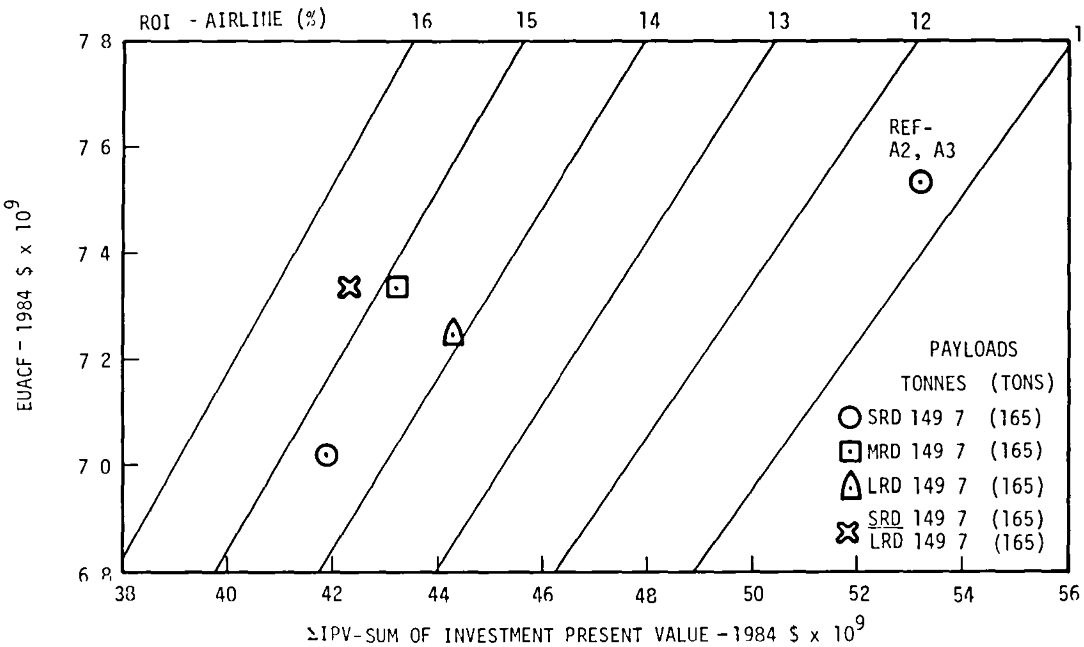


Figure 5-3. Economic Worth - Derivative Aircraft, 1980 Technology

and sizes of aircraft determined on the basis of maximizing the airline return on investment (ROI) with the derivative aircraft operating in competition with the current A2 and A3 aircraft. Also shown are the corresponding fleet values of the equivalent uniform cash flow (EUACF) and the sum of investment present value (ΣIPV). Due to technology advances the price and trip cost of these derivative aircraft would be reduced 15 and 20 percent respectively relative to a comparable current wide-body aircraft viewed in 1984 dollars.

Although the preferred payload was 149.7 tonnes (165 tons) at all ranges, reducing the payload to 91 tonnes (100 tons) would reduce the ROI by less than one percent. The economically preferred derivative program would entail the development of both the short (SRD) and long range (LRD) models. This combination would increase the airline ROI four percentage points and decrease the airline investment by 20 percent relative to the reference fleet of A2 and A3 aircraft. In addition, this combination would bring the airline ROI up to 15 percent, the level often identified as a desirable economic objective. This performance would make the derivative an attractive addition to the post-1985 fleet. As evidenced in Figure 5-3 there would be little penalty associated with producing only the medium range derivative (MRD). However, considering the number of manufacturers currently producing wide-body aircraft it appears quite likely that more than one model will be produced. It is equally likely that these developed aircraft will differ in design range.

The fleet mix that evolved following introduction of the SRD/LRD combination in 1985 is shown in Figure 5-4. Although there is a steady increase in

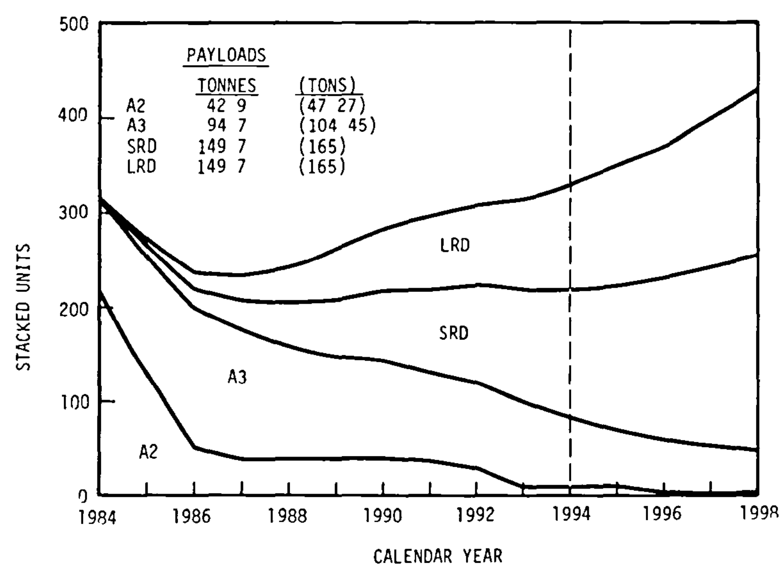


Figure 5-4. 1984-1998 SRD/LRD Fleet Mix

the number of derivative aircraft the number of wide-body A3's also increased to a maximum of about 150 units in the mid-80's as they began to take over from the large narrow A2 aircraft on the shorter routes. However, if refitted with more efficient engines that are compatible with future noise regulations the A2 aircraft could remain in service until 1998.

The derivative aircraft began to replace the A3's in the late 80's reaching the number of units tabulated below. Although the derivative program is

Year	1994	1998
Number of SRD	136	210
Number of LRD	112	176

clearly economically desirable from the standpoint of the airlines such may not be the case from the viewpoint of the manufacturers. In the presence of multiple manufacturers a considerable number of additional passenger units would have to be sold. Without such additional orders, and/or an increase in price that would degrade the airline economics, the ROI to the manufacturers would be marginal making it quite unlikely that they would intitate the development of a new dedicated freighter for the post-1995 time period.

The exterior dimensions of the 149.7 tonne (165 ton) payload aircraft would be very near the limiting values that can be accommodated on existing major airports without creating serious interface problems. With this larger payload the cargo market growth out to 1998 could be accommodated with an average annual frequency growth rate of less than 4 percent compared to a 6.4 percent growth in the absence of the derivative aircraft. Such operational reduction may be a determining factor in selecting a future cargo aircraft to be compatible with the anticipated airport congestion discussed in Section 3.

Dedicated Freighter Aircraft 1994-2008

Analysis of the dedicated freighters considered that production of these aircraft would be solely dependent upon the demand generated by cargo operations, with no additional sales for passenger operations. The price of all models were therefore determined on the basis of both one and two manufacturers and on providing each manufacturer with a 15 percent return on investment as determined by the actual number of units required to meet the cargo market demand and fleet competition. With this approach compared to the normal break-even approach the trend with aircraft size is reversed showing increasing airline investment and decreasing airline ROI with increasing payload. In the basic analysis all considered aircraft incorporated 1990 technology and turbofan engines in combination with a low wing, conventional configuration as illustrated in Figure 5-5.

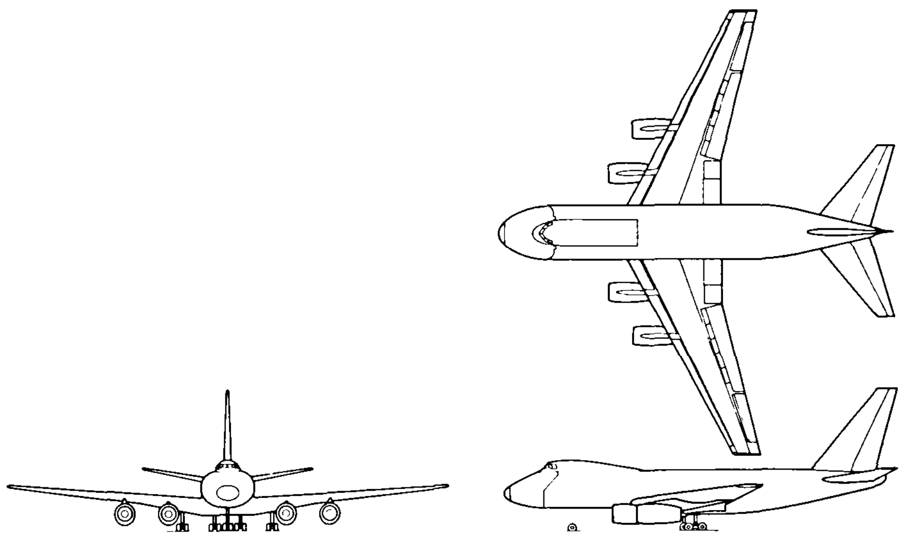


Figure 5-5. Dedicated Civil Cargo Aircraft

Viewed in 1994 dollars the price of the dedicated freighter was 48 percent lower than the comparable current A3 wide-body when produced by one manufacturer. With two manufacturers this reduction in price was decreased to 31 percent. The comparable trip cost is not affected by the number of manufacturers and showed a 43 percent reduction for the dedicated freighter compared to the A3.

Fleet performance and economics were investigated parametrically for design ranges of 3219 and 7025 kilometers (2000 and 4356 statute miles) for the advanced short range (ASR) and long range (ALR) models respectively. Payload size was varied between 22.7 and 362.8 tonnes (25 and 400 tons). Preferred sizes of the dedicated freighters were selected on the basis of maximizing the airline ROI as established by fleet performance in competition with the reference fleet of A2, A3, SRD and LRD aircraft. Selections were based upon a single manufacturer since it was established that the number of manufacturers did not effect the preferred payload size.

The resulting economic worth of the preferred 45.4 tonne (50 ton) payload ASR and the 68.0 tonne (75 ton) ALR are presented in Figure 5-6. With one

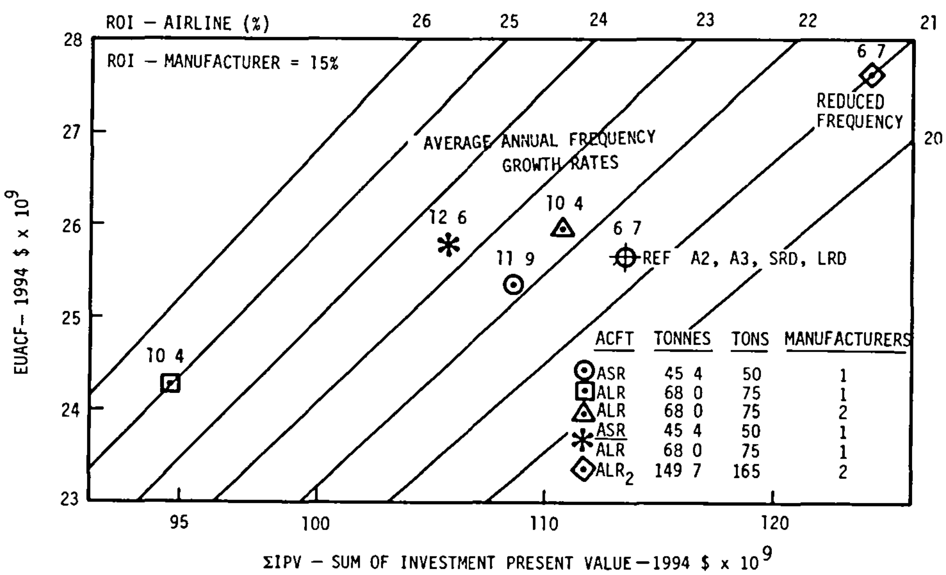


Figure 5-6. Economic Worth - Dedicated Aircraft, 1990 Technology

manufacturer the economic performance of the short range ASR was marginal providing less than a one percent improvement in airline ROI while reducing the required investment by a mere four percent. On the other hand, the long range ALR would be extremely desirable providing the airlines a potential four percent increase in ROI and an 18 percent reduction in investment. This performance of the ALR underscores the desirability of a long range aircraft to meet the 1994 to 2008 market demand.

Values of the airline ROI shown in Figure 5-6 are higher than normal indicating that the forecast tariff reductions were conservative. In actual practice the tariffs would be reduced to stimulate the market while still providing the airline a reasonable ROI. As an example, an average annual tariff reduction of 1.6 percent over a 10 year period would reduce the airline ROI of the reference fleet from the 21.4 to 15 percent and result in a potential two percent additional annual growth in market demand.

Considering the number of aircraft required, 1253 ALR's by the year 2008, and the changes anticipated in the aircraft industry, it is very unlikely that only one manufacturer would be involved in supplying this market. As shown in Figure 5-6 the introduction of a second manufacturer deteriorated the ALR program to the point of being less desirable than the ASR with one manufacturer. In the case of dual manufacturers the preferred program entailed the development of both the ASR and ALR each by a separate manufacturer. This ASR/ALR combination provided a two percentage point increase in airline ROI and a seven percent reduction in investment relative to the reference fleet containing the derivative aircraft. With this level of improvement the desirability of the ASR/ALR combination program is considered economically marginal.

The smaller size aircraft were economically preferred because the smaller payload increased the number of units required thereby reducing their price and hence the depreciation and insurance costs to the airlines. However, integration of the relatively small payload ASR and ALR aircraft into the fleet was accompanied by a substantial increase in operational frequency (trips) as shown in Figure 5-6. The frequency growth rate of the ASR/ALR combination, 12.6 percent, was nearly double the growth rate, 6.7 percent, for the reference fleet. This behavior was considered a disadvantage that could conflict with projected airport capacities discussed in Section 3 and/or reduce the decrease in IOC, to the forecast level of 24 percent of the total revenue discussed in Section 4. To reduce the frequency growth rate of the dedicated aircraft fleet to the 6.7 percent of the reference fleet required increasing the payload of the dedicated aircraft to 149.7 tonnes (165 tons). This size aircraft when produced by two manufacturers was designated the ALR_2. 573 of these aircraft would be required by 2008 resulting in the fleet economics shown in Figure 5-6.

Comparing the ALR_2 fleet to the derivative reference fleet indicates that the latter would require a nine percent smaller investment while providing essentially the same ROI despite being heavier, and having inferior aerodynamics and a greater specific fuel consumption than the ALR_2. As discussed in Section 4, the lower price for the derivative aircraft negated the cost benefits of the 1990 technology in the dedicated aircraft. In addition, analysis showed that if the cargo market demand were less than forecast the derivative and dedicated aircraft would be less competitive against the current

A3 wide bodies and the undesirable economic effects would be increased in severity in the presence of the large dedicated freighter. Manufacturers and airlines would therefore be reluctant to initiate a dedicated freighter program such as the ASR/ALR or ALR_2 over a program of continuing derivative improvement. However, the combined effects of the cargo market demand, airport and airway development, international agreements, and military participation and/or government subsidy may be sufficient to overcome the low economic incentive of the dedicated freighter program.

The fleet mixes that resulted with ASR/ALR combination and the ALR_2 aircraft are presented in Figure 5-7. Even in competition with the derivative

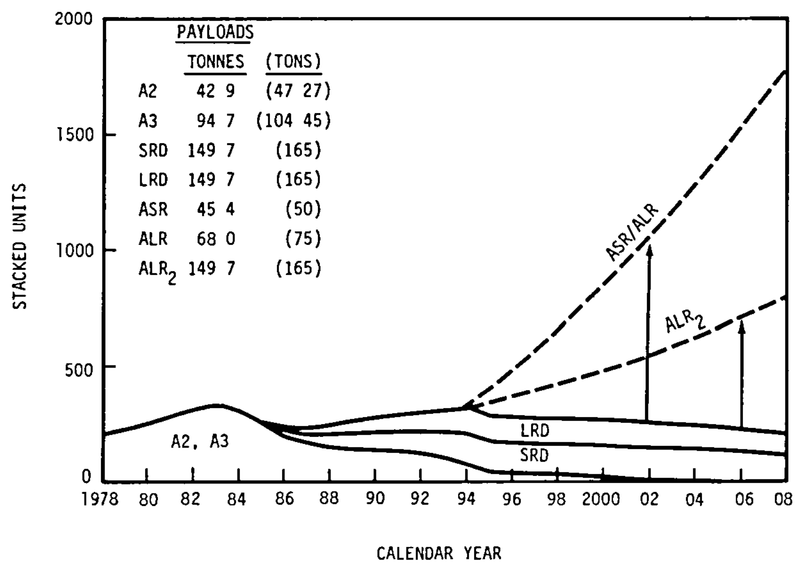


Figure 5-7. 1978-2008 Fleet Mix

and dedicated aircraft the current wide-bodies, A3, remained in service as late as the year 2005 although they were gradually relegated to shorter range operations as the large narrow-bodies, A2, were phased out. In 1994 there would be 136 SRD's and 112 LRD's in the fleet. Following the introduction of the dedicated freighter in 1995 the number of SRD and LRD aircraft remained essentially unchanged until the late 90's when they began to phase out decreasing to a little over 200 units by 2008. The number of dedicated freighters steadily increased reaching 949 ASR's and 623 ALR's for a total of 1572 units by the year 2008. Similar changes would occur if the larger payload ALR_2 were introduced instead of the smaller ASR/ALR combination. By 2008 the number of ALR_2's in service reached 570 resulting in a fleet that was 56 percent smaller than the ASR/ALR combination fleet. Such reduction in fleet size would have a favorable impact on the anticipated growth in airport congestion.

Program subsidy. - The impact of subsidy was investigated from the viewpoint of developing an advanced dedicated civil-military freighter aircraft. It was postulated that military participation would occur in a single program directed to the development of an ALR type aircraft; that two manufacturers would produce the total number of units required, commercial plus military, but only one of these would produce the military units with both realizing a 15 percent ROI; that the military would provide half of the required research, development and test funding (RD&T) and would subsequently purchase a number of units equal to 25 percent of the commercial buy for the U.S. Domestic and U.S. International fleet; and that the weight and performance of the commercial version would not be penalized for military requirements.

Military participation lowered the unit price about 48 percent and made a dramatic improvement in the economic attractiveness of the dedicated freighter program. Although the preferred payload size of the long range aircraft, ALR, remained at 68 tonnes (75 tons), its fleet economics were substantially improved. The airline ROI for the ALR was 6.4 percentage points greater and the required fleet investment 31 percent less than the reference fleet of A2, A3, SRD and LRD aircraft. The borderline ALR_2 program showed similar improvements developing an ROI that was 5.6 percentage points greater while requiring an investment 27 percent smaller than the reference fleet. These economic improvements were primarily due to sharing the RD&T costs since the military buy was relatively small amounting to 43 of the 149.7 tonne (165 ton) ALR_2 aircraft. Fifty percent subsidy of the RD&T costs, whether by the military or some other agency, would make the dedicated freighter program economically feasible for payloads well above the aircraft size limitations imposed by many major existing airports. This flexibility in aircraft size indicates that the underlying economics may have sufficient latitude to accommodate some degradations in weight and/or performance due to the compromises necessary to meet military requirements.

However, the compromise problem has no easy solution because the answer does not rest with the individual examination of design features and penalties but in the accumulative and interrelated impacts of all necessary configuration changes.

Variation of aircraft configuration. - In a study of this type there is always the question as to the relative effectiveness of configurations that depart from the conventional. To answer this question two propfan powered aircraft, Propfan 1 and Propfan 2, illustrated in Figure 5-8; a turbofan powered Spanloader (distributed payload), illustrated in Figure 5-9; and a conventional turbofan powered aircraft (Figure 5-5) equipped with laminar flow control (LFC), were evaluated. These configurations were sized equal to and were compared to the 149.7 tonne (165 ton) payload ALR_2 and a 235.8 tonne (260 ton) payload ALR_3. There was no attempt to economically determine their preferred size as done for the conventional aircraft. All configurations utilized 1990 technology which provided the incremental changes in design parameters presented below based upon the respective values for the conventional, advanced turbofan type aircraft.

1990 TECHNOLOGY PARAMETRIC AIRCRAFT CONFIGURATION

		Incremental Changes Relative to Contemporary Aircraft									
Configuration	M	ΔW_{P+N}	ΔW_{STRU}	$\Delta L/D$	ΔSFC	ΔW_{ENG}	$\Delta C_{L_{TO}}$	Mfg. Acft	Cost Eng.	Acft Maint. Cost	ΔS_W
Propfan 1	0.8	-7%	-4%	-10%	-20%	+112%			+29%		-10%
Propfan 2	0.7	-11%	-26%	-6%	-30%	+103%			+29%		-14%
Spanloader	0.75	-17.6%	-43%	-13%	-4%			-15%			+10%
LFC	0.85		+6.5%	+22%	+2%	+2%	-13%	+4%		+10%	+8%

Utilizing the preceding improvements in technology, the trip cost for each type aircraft was determined. Each of the parametric aircraft were then competed against the reference fleet of A2, A3, SRD and LRD aircraft to define the respective number of units required and subsequently the aircraft price. The latter values were based upon two manufacturers each realizing a 15 percent ROI. The ALR_3 was the highest priced aircraft of the considered configurations

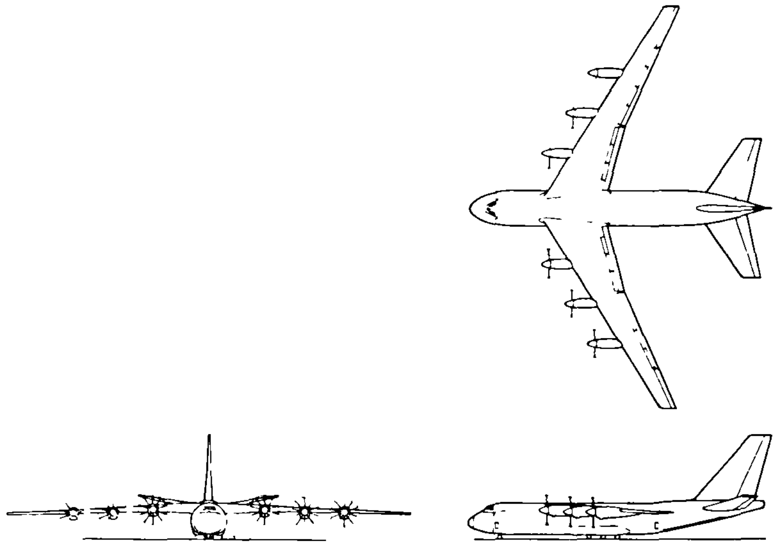


Figure 5-8. Conventional Propfan Configuration

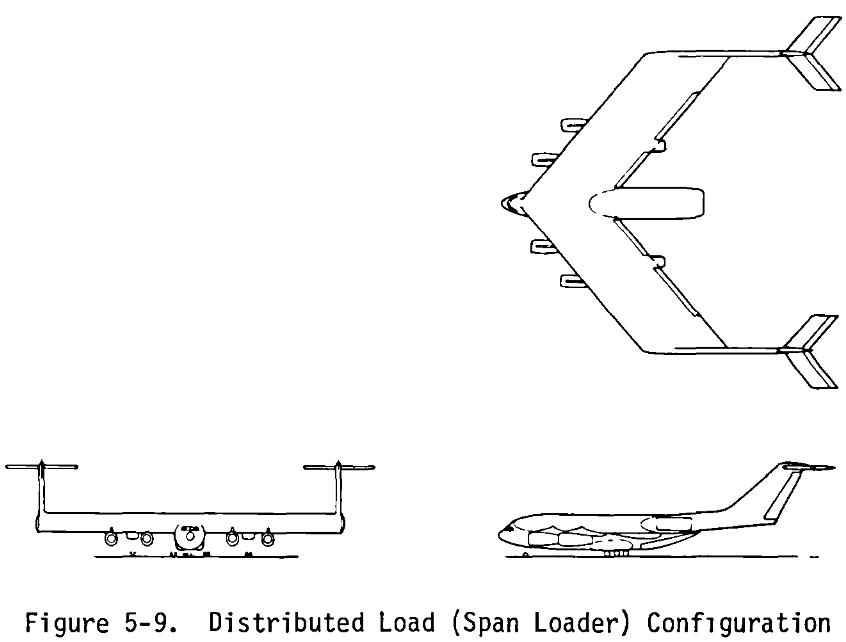


Figure 5-9. Distributed Load (Span Loader) Configuration

and the lowest priced aircraft was the Spanloader which also had the highest trip cost per unit payload. The lowest trip cost was provided by the LFC configuration. Although such comparisons are interesting, the fleet economics developed by each of the respective configurations is the true determinate of their relative worth.

Results of the competitive economic analysis of the non-conventional aircraft configurations are presented in Figure 5-10 along with comparable data for some conventional configurations previously discussed. In spite of its higher trip cost the Spanloader provided an airline ROI and required a fleet investment nearly equal to the values for the ASR/ALR combination. Past analysis has shown the 235.8 tonne (260 ton) payload Spanloader to be near the minimum size at which this concept can equal or exceed the effectiveness of a comparable conventional aircraft. While the M=0.7 Propfan 2 showed improvement over the conventional ALR_2 it required an investment 3.5 percent greater than the reference fleet. The M=0.8 Propfan 1, ALR_3, and LFC were considered undesirable program candidates based upon the decreased ROI and increased investment which they incurred.

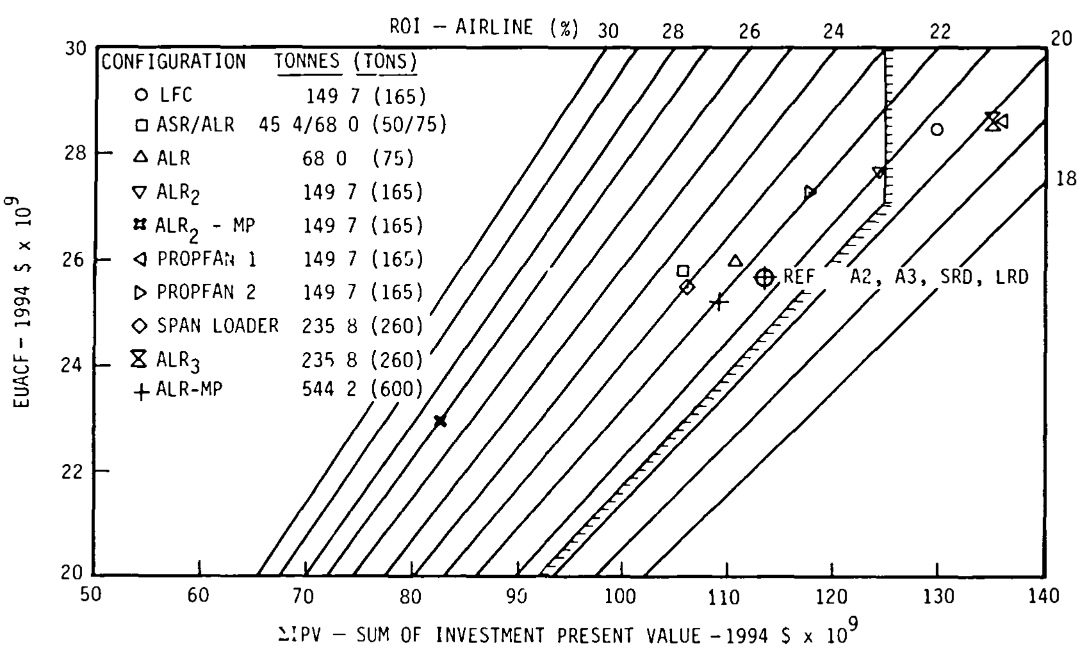


Figure 5-10. Economic Worth of Considered Configurations

The impact of military participation (MP), or RD&T subsidy, is also shown in Figure 5-10. Such combined commercial/military program could bring payloads up to 544.2 tonnes (600 tons) within the relm of economic feasibility. Noting the relative magnitude of the economic improvement of the ALR_2-MP over the ALR_2 indicates that MP in either the Spanloader or Propfan 2 program could make it economically desirable to the airlines. However, such favorable situation could be negated by other considerations such as airport compatibility previously discussed. A second consideration involves the CAB and ICAO noise suppression requirements. Above takeoff gross weights (TOGW) of about 385.5 tonne (425 ton), comparable to a payload of about 118 tonne (130 ton) for conventional aircraft, the noise certification requirement is constant and applicable to aircraft having four or less engines. Since the required thrust and/or number of engines increases with TOGW there will be an upper limit on aircraft size determined by the level of development of the quiet engines. A third consideration is based upon the fact that the airways are now keyed to cruise speeds of 0.8 to 0.85 Mach number. The introduction of a slower Mach 0.7 aircraft (irrespective of the type of powerplant) on prime routes could cause difficulties although the implementation of the expected advanced traffic control system should eleviate the problems that arise.

The fleet mixes that result with the more promising configurations are presented in Figure 5-11. Due to its payload size, the Spanloader reduces the number of dedicated freighter aircraft required by 2008 by 75 percent compared to the ASR/ALR combination. While this is favorable to the airport congestion problem, reducing the departure frequency growth to 5.2 percent annually, the small number of units required, 392, is responsible for the Spanloaders relatively higher price in spite of its design features that lower the manufacturing cost. Although it had the same payload, there were 13 percent more Propfan 2 units required than ALR_2's due to the reduced block speed resulting from the Mach 0.7 cruise.

The results presented in this section substantiate the conclusion that bigger is not necessarily better and that lower trip cost is not a sufficient criterion upon which to select a preferred new freighter aircraft size or configuration for development. Of equal or more importance are the aircraft manufacturer's and airlines ROI as affected by the size and number of aircraft

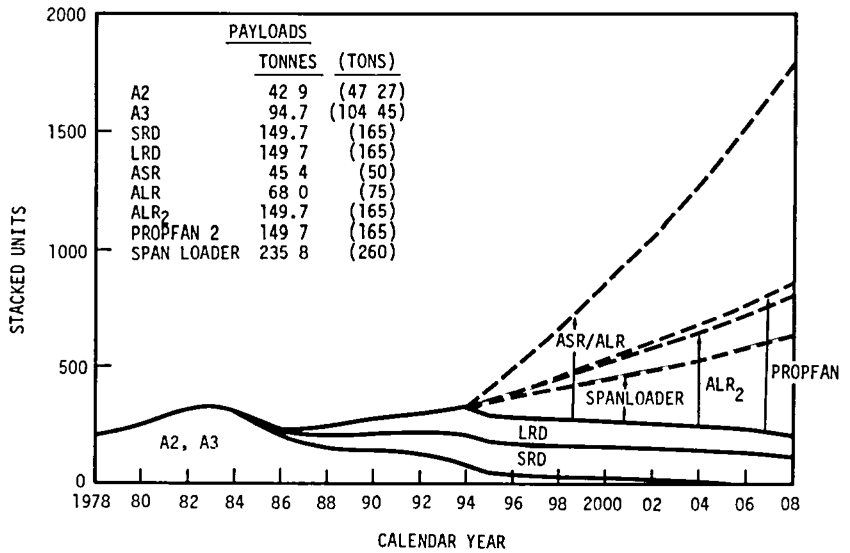


Figure 5-11. Configuration Changes - 1978 to 2008 Fleet Mix Summary

required. While small payloads can be economically preferred over large payloads they pose operational problems such as large increases in operational frequency. On the other hand, large payloads offer operational advantages but at a possible economic penalty to the airline in spite of their reduced trip cost. These relationships compound the problems of defining the requirements for a future dedicated freighter aircraft.

Future work. - Results of the CLASS show that while the 1985 derivative cargo aircraft program was clearly desirable, the 1995 dedicated freighter program was economically marginal. These data showed program desirability to be a function of aircraft size and production as affected by the cargo market demand, operational frequency, airline and manufacturers economics, and RD&T subsidy. However, many of the related and/or affecting issues, such as military participation and energy, were not fully addressed or ignored due to available study resources. The more important of these shorted issues are identified below but not in order of considered importance.

- An advanced, 1990 technology, passenger aircraft modified for cargo operations to compete with the 1985 derivative aircraft.
- The effect of fleet energy consumption considering fuel availability in addition to the fuel cost considered in the CLASS.

- Detailed investigation of the impact of future airport operational capacities both domestic and international.

- The impact of military versus civil freighter requirements on airline fleet economics and aircraft size considering both airline and manufacturers ROI.

- The relative importance of technological developments as determined by airline fleet economics.

- The preferred payload size of the Spanloader and M=0.7 Propfan 2 configurations based upon fleet economics.

NASA-Langley, 1980

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