

Jean-Paul Rodrigue

Sixth Edition



Transportation Modes (Part II)

CHAPTER 5

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The Geography of R Transport Systems

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Air Transport

Chapter 5.5

US Post Office Airmail Routes, 1921-26



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Selected Transcontinental DC-3 Routes, Late 1930s



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Early Intercontinental Air Routes, 1930s



Flight Times by Piston and Jet Engines from New York



Shortest Air Route between London and Sydney, 1955 - 2020



Concorde Services, 1976-2003



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Average Airfare (roundtrip) between New York and London, 1946-2015 (in 2012 dollars)



Flight Time and One-Way Airfare, 1955



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Regional Sales of Boeing 747s, 1960s-2010s



Deliveries of Boeing 747s, 1969-2022



Main Commercial Passenger Aircraft, 1935-2015

Aircraft	Year of First Commercial Service	Speed (km/hr)	Maximum Range at Full Payload (km)	Seating Capacity
Douglas DC-3	1935	346	563	30
Lockheed L-649 Constellation		560		
Douglas DC-7	1953	555	7,500	105
Boeing 707-100	1958	897	6,820	
Boeing 727-100	1964	870	4,300	134
Boeing 737-200	1967	780		
Boeing 747-100	1970	907	9,045	385
McDonnell Douglas DC-10		908		260
Airbus A300	1974	847	3,420	269
Boeing 767-200	1982		5,855	
Boeing 747-400	1989	939	13,444	416
Boeing 777-200ER	1995			
Airbus A340-500	2003	886	15,800	313
Airbus A380			14,800	
Boeing 787-8	2012	902	15,700	250
		902		280

The World's Longest Nonstop Air Transport Routes, 2016



The World's Longest Nonstop Air Transport Routes, 2021



The World's Longest Nonstop Air Transport Routes, 2021



Selected Ultra-Long-Range Nonstop Airline Routes

From	То	Airline	Aircraft	Flying Time	Distance (km)
Singapore	Newark	Singapore	Airbus A340-500	18:50	15,345
Singapore	Los Angeles	Singapore			
Sydney	Dallas	Qantas	Boeing 747-400ER	15:25	13,804
Johannesburg	Atlanta	Delta	Boeing 777-200LR		13,582
Dubai	Los Angeles	Emirates	Boeing 777-200LR	16:30	13,420
Dallas	Brisbane	Qantas	Boeing 747-400ER		13,363
Los Angeles	Bangkok	Thai Airways	Airbus A340-500	17:20	13,309
Dubai		Emirates	Boeing 777-200LR		
Dubai	San Francisco	Emirates	Boeing 777-300ER	16:00	13,041
New York		Cathay Pacific	Boeing 777-300ER		12,990
Newark	Hong Kong	United	Boeing 777-200ER	15:55	12,980
Doha		Qatar Airways	Boeing 777-200LR		12,951
Johannesburg	New York	South African Airways	Airbus A340-600	16:05	12,825
Melbourne	Los Angeles	Qantas	Airbus A380		12,748
Detroit	Hong Kong	Delta	Boeing 777-200LR	15:45	12,645
Chicago			Boeing 747-400		12,517
Toronto	Hong Kong	Air Canada	Airbus A340-500	15:20	12,569

Main Air Transport Service Ranges (From New York)



Factors behind the Development of Global Air Transportation

TECHNICAL IMPROVEMENTS

- Jet engines considerably reduced distances (1958: Boeing 707).
- Greater speeds (minor) and improved ranges (major).
- Almost every part of the world can be serviced in less than 24 hours.

RISING AFFLUENCE



- Linked with income and economic output growth.
- Disposable income available for leisure.
- International tourism and air transportation mutually interdependent.

GLOBALIZATION



• Increasing migration and family relations (social networks).

• Commercial networks established by multinational corporations.

World Air Travel and World Air Freight Carried, 1950-2021



Annual Air Transportation Growth (Passengers and Freight) and Economic Growth, 1950-2020



Monthly Global Air Passenger Traffic, 2010



Share of US Adult Population that Took a Commercial Flight



Daily Air Travelers in the United States, 2019-2023



The Development of Polar Air Routes



SEATTLE BOSTON MINNEAPOLIS SALT LAKE NEW YORK CLEVELAND CHICAGO OAKLAND INDIANAPOLIS DENVER WASHINGTON KANSAS CITY Atlantic Ocean LOS ANGELES MEMPHIS ATLANTA ALBUQUERQUE FT. WORTH JACKSONVILLE HOUSTON MIAMI Pacific Ocean Gulf of Mexico

AIR TRAFFIC CONTROL ZONES

Source: Navtech

New York / Hong Kong Air Routes: Conventional and Polar



Characteristics of Major Air Travel Markets

United States	Europe	Pacific Asia
Deregulation started in 1978	Deregulation started in 1997	Regulated markets with government ownership
Low population density and dispersed urban centers	High population density and concentrated urban centers	Dispersion of urban centers but high regional concentrations
Relatively open air spaces and airports	Congested air spaces and airports	Congested gateway airports and underutilized regional airports
Rail minor competitor; Car compete for short distances	High speed rail is a direct competitor; Rail is a minor competitor; Car compete for short distances	Except for Japan, less competition from other transportation modes; In China HSR becoming a competitor
No loyalty to carriers (pricing and frequent flyers)	Some lingering loyalty to carriers	Strong "imposed" loyalty to carriers
Price transparency	Price becoming transparent	Price becoming transparent
Limited income growth and limited leisure	Limited income growth and more leisure time	Growing income levels and more leisure time

Airline Deregulation and Hub-and-Spoke Networks





Canada Aviation Statistics Centre, Bank of Canada Review.

Annual Passenger Plane Load Factor, World and United States, 1950-2021 (in %)



Monthly Passenger Plane Load Factor, United States, 2000-2022 (in %)



Domestic Market Share of the top American Airlines, 1977-2022



Major Mergers in the American Air Industry since the 2000s


Largest Airlines by Revenue, 2019



Strategies of Low-Cost Carriers

On-board operations	Optimum use of seating space. Minimal crew. Limited and paying cabin service.
Aircraft operations	Few (often one) types of aircraft used to minimize maintenance costs. Stair boarding instead of air bridges. Maximal usage of runway length (take-off thrust and braking on landing). Fast turnaround to maximize aircraft use. No freight carried in bellyhold.
Service network	Point-to-point services. Destinations commonly of less than two hours apart. Usage of secondary airports (lower gate rates).
Booking	Yield management. Online booking to minimize transaction costs (become the norm). No travel agent commissions.

Strategies of Low-Cost Carriers

ON-BOARD OPERATIONS

- Optimum use of seating space (no reclining seats).
- Minimal crew.
- Limited and paying cabin service.

AIRCRAFT OPERATIONS

• Few (often one) types of aircraft are used to minimize maintenance costs.



- Stair boarding instead of air bridges.
- Maximal usage of runway length (take-off thrust and braking on landing).
- Fast turnaround to maximize aircraft use.
- No freight carried in bellyhold.

SERVICE NETWORK



- Point-to-point services.
- Destinations commonly less than two hours apart.
- Usage of secondary airports (lower gate rates).

BOOKING



- Yield management.
- Direct sales (No travel agent commissions).

Strategies Used by Airlines to Save Fuel

Dimension	Strategy
Fleet	Retiring less fuel-efficient aircrafts (e.g. DC-9, DC10, MD-80). Switching to more fuel-efficient aircrafts (e.g. A330, A319).
Operations	Less engine idle at gates (electrical systems). Lower flying speed (-5%). More frequent plane and engine washing.
On board	Lighter seats. Removal of seat-pocket documents (e.g. magazines). Less water in bathrooms. Lighter service carts.
Passengers	Weight restrictions for luggage. Surcharges for first or second check-in luggage. Passengers weight surcharges (?)

Selected Low-Cost Carriers

Airline	Country	2005 Fleet	2005 Revenue (USD Millions)
Southwest	USA	454 B737s	7,584
EasyJet		62 A319s; 43 B737s	2,365
Ryanair	Ireland	107 B737s	2,044
jetBlue	USA	89 A320s; 19 ERJs	
Air Berlin	Germany	8 A319s/A320; 40 737s; 3 Other	1,457
Virgin Blue	Australia	47 B737s	
WestJet	Canada	56 B737s	1,197
	Brazil	47 B737s	
Frontier	USA	51 A318s/A319s/A320s	944
AirAsia	Malaysia	6 A320s; 21 B737s	

Air Freedom Rights



Air Hubs and Market Fragmentation: The Case of Chicago



Longitudinal Intermediacy: Icelandair



Latitudinal Intermediacy: COPA Airlines



Development Costs for Selected Aircraft

Aircraft	Year of First Service	Development Costs (2004 Dollars)
Douglas DC-3	1936	4,300,000
Douglas DC-6	1946	144,000,000
Boeing 707	1958	1,300,000,000
Boeing 747	1970	
Boeing 777	1995	7,000,000,000
Airbus A380		14,400,000,000
Boeing 787	2012	13,400,000,000

Operating Profit in the Global Airline Industry, 1960-2018



The World's Most Profitable Airlines, 1994-2004



Jetliners Deliveries from Boeing and Airbus, 1974-2019



Stages in Air Network Development



World's 10 Largest Passengers and Freight Airlines, 2018



Passenger and Cargo Share of Operating Revenues, Selected Airlines, 2013



Commodities Shipped by Air Freight, 2003

Total: 144 billion freight ton-kms



Market Share of Main Airline Alliances, 2020

(JP) Adria Airways (2004), (A3) Aegean Airlines (2010), (AC) Air Canada (founder), (CA) Air China (2007), (AI) Air India (2014), (NZ) Air New Zealand (1999), (NH) All Nippon Airways (1999), (OZ) Asiana Airlines (2003), (OS) Austrian Airlines (2000), (AV) Avianca (2012), (SN) Brussels Airlines (2009), (CM) Copa Airlines (2012), (OU) Croatia Airlines (2004), (MS) EgyptAir (2008), (ET) Ethiopian Airlines (2011), (BR) EVA Air (2013), (LO) LOT Polish Airlines (2003), (LH) Lufthansa (founder), (SK) Scandinavian Airlines (founder), (ZH) Shenzhen Airlines (2012), (SQ) Singapore Airlines (2000), (SA) South African Airways (2006), (LX) Swiss International Air Lines (2006), (TP) TAP Portugal (2005), (TG) Thai Airways International (founder), (TK) Turkish Airlines (2008), (UA) United Airlines (founder)

(AA) American Airlines (founder), (BA) British Airways (founder), (CX) Cathay Pacific (founder), (AY) Finnair (1999), (IB) Iberia Airlines (1999), (JL) Japan Airlines (2007), (LA/JJ) LATAM Chile (2000) / LATAM Brasil (2014), (MH) Malaysia Airlines (2013), (QF) Qantas (founder), (QR) Qatar Airways (2013), (RJ) Royal Jordanian (2007), (UL) SriLankan Airlines (2014)

(SU) Aeroflot (2006), (AR) Aerolíneas Argentinas (2012, (AM) Aeroméxico (founder), (UX) Air Europa (2007), (AF) Air France (founder), (AZ) Alitalia (2009), (CI) China Airlines (2011), (MU) China Eastern Airlines (2011), (CZ) China Southern Airlines (2007), (OK) Czech Airlines (2001), (DL) Delta Air Lines (founder), (GA) Garuda Indonesia (2014), (KQ) Kenya Airways (2007), (KL) KLM (2004), (KE) Korean Air (founder), (ME) Middle East Airlines (2012), (SV) Saudia (2012), (RO) TAROM (2010), (VN) Vietnam Airlines (2011), (MF) Xiamen Airlines (2012)



Network Effect of Strategic Alliances



Operating Expenses of the Global Airline Industry, 2005



Passenger Airlines Operating Costs, United States, 2019



Jet Fuel Prices, 1990-2023



Baltic Exchange Airfreight Index, 2015-2023



Operating Revenues of the Airline Industry



Cost Structure of a Typical 100 Passengers Domestic Flight, c2012





- Salaries
- Ownership costs
- Fees and taxes
- Maintenance
- Other
- Profit

Seat Capacity of Selected Aircrafts, pre-1985 and 1985-2000



Main 1985-2000 Models

Major Air Traffic Flows Between Regions, 2010



The World's Busiest Air Transport Routes, 2018



Generation and Attraction of Global Air Freight Flows, 2003 (in billions of ton-km)



Changes in the Duration of Selected Scheduled Flights, 1996-2019





The Geography of R Transport Systems

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Intermodal Transportation

Integrated Transport Systems

FACTOR		CAUSE	CONSEQUENCES
	TECHNOLOGY	Containerization & IT	Modal and intermodal innovations; Tracking shipments and managing fleets
	CAPITAL INVESTMENTS	Returns on investments	High costs and long amortization; Improve utilization to lessen capital costs
\succ	ALLIANCES AND M&A	Deregulation	Easier contractual agreements; Joint ownership
•	VALUE CHAINS	Globalization	Coordination of transportation and production (integrated demand)
*	NETWORKS	Consolidation and interconnection	Economies of scale, efficiency and control

Major Steps in Intermodal Integration



The Four Revolutions of Containerization



Intermodal Transportation as an Integrative Force


Intermodalism, Multimodalism and Transmodalism



Integrated Freight Transport Systems: Intermodal and Transmodal Connectivity



Intermodal Transport Chain



Conditions and Outcomes of Intermodal Transport

CONDITIONS		OUTCOMES		
Load unit	Intermediate and finished goods in load units of less than 25 tons.	Total transport costs	From economies of scale and the use of more effective modes and intermodal operations.	
Modal continuity	Sequence of connected infrastructure; an intermodal transport chain.	Modal shift O O O O O	Each mode according to their respective time and cost advantages.	
Transport distance	Distances above 500 km (longer than one day of trucking) usually require intermodal transportation.	Consolidation	Requirement to consolidate and deconsolidate load units at intermodal terminals.	
Cargo Value	Suitable for intermediate cargo values. Low and high-value shipments are usually less suitable.	Higher load factor →	Less LTL and more TL. Better utilization of existing capacity.	
Frequency of shipments	Cargo flows need to be continuous and in similar quantities.	Less empty backhauls	Less vehicle-km of empty backhauls due to modal shift, higher load factor and consolidation.	

Piggyback and Doublestack Train Cars



Multimodal Transport System



The Benefits of Containerization



Driving Forces of Containerization and Intermodalism

CONTAINERIZATION					
Unitization	Cellular ships	Specialized terminals	Land consumption		
Standardization	Gantry cranes	Transshipment	Multi-rate structure		
			© GTS		
Management and coordination	Mergers	Modal integration	Logistics		
Control over cargo Multimodal operators		Through rates and Deregulatio			

Carrying Capacity of Containers



Standard Container Road Weight Restrictions in the United States



Container Identification System



Common ISO Container Size and Type Codes



The Container as a Transport, Production and Distribution Unit



Shifts in Containerized Maritime Transportation



Number of Units and Weight of Consumption Goods Carried by a 20-Foot Container



World Container Throughput, 1980-2022



Containerization Growth Factors

FACTOR	Volume Growth	Volume Decline
Derived	Economic and income growth.Outsourcing and offshoring.Complex supply chains.	Economic recessions.Trade protectionism.Automation.
Substitution	Capture of bulk and break-bulk markets.New niches (commodities and cold chain).	Peak substitution.Composition of container fleet.
Incidental	Trade imbalances.Repositioning of empty containers.	Trade protectionism.Automation.
Induced	 Transshipment (hubbing, relay and intersection). 	 Changes in shipping networks (more direct services).

Container Usage during its Life-Span



Advantages of Containerization

Factor	Advantage
Standard transport product	ISO standard. Specialized ships, trucks and wagons. Unique identification number and size type code.
Flexibility of usage	Commodities (coal, wheat), manufactured goods, cars, frozen products. Adapted containers for dry cargo, liquids (oil and chemical products) and refrigerated cargo. Reuse of discarded containers.
Costs	Low transport costs; 20 times less than bulk transport. Economies of scale at modes and terminals.
Velocity	Fast transshipment operations. Low terminal turnaround times (port time reduced from 3 weeks to about 24 hours).
Warehousing	Own warehouse; Simpler and less expensive packaging. Stacking capability on ships, trains (doublestacking) and on the ground.
Security and Safety	Contents of the container is unknown to carriers. Can only be opened at the origin, at customs and at the destination. Reduced spoilage and losses (theft).

Challenges of Containerization

Factor	Challenge
Site constraints	Large consumption of terminal space (mostly for storage); move to urban periphery. Draft issues with larger containerships (more than 13 meters).
Infrastructure costs	Container handling infrastructures and equipment (giant cranes, warehousing facilities, inland road, rail access), are important investments.
Stacking	Complexity of arrangement of containers, both on the ground and on modes (containerships and double-stack trains). Restacking difficult to avoid.
Empty movements	Many containers are moved empty (20% of all flows). Either full or empty, a container takes the same amount of space. Divergence between production and consumption; repositioning.
Theft and losses	High value goods and a load unit that can opened or carried (on truck). Vulnerability between terminal and final destination. 10,000 containers are lost at sea each year (fall overboard).
Illicit trade	Common instrument used in the illicit trade of goods, drugs and weapons, as well as for illegal immigration. Concerns about the usage of containers for terrorism.

Advantages and Challenges of Containerization



CHALLENGES



Capital intensiveness



Stacking



Theft and losses

Illicit trade

Large consumption of terminal space. Draft issues with larger containerships.

- Container handling infrastructures and equipment are important investments.
- Complexity of arrangement of containers, both on the ground and on modes.
- Divergence between production and consumption; empty repositioning. 20% of all containers.
- High value goods vulnerable to thefts, particularly between terminal and final destination.

Illicit trade of goods, drugs and weapons, as well as for illegal immigration.

Container Shipping Costs and Cargo Value

Products	Items / 40 Foot Container		Retail Value (USD)		Freight / Value (%)	
	Low	High	Low	High	Low	High
Clothing (low value)	90,000				0.56	
Clothing (mid range)	25,000	60,000	500,000	3,600,000	0.08	0.86
Sports shoes		28,000				
Bicycles	1,200	1,600	240,000	480,000	0.60	1.79
Toys (low quality)		60,000	60,000			
Consumer electronics (small)	2,800	3,600	170,000	430,000	0.67	2.53
Consumer electronics (large)		480				
Appliances (small)	600	1,200	45,000	100,000	2.90	9.56
Appliances (large)						
Furniture (assembled)	250	600	20,000	150,000	1.93	21.50
Furniture (flat packed)				360,000	0.80	
Automobile parts	600	15,000	50,000	375,000	0.77	8.60

Container Shipping Costs and Cargo Value (updated)

Products	Items per 40 Foot Container (FEU)		Retail Value (USD per FEU)		Freight Rate (\$1,383 per TEU) per Retail Value (%)	
	Low	High	Low	High	Low	High
Clothing (low value)	90,000					
Clothing (mid range)	25,000	60,000	500,000	3,600,000	0.55	0.08
Sports shoes		28,000				
Bicycles	1,200	1,600	240,000	480,000	1.15	0.58
Toys (low quality)		60,000	60,000			0.38
Consumer electronics (small)	2,800	3,600	170,000	430,000	1.63	0.64
Consumer electronics (large)		480				1.98
Appliances (small)	600	1,200	45,000	100,000	6.15	2.77
Appliances (large)						
Furniture (assembled)	250	600	20,000	150,000	13.83	1.84
Furniture (flat packed)				360,000		
Automobile parts	600	15,000	50,000	375,000	5.53	0.74

Container Shipping Costs and Cargo Value



Containerized Cargo Flows along Major Trade Routes, 1995-2022



Containerized Cargo Flows along Major Trade Routes, 2020 (in million TEUs)



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Containerized Imports and Exports between Main Economic Region, 2013



Containerized Cargo Flows along Major Trade Routes, 2012



North American Containerized Trade with East Asia, 1995-2022 (TEUs)



Intermodal Transportation Cost Function



Time and Cost Involving Moving a 40 Foot Container between the American East Coast and Western Europe



Cumulative Cost and Time of Moving a 40 Foot Container between the American East Coast and Western Europe



Time and Cost for Moving a 40 Foot Container between the American East Coast and Western Europe



Container Transport Costs, 2000s



Monthly Intermodal Equipment Depreciation Factors



Container Transport Costs from Inland China to US West Coast (\$US per TEU)


Price of New Containers, 2001-2008



Container Lease Rates, 2003-2008



Composition of the Global Fleet of Containers, 2008



Composition of the Global Fleet of Containers, 2012



Global Container Fleet, 2003-2009



World Container Production, 2007



Composition of the American Domestic Container Fleet, 2003-2012



Economies and Diseconomies of Scale in Container Shipping



Impacts of River / Sea Shipping



Digital Intermodalism: Blockchains and Intermodal Transportation

