Military and Commercial Cargo Mission Needs

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Introduction

• The cargo world attempts to solve a very complex mission (problem)
• This presentation outlines the elements of the problem but does not define a specific mission
• I have been trying to understand this subject for a few years now
  – I may only be a few weeks ahead of you (if that)!
• This presentation is non-linear
  – Requires integration by the student after the fact…
• Military and commercial needs are similar in structure
  – Widely different values
  – Military values very dependent on situation
General Problem

• Object of the game: Devise a goods creation and distribution system that creates greater value than it costs
  – Measure of merit varies
• Elements of the system include:
  – Creation of the goods (manufacturing, mining, farming)
  – Distribution
  – Customers
General Solution

• Provides overall production/transport architecture to maximize an economic measure
• This optimization results in the need for global distribution of goods
  – System seeks a balance between production and transport costs:
    • Low-cost or expert labor
    • Mass production
    • Product type consolidation (cars in Detroit, movies in LA)
    • Farmland
    • Proximity to market
    • Good transport system access
    • Etc
• Production and distribution are a linked system
Transport Problem

• The problem pertains to the distribution of non-human objects (not electronic information)
  – Humans are “self-loading cargo” and are a special case not addressed here
  • Chief difference between people and cargo is that people’s time is generally much more valuable than cargo’s
    – Transoceanic transport:
      » Cargo: 99% ship, 1% air (by weight)
      » People: 1% ship, 99% air (approximately)
    – As a result, cargo systems are much different than passenger systems

• Addressing the transport problem in isolation from production, the object is to obtain the lowest total cost of transport
Total Distribution Cost

• Object of logistics systems is to minimize Total Distribution Cost (TDC)

• TDC is the total cost of transporting goods
  – Sum of cost of transport and cost of holding inventory

• Cost of transport is fees paid to carriers (ship, truck, etc)

• Annual cost of inventory is typically a fraction of the value of the inventory
  – This fraction is called “Inventory Carrying Cost”
    • Typical fraction is 25%, but depends heavily on actual goods, timing
      – Diamonds have low ICC, food has high ICC
    • Consists of interest, depreciation, taxes, insurance, losses, warehouses
Depreciation

- Depreciation is the most powerful and variable factor in ICC
- Depreciation refers to loss of potential value over time
- Depreciation may not be linear at all
  - Seasonal variation
    - If you get the air conditioners in one month late they may be on the shelves for 10 months – very expensive
    - Lots of stuff is seasonal!
  - Spoilage
    - Food is worth less than nothing after it spoils
- Depreciation may pertain to loss of value in the larger system, not just the cargo proper
  - Airplane on ground, factory halted, troops die, etc
- Obsolescence and Hits
  - Rapid technical change can cause high depreciation
    - Michael Dell says his computers depreciate 1%/week!
  - Inability to deliver a hit product will result in a loss of sales
  - Military version of obsolescence and hits pertains to war
    - Value of time can be very, very great in wartime
Cost of Transport

• Cost of transport is split into two parts:
  – Direct operating cost
  – Indirect operating cost
• Direct operating cost pertains to vehicle operation
  – Fuel, crew, vehicle depreciation, maintenance, etc
• Indirect operating cost pertains to other costs
  – Sales, cargo handling, administration, profit, etc
• Sum of direct and indirect operating costs is “cargo rate”
2002 Cargo Rates

Air and Ocean Cargo Rate ($/ton-nm) on Great Circle Basis

- **Aircraft**
  - $0.025/ton-nm + $25/ton
  - ($0.025 + $0.008 per ton-mile @ 3000 nm)

- **Container Ships**
  - $0.18/ton-nm + $450/ton
  - ($0.18 + $0.15 per ton-mile @ 3000 nm)
Comments on Cargo Rates

- Rates decline with range
  - Much of indirect operating cost is independent of range
    - Cargo handling, sales costs don’t depend on range
      - So indirect cost per mile is less at greater ranges
- Ships are much less expensive than airplanes
  - Ships are very efficient: L/D ~400
  - Ships indirect costs are much less than airplane’s
    - Large containers, mechanized loading
- Trend curves can be approximated by a simple formula
  - Rate = cost/ton-nm + cost/ton
    - Cost/nm can be thought of as DOC
    - Fixed cost can be thought of as IOC
- Scatter in rates due to two factors
  - Asymmetrical demand (east versus west for instance)
  - Airplane main deck pays full rate, belly cargo rides for ~IOC,
Total Distribution Cost

\[
TDC = (\text{cargo rate} \times \text{tons} \times \text{nautical miles}) + (\text{time} \times \text{cargo value} \times \text{ICC})
\]

so

\[
\frac{TDC}{\text{ton-nm}} = \text{cargo rate} + \left(\frac{1}{\text{speed}} \times \frac{\text{cargo value}}{\text{pound}} \times \text{ICC} \times 0.2283\right)
\]

Where units are $, tons, nautical miles, knots
Total Distribution Cost

- Plot shows relationship between value, ICC, TDC and speed
  - For three vehicle systems
- Y-intercept is cargo rate, slope is proportional to 1/speed
  - Note that speed is not vehicle speed alone, but entire supply chain speed. Very important!
- Line for WIG is speculative
- Fast, intermediate-cost vehicles can provide lower TDC for some types of goods

Supply Chain

• The “supply chain” refers to all the steps in the transport process in which the goods are “out of service”
  – So ICC applies to all of the inventory in the supply chain
    • In transit
    • Waiting between transport modes
    • At the origin being built up
    • At the destination being broken down
    • In the store until sold
  – An alternate definition of supply chain may include all the time your money is “out of service”
    • Some companies pay for the goods before they are manufactured
Inventory

• Inventory is expensive
  – Typically 25% of value per year

• Inventory performs several functions:
  – Buffer between a relatively steady production and an intermittent transport
  – “Safety stock” to assure an acceptable level of service (acceptable likelihood of delivery)
    • A function of system schedule reliability
    • Also a function of variability and predictability of demand
  – Buffer to connect two asynchronous transport modes
  – Buffer to build inventory sufficient for efficient transport
    • Between transport modes

• There is room for improvement in reducing inventory
  – Perfect knowledge would be a good start
Inventory Drivers

• Frequency of service
  – More frequent service reduces inventory at origin and destination
  – Reduces period between asynchronous transport modes

• Reliability of service from a schedule standpoint
  – Vehicle may be late
  – Vehicle may not be available (full)
  – Reliable service permits reduced safety stock
    • Uncertain ship availability drives shippers crazy

• Variability of demand

• Predictability of demand

• Supply chain architecture
Variability

• Variability in demand influences supply chain architecture
• Variability is roughly proportional to the square root of the quantity involved.
  – Large quantities provide proportionally less variability
    • 10/100 versus 100/10,000 (10% versus 1%)
  – This favors reduced product differentiation, centralized distribution centers
    • However:
      – Customers prefer differentiated products
      – Centralized distribution centers have longer delivery distances

• Architecture must balance quantity, differentiation and distance
  – Compare warehouse store with corner hardware store
  – Compare mail-order with local store
  – Some organizations use different architecture within same system
    • High-value goods centralized, low value goods dispersed
Predictability of Demand

• Suppliers attempt to match supply to demand at optimum price
  – Some architectures force long lead times (time between order and delivery)
    • This reduces predictability since market or competition may change in the meantime
    • Note that lead times can be cumulative
      – Many products are the sum of numerous separate products, sometimes serial

• Market serves as feedback for production
  – Long lag time between production and market feedback reduces precision of control
    • Very expensive mistakes
    • Exacerbated by seasonal aspect – cannot fine-tune over the long run

• Some architectures improve responsiveness despite long supply chains
  – Restaurants: generalized, low-value inventory held until the last moment when custom product is created
  – Dell Computer: same as restaurant
  – Last minute allocation: Mass order on ships, allocated to specific regions or stores just before docking according to present demand
Vehicle Size

- In transport systems, bigger is usually more efficient
  - Ships:
    - Volume/wetted area; Reynolds number; Froude number
      - Faster and more efficient
    - More cargo per crew
  - Airplanes:
    - Volume/wetted area; Reynolds number
    - More cargo per crew
    - Structural penalty of large size (wing bending mostly) is offset by other benefits (compact fuselage)
- However, large size implies lower schedule frequency
  - Optimum system must balance transport cost reduction of larger vehicle with reduced inventory of smaller vehicle
    - Because airplanes generally carry goods with greater value or ICC, they will tend to be smaller than ships
  - As world traffic increases, vehicles tend to increase in size
• Total Distribution Cost is influenced by the number of nodes (ports, distribution centers, stores, etc)
  – Fewer nodes result in more frequent service and/or larger vehicles
• In the case of ships, fewer ports means that the cargo must travel farther on more expensive trucks or trains
  – Number of ports must balance the value of frequent service and larger vehicles with the increased cost of surface transport
    • Casual observation indicates a tendency toward few, major ports
• In the case of airplanes, fewer airports means the cargo must travel farther in slower surface vehicles
  – Must balance value of frequency of service and vehicle size with slower delivery
  – Note that for airliners there are approximately one zillion airports worldwide
    • The number for cargo is much less because cost is more important than time
  – Route structure design can improve schedule frequency by combining loads
• In the case of distribution centers, fewer, larger centers are more efficient and require less safety stock (lower variability), but are farther from their customers
  – Cargo transport into distribution centers is typically less expensive that cargo going out
    • Packaging efficiency, variation due to quantity
• The size and/or number of nodes may increase over time as traffic increases
Supply Chain Speed

• Supply chain speed drives Total Distribution Cost (TDC)
  – More important for goods with high value per pound, high depreciation

• Supply chain speed driven by:
  – Vehicle speed
  – Supply chain architecture
  – Vehicle size

• Optimum supply chain architecture driven by:
  – Vehicle speed, size and cost
  – Value and ICC of goods
  – Distance between origin and destination
Alternative Supply Chain Architectures

Factory to Factory

- **Via ship**: Supply Chain ~5 wks
- **Via air**: Supply Chain ~1 wk

Key:
- → Input/output
- • Inventory
- • Manufacturing
- ▲ Ground transport
- △ Ocean transport
- ▲ Air Transport
Ship Time and Cost Profile
NYC to Rotterdam – a Direct, Best Case Route

Move to back-up
Alternative Supply Chain Architectures

Factory to Store to Customers

- **International**
  - Factories (n) → Loads by product → DC → Loads by store → Stores → Customers
  - ~8 weeks
  - "Store for Stores"
  - ~20 wks

- **Domestic**
  - Factories (n) → DC → Loads by store → Stores → Customers
  - ~6 wks
  - "Cross-Dock"
  - ~3 days

- **Domestic**
  - Factories (n) → Loads by store → DC → Stores → Customers
  - ~3 days
  - "Domestic"
  - ~6 wks
Alternative Supply Chain Architectures

Factory to Store to Customers

- **DC Stores Customers**
  - Loads by store
  - International w/ Foreign DC
  - Loads by product
  - ~4 weeks
  - “Store for Stores”
  - ~10 wks (0 hrs from order)

- **International w/ Foreign Cross Dock**
  - Loads by store
  - ~3 days Cross-Dock at airport
  - Loads by product
  - Factories (n)
  - ~6 wks (0 hrs from order)
Alternative Supply Chain Architectures

Restaurant / Dell Computer Model

**Restaurant**
-Loads by ingredient
- Fridge
- Kitchen
- Customers
- Factory (n)
- ~1 week?
- Low-value inventory
- ~2 wks? (~30 minutes from order)

**Dell Computer Model**
- Loads by component
- “Fridge”
- ~3 wks? (4 days from order?)
- Factory (n)
- ~1 week?
- Lower-value inventory

- Restaurant
- Dell Computer Model
Alternative Supply Chain Architectures

Offshore Dell Computer Model

Loads by component

Factories (n)

“Fridge”

~3 wks? (5 days from order?)

~1 week?

Lower-value inventory

Offshore Dell Computer Model
Alternative Supply Chain Architectures

Foreign Cars

Foreign Cars w/ DC

Factory → General, speculative load → DC → Loads by dealer
→ Customers

2 weeks?
“Car lot for dealers”

~8 wks?
Can be 0, 1, or 10 weeks from order

Foreign Cars w/o DC

Factory → Load per dealer’s order → Dealer → Customers

~6 wks?
Can be 0 or 8 wks from order
Alternative Supply Chain Architectures
Foreign Cars, Global “Mail” Order

Foreign Cars Built to Order

Customer's order

~1 wk? (~2 wk from order?)

Consumer Goods from Manufacturers Inventory

~1 wk (~1 wk from order)
Some Observations

• The value of speed comes from:
  – Reduced time in transit
  – The ability to reorganize architecture

• It’s not just the long trip that hurts. It’s also the slow feedback loop.
  – Between demand and supply
  – Seasonal or time-sensitive demand exacerbates this

• Fast transit can tighten the feedback loop

• Fast transit can permit customer to obtain goods from greater distance with acceptable delay
  – Global mail-order
More Observations

• It used to be that one went to a store or show to obtain information about goods
  – Information now flows for free via Internet
    • Often one can find better info on web than in store
    • This supports global mail order

• It may be that the best architecture combines more than one system
  – Slow and cheap plus fast, responsive and expensive
    • The tweeter has less throw than the bass speaker
How to Determine Cargo Mission Needs

• Examine current production/transport/customer system in a field of interest.
  – Evaluate value and ICC of goods, cost of system

• Generate alternative system architectures
  – Include production, transport and customer characteristics
    • Generate alternative transport vehicles

• Evaluate alternative system architectures
  – Primarily against total economic performance
  – Consider applications of the architecture beyond your chosen field, especially for the vehicle
  – Consider the future
  – Consider what competition can do to you

• Choose the best one
  – This defines your mission
Some Potential Systems of Interest

• Military deployment
  – Currently performed with transport and tanker airplanes, ships, dispersed US bases, prepositioned materiel, forward bases and ports, etc

• Transport of food
  – Elements to consider:
    • Wealthy northern hemisphere, poorer southern; offset seasons
    • Perishability, seasonality increase ICC

• Factory to factory
  – Serial buildup of lead times

• Car manufacture and delivery
  – Current system appears to have large inventories, is seasonal
  – Global manufacture may cause serial buildup of lead times
    • Design, tooling, components, assembly, delivery
    • Leads to over or under production, less advanced products
More Potential Systems of Interest

• Manufacture and delivery of consumer products
  – Currently a wide mix of system architectures

• What about housing?
  – Can you make houses in China and put them up in Kansas?

• What about health services?
  – Can you have a roving specialist (or general) hospital?
    • Example is Orbis, an eyesight hospital in a DC-10
Cargo Airplanes

- I suspect that your analysis will show that cargo airplanes have a substantially different mission than passenger airplanes.
- In the past, commercial cargo airplanes were derived from airliners to save development cost.
  - It may be now that the cargo market can support a purpose-built cargo airplane.
- Your analysis may show that a low cargo rate is more important than speed.
  - This requires an emphasis on low DOC and IOC.
  - Note that speed is good for productivity and therefore DOC.
- What airplane type provides the lowest cargo rate?
Questions?