Appendix F

Estimating Transport Costs

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There are a variety of measures commonly used for expressing the transport costs of a shipment or set of shipments. Shippers are most interested in measures, such as cost per shipment or cost per ton, that summarize the total costs they incur. However, transport costs vary with shipment size and length of haul. Accordingly, analysts find measures that reflect shipment size and/or length of haul to be more useful. These include cost per ton-mile, cost per shipment-mile, cost per container-mile, etc.

This appendix discusses sources of cost estimates for the truck, rail, water, and air modes.

■ F.1 Truck Costs

In general, truck costs rise with distance at a somewhat less than linear rate. However, for lengths of haul above 50 or 100 miles, truck costs increase only slightly more slowly than length of haul. Accordingly, cost per vehicle-mile is a particularly useful measure for analyzing truck costs.

Although the cost per mile of haul for intercity truck transport is relatively independent of length of haul, there are a number of other factors that influence this cost. These factors include:

- trailer type;
- configuration (number and sizes of trailers, number of axles, etc.);
- annual mileage of tractors and trailers;
- percentage of miles operated empty;
- payload;
- driver costs;
- fuel efficiency;
- type of vehicle ownership;

- truckload vs. less-than-truckload operation; and
- local conditions (taxes, terrain, congestion, etc.).

Exhibit F.1 shows Jack Faucett Associates (JFA) estimates of typical truck transport costs.[1] These costs were developed in 1991 using forecasts of 1995 conditions and expressed in 1988 dollars. The exhibit shows how costs vary by vehicle configuration, gross vehicle weight (GVW), and trailer type. For each trailer type, the exhibit shows a typical percentage of miles that vehicles operate empty and how this percentage affects the cost per loaded mile. Also, for each GVW, the exhibit shows payload carried and cost per ton-mile. For a given configuration and trailer type, costs per mile rise slowly with GVW and payload, but costs per ton-mile drop appreciably.

All costs shown in Exhibit F.1 are for truckload operation. Taking into consideration the increased handling required for less-than-truckload (LTL) operation, JFA estimated costs for intercity LTL shipments to average about 15 cents per ton-mile (in 1988 dollars) – equivalent to $2.40 per vehicle-mile of operation for a five-axle twin 28-foot configuration.

A factor of 1.16 for converting the JFA cost estimates from 1988 dollars to 1995 dollars is developed in the first subsection below. Applying this factor to the Exhibit F.1 estimates for the operation of 48-foot dry vans produces an estimate of $1.19 to $1.25 per vehicle-mile in 1995 dollars. As indicated in Exhibit F.1, costs per mile for longer and heavier configurations are somewhat higher, as are costs per mile for conventional length refrigerated vans and tank trailers.

The issues of how to estimate truck costs and the effect that a change in the highway system or in public policy might have on truck transport costs are complex and, when accurate estimates are needed, the development of such estimates requires quite detailed analyses. Such analyses may be performed using an updated version of the JFA spreadsheet or any of several proprietary models developed by consulting firms and software vendors. Two such models are described in the second subsection below. For those purposes for which an order-of-magnitude estimate will suffice, an estimate of $1.25 per vehicle-mile may be used.

Adjustment for Inflation

Exhibit F.2 documents the development of an inflation factor for converting the JFA cost estimates from 1988 dollars to 1995 dollars. For the

[1] Jack Faucett Associates, *The Effect of Size and Weight Limits on Truck Costs*, Working Paper, Revised October 1991, Appendix A.

Exhibit F.1 Estimates of 1995 Costs for Truckload Operations (1988 dollars)

Configuration	GVW (lbs)	Cost per Vehicle Mile	Percent Miles Empty	Cost per Loaded Mile	Payload (lbs)	Density (lbs/ft³)	Cost per Ton-Mile (cents)
Dry Vans							
5 Axle 48′	52,000	$1.03	15%	$1.20	24,500	7.0	9.78
	61,000	1.04	15%	1.21	33,000	9.4	7.36
	78,000	1.08	15%	1.25	50,000	14.3	5.01
5 Axle 53′	56,000	1.04	15%	1.21	27,100	7.0	8.94
	78,000	1.09	15%	1.26	49,100	12.7	5.13
6 Axle 48′	54,000	1.06	15%	1.24	24,500	7.0	10.13
	80,000	1.11	15%	1.29	50,500	14.4	5.12
	86,500	1.13	15%	1.31	57,000	16.3	4.59
5 Axle Twin 28′	59,800	1.07	15%	1.25	28,600	7.0	8.76
	80,000	1.12	15%	1.30	48,800	12.0	5.32
7 Axle 40′ + 28′	105,500	1.16	15%	1.35	69,200	14.0	4.13
9 Axle Twin 48′	95,200	1.27	15%	1.49	49,000	7.0	8.80
	127,400	1.37	15%	1.59	81,200	11.6	3.91
7 Axle Triple 28′	83,400	1.26	15%	1.47	42,900	7.0	7.43
	116,000	1.34	15%	1.55	75,500	12.3	4.10
Other Trailer Types							
Refrigerated Van (5 Axle 48′)	78,000	1.17	15%	1.36	48,100		5.65
Flatbed (5 Axle 48′)	78,000	1.08	25%	1.40	50,400		5.56
Tank (5 Axle 42′)	78,000	1.35	45%	2.36	53,400		8.85
Hopper (5 Axle 42′)	78,000	1.04	40%	1.67	53,400		6.21
Dump (5 Axle 36′)	70,000	1.02	40%	1.64	43,600		7.53

Source: Jack Faucett Associates, *The Effects of Size and Weight Limits on Trucks Costs*, Working Paper, Revised October 1991, Appendix A.

Exhibit F.2 Estimating Effects of Inflation

(1) Cost Component	(2) Data Source	(3) 1988 Value	(4) 1994 Value	(5) Growth Ratio 1988-1995[1]	(6) Weight[1]	(7) Contribution to Cost Change (5) x (6)
Drivers	U.S. Bureau of Labor Statistics (BLS), Occupational Earnings in all Metropolitan Areas, mean hourly pay for all drivers of tractor-trailers.	\$12.24	\$13.48[2]	1.145	28%	0.321
Vehicle	BLS Producer Price Index (PPI) for trucks over 10,000 lbs. GVW (Series 1106).	112.4	138.7	1.278	19%	0.243
Fuel	U.S. Department of Energy, Energy Information Administation, U.S. average retail diesel fuel price per gallon.	\$1.25[3]	\$1.126[4]	0.901	20%	0.180
Tires	BLS PPI for tires (Series 1201).	93.6	97.8	1.053	3%	0.032
Repair	BLS Consumer Price Index for automotive maintenance and repair (SE 49).	119.7	150.2	1.303	9%	0.117
Overhead	U.S. Bureau of Economic Analysis, Implicit GDP deflator (current dollar GDP divided by constant dollar GDP).	1.039	1.261	1.254	21%	0.263
					100%	
Overall Adjustment Factors						1.156

[1] See text.
[2] 1993 value.
[3] Model's forecast of 1995 fuel price in 1988 dollars.
[4] Average fuel price, week of May 8, 1995.

purpose of the conversion, truck costs were decomposed into six components, corresponding to the six components considered in the original JFA analysis, and separate adjustments were developed for each of these components.

For all components except fuel, the adjustment was performed using an appropriate price index or, in the case of driver costs, average driver wage rates. The price indexes and wage-rate series used are identified in Column 2 of the exhibit. These series were used to obtain an annual compound rate of change for each cost component, generally using 1988 and 1994 values, and this inflation rate was extrapolated to 1995. The ratios of the extrapolated 1995 values to the 1988 values are shown in Column 5 of the exhibit.

The adjustment for fuel costs was handled somewhat differently. JFA fuel costs were based on a forecast 1995 diesel-fuel price of $1.25 per gallon (in 1988 dollars). The actual average price of diesel fuel is only $1.126 per gallon, a price that is about ten percent lower than the price assumed by JFA. The ratio of $1.126 to $1.25 is shown in Column 5 of the exhibit.

The sixth column of Exhibit F.2 shows the approximate percentage of JFA's forecast of total costs contributed by each of the six cost components. Multiplying each of these percentages by the corresponding Column 5 growth ratios and adding produces the overall inflation adjustment factor, 1.156, developed in Column 7.

It may be noted that the above adjustment procedure excludes the effects of changes in technology between 1988 and 1995. This exclusion is appropriate since the JFA cost estimates were intended to reflect forecasts of 1995 technology. However, additional use of this procedure to adjust the cost estimates to current dollars in some future year is not recommended. Such use of this procedure would not reflect the effects of future improvements in technology, and so it would tend to overstate the effects of inflation.

For the purpose of future price adjustments, it is recommended that the Producer Price Index (PPI) for nonlocal trucking or one of its subcomponents be used. This price index (PCU4213) was initiated by the Bureau of Labor Statistics in June 1992. Its subcomponents include indexes corresponding to agricultural trucking (#1), LTL general freight (#311), and truckload general freight (#312).

Software Packages

This subsection discusses software packages for performing detailed analyses of truck costs. Packages from two vendors are discussed below.[2] The first package, MicroTOCS (produced by Snavely, King & Associates of Washington, D.C.) is primarily designed to provide detailed cost estimates for individual truckload (and multi-truckload) shipments. The second package, the Truckload Cost Information System (TL/CIS) (produced by the Transportation Consulting Group of Bethesda, Maryland), has a more carrier-oriented focus, producing less cost detail for individual shipments but a substantial amount of aggregate information describing the overall costs incurred by truckload carriers. Both vendors also have corresponding packages for analyzing costs for LTL shipments and operations.

The prices of the software packages vary with: the specific configuration (PC versus mainframe version); amount of technical support needed; whether any consulting services are required in preparing data for input into the models and in interpreting results; and the number of work stations and sites involved. The Transportation Consulting Group charges $3,900 for a site license for TL/CIS and $250 per update.

MicroTOCS

MicroTOCS is a package produced by Snavely, King & Associates for estimating the costs of truckload movements. In MicroTOCS, the basic costing unit is a truckload shipment from a particular origin to a particular destination. The shipment costs can be reported in a variety of ways, including: total operating cost per mile; total cost per mile; total cost per ton; and total cost per ton-mile. Total cost includes equipment capital cost, while operating cost does not. All costs exclude loading and unloading costs and the cost of any associated waiting time. However, empty return ratios are reflected in the cost estimates.

Linehaul operating costs are estimated as consisting of: driver costs; fuel costs; miscellaneous costs; tires; maintenance; user taxes; and administrative and overhead. The estimates of tire and maintenance costs distinguish the tractor and trailer components; and insurance costs and licensing and permit charges are also distinguished. Total costs include all operating costs plus capital costs for tractors and trailers.

The operation of the system requires the user to move through a series of menus specifying model inputs. The first menu requires specification of

[2] Some other firms that have developed proprietary models for estimating truck costs are IBI Group (Toronto), Peat Marwick Stephenson & Kellogg (Toronto), and Trimac Consulting Services (Calgary, Alberta).

shipment characteristics: total tons; tons per trailerload; trip distance; and estimated empty return mileage. The remaining menus provide default settings for various costs required by the model and provide the user with the opportunity to modify these settings.

The Truckload Cost Information System

The Transportation Consulting Group's Truckload Cost Information System (TL/CIS) is designed primarily for use by truckload carriers for analyzing the costs of various aspects of their operations. Accordingly, TL/CIS provides less detail than MicroTOCS about costs relating to individual shipments, though, unlike MicroTOCS, it does reflect data on pickup, delivery, and unloading costs. With its broader focus, TL/CIS makes greater demands on the user in terms of data gathering and information collection and provides correspondingly more detail.

The underlying basis for TL/CIS is the activity-based accounting system required by the Interstate Commerce Commission in its annual report process. This accounting system requires Class I and II carriers to break down all cost categories by activity. For example, driver wages are broken down into wages paid for pickup and delivery activities versus those paid in linehaul activities. Accordingly, the TL/CIS model requires carriers to break down all of their costs into individual components and then account for the cost components by activity. The major activity categories for a truckload carrier are linehaul, loading, unloading, stopoff, claims, and billing and collecting.

At the most disaggregate level, the program produces output in terms of costs for a particular shipment (with origin and destination specified) or a round-trip movement. In contrast to MicroTOCS, however, TL/CIS reports not only the total linehaul costs for a shipment, but also includes costs for pickup, delivery, unloading and any stopoff costs. In TL/CIS, the basic unit of costing analysis is costs per mile. There is no information on type of commodity, nor is there any effort to determine load capacity, cargo weight, cost per ton, or cost per ton-mile. Instead, the program is designed to operate in batch processor mode to summarize and report on shipments from a particular terminal, on a specific traffic lane, from a particular customer, or by a particular salesperson, during any given time period. These summary reports form the backbone of the costing system. It allows the carrier to determine how specific terminals, traffic lanes, accounts, and salespeople are doing and where trouble spots exist within the entire system.

TL/CIS has a module designed to provide the interactive costing of specific loads and trips by means of an on-screen "input log" which the user completes to describe a particular move. This input log gives the user the flexibility to select from a choice of over 100 different driver and equipment configurations.

■ F.2 Railroad Rates and Costs

Average 1992 railroad rates per ton-mile are summarized in Exhibit F.3 for selected major commodity groups. The commodity groups shown in the exhibit account for about 87 percent of rail tonnage and 88 percent of rail revenue.

The average railroad rate in 1992 was 3.03 cents per ton-mile. The average rate in 1994 can be estimated by multiplying by 1.017 (from the U.S. Bureau of Labor Statistics, PPI for railroad line haul operations) to produce a rate of 3.08 cents per ton-mile. Extrapolating an additional year produces an adjustment factor of 1.026 and an average rate of 3.11 cents per ton-mile for 1995.

Rates per ton-mile tend to vary inversely with length of haul, size of shipment, and commodity density. If rate and cost estimates are required that reflect the effects of these influences on actual transport costs, estimates can be obtained using the Interstate Commerce Commission's Uniform Rail Costing System (URCS). Computer implementations of this system are available from several commercial sources. One such implementation, MicroURCS (produced by (Snavely, King & Associates of Washington, D.C.) is discussed in the subsection below.

For many purposes, less precise rate estimates should suffice and data presented in Exhibit F.3 should prove adequate. The average rates for the commodities shown in this exhibit are all between two and four cents per ton-mile with one very significant exception: the average rate for transportation equipment is 9.01 cents per ton-mile. This high rate occurs primarily because of the low density of assembled motor vehicles (which average only 22 tons per carload as compared to an average of 66 tons per carload for all commodities). The lowest average rates are for coal and farm products (particularly grain), both of which are frequently shipped by unit train, qualifying for significant volume discounts.

A Software Package

This section discusses a software implementation of the ICC's Uniform Rail Costing System (URCS). The package, MicroURCS, was developed by Snavely, King & Associates (of Washington, D.C.). Its price varies with the specific configuration (PC versus mainframe version); amount of railroad-specific cost data purchased; amount of technical support needed; whether any consulting services are required to prepare data for input into the model or to interpret results; and the number of work stations and sites involved.

For each shipment, the minimum information required of the user by MicroURCS consists of commodity, tonnage shipped, railroads used, and

Exhibit F.3 Average Rail Rates per Ton-Mile for Selected Commodity Groups

STCC Code and Commodity Group		Cents per Ton-Mile (1992 Dollars)
01	Farm Products	2.19¢
11	Coal	2.10
14	Nonmetallic Minerals	2.98
20	Food Products	2.92
24	Lumber and Wood Products	2.89
26	Pulp and Paper Products	3.93
28	Chemical Products	3.90
29	Petroleum and Coal Products	4.03
32	Clay, Concrete, Glass, and Stone Products	3.59
33	Primary Metal Products	3.18
37	Transportation Equipment	9.01
40	Waste and Scrap Materials	3.83
42	Empty Shipping Containers	3.83
46	Miscellaneous Mixed Freight	2.91
All Commodities		**3.03¢**

mileage on each railroad. With just this information, the program will set a number of default values to estimate railroad costs for the shipment. Alternatively, users can provide additional data, overriding the defaults, and enabling the program to produce better cost estimates.

The ICC's URCS is a three-phased process. Phase 1 involves an exhaustive regression analysis based on data supplied by the railroads. Phase 2 involves the conversion of the regression results into unit costs and operating parameters. The third phase uses unit costs and operating parameters, along with the detailed shipment characteristics supplied by the user, to determine shipment costs.

Within the structure of MicroURCS, users can change parameters and assess the impact of these changes on shipment costs. The sensitivity analysis, making individual changes and assessing impacts, is straightforward and a strong point of this software package.

MicroURCS develops cost estimates for specific, individual railroad shipments from data supplied by the individual railroads and analyzed through the URCS. If the user of MicroURCS purchases costing data from all the individual railroads, then cost estimates for a given movement will be based on data from the actual railroads participating in the movement. Otherwise, the cost estimates will be derived from data from all the railroads operating in the appropriate region.

The user begins the input process by specifying information about the commodity being moved and its specific requirements. The user specifies the commodity; whether a TOFC/COFC movement is involved; the net tons in the shipment; whether any protective services, accessorial services, or refrigeration services are needed; and whether the shipment involves movement of motor vehicles.

Users are then directed to provide information on the equipment used, routing, and handling requirements for the shipment. If the shipment is a TOFC/COFC shipment, the user is asked whether the railroad or the shipper is supplying the trailer/container and the number of units involved. The program requests information on the number of cars, car type (with default car types selected on the basis of commodity specification), and whether the cars are supplied by the railroad or by the shipper. The program also requests information on the specific railroads in the route, the mileage on each railroad, the origin and destination, and any special handling required at the origin or destination. As previously observed, default values can be used for all inputs except commodity, tons, and mileage by railroad.

The program next moves into a costing section based on the line-haul characteristics of the shipment. This involves determination of whether the specific shipment is part of a multi-car shipment. Switching costs at origin and destination are reduced by 75 percent for unit-train movements and by 50 percent for other multi-car shipments. This section of the program computes car-miles, gross tons, gross ton-miles, number of intra/inter -train switches, and interchange switches. These inputs and intermediate results are used to develop detailed cost data for the individual shipment. The program calculates total variable costs per car, per net ton-mile, and per net ton, and also fully allocated cost per net ton-mile.

■ F.3 Water Transportation

Cost and time analysis for water transport facilities can either be based on the marginal impact on existing rate and service characteristics or the development of fully-allocated system costs and service parameters for representative cargo flows. The virtual elimination of meaningful tariff rates for most water transportation limits the ability to use rate analysis for public use facilities with a mixture of commodities. The more common method is to estimate the underlying cost and transit-time structure, calibrated against available rate and service data. This section examines the specific elements used in water transport costing, provides some representative sources, and also identifies critical issues which affect the results.

Types of Operation

The structure for the cost analysis depends on the operating and market patterns specific to various vessel and service types. The various types of water transportation can be categorized:

- inland barge;
- intercoastal tug-barge;
- deep-sea bulk carriers (liquid, dry, and mixed);
- deep-sea breakbulk carriers (liner and tramp); and
- deep-sea container carriers (liner).

Inland barge and intercoastal tug-barge operations generally are limited to the carriage of bulk commodities. Barge transport includes the dedicated transport of single commodities between two points, as well as common carrier distribution of common barge types between river systems. As with other bulk operations, the shipper often owns and operates dedicated equipment, particularly for coastal operations. Inland barges typically are moved in multi-barge tows which may combine barges for several shippers. For example, an upper Mississippi tow operator may pick up grain, fertilizer and chemical barges at various points on the upper river for transfer to operators on the lower Mississippi at an interchange point. On the other hand, dedicated services will shuttle between a limited number of river points, with the towboat often waiting with the barge for the return.

Deep-sea operations are primarily distinguished by the combination of vessel type and operating pattern. "Tramp" operations are based on single voyages moving one or more commodities, often on a single charter basis. Bulk and high-volume or seasonal breakbulk commodities typically move in this fashion. Tramp operations generally include full shipload lots and empty deadhaul legs between discharge and load ports. Some vessels may be dedicated to a particular cargo flow (e.g., Alaskan oil carriers), or may shift between trade routes and commodities on a seasonal or market-driven basis (e.g., tramp refrigerated vessels).

"Liner" operations are based on multi-commodity markets using multiple vessels in fixed port rotations and schedules. These services are designed for containerized and general breakbulk cargoes, and typically make multiple port calls over a coastal range. For example, a North Atlantic carrier might operate four vessels with weekly calls at Charleston, Baltimore and New York in the U.S. and Felixstowe and Rotterdam in Europe. A single voyage for each vessel would take 28 days. Container operators also maintain inland distribution systems for their containers, which must also be considered in a costing analysis.

Cost Elements

Total transport costs can be estimated from a combination of physical characteristics, operating and productivity factors, and unit cost elements. The physical characteristics relate to items such as vessel type, cargo handling equipment, and commodity density. Operating and productivity factors include vessel and cargo processing time, fuel efficiency, and vessel speed. The unit costs are typically based on volume or time and are combined with operating estimates to generate total system costs.

Inputs for water transportation costing can be categorized:

- vessel;
- voyage and port;
- cargo-related; and
- inland and other.

Vessel-related inputs encompass physical and cost characteristics which apply regardless of the voyage or service patterns (with some exceptions). The physical characteristics of the vessel affecting costs include:

- type and utilization (e.g., tramp bulk vessel);
- physical dimensions (for accessibility and port charges);
- capacity (cargo load and design speed);
- operating efficiency (fuel consumption and maneuverability);
- manning requirements;
- safety characteristics (for annual repair and insurance estimates); and
- annual operating availability (for allocating annual costs).

The cost inputs associated with the vessel include:

- capital or lease cost (on annual or other basis);
- annual insurance (hull and machinery, personnel and injury);
- maintenance and repair (periodic and overhaul);
- supplies and stores;
- crew costs;
- fuel; and
- administrative/overhead.

Annual costs for capital/lease, maintenance and insurance are generally specific to a particular type of vessel, but may vary with the type of utilization (e.g., high risk voyages). Supplies and stores and crew costs can be estimated on an annual or daily basis. Unit fuel costs vary with fuel type and the point of purchase. Administrative and overhead costs typically are estimated as a percentage of all other costs (perhaps excepting capital costs).

Sources for vessel data include: Lloyd's Registry of Shipping (and an associated on-line database); the U.S. Maritime Administration; special industry reports by Drewry Shipping Consultants of London; and various industry journals (such as *Containerization International, Lloyd's Shipping Economist, Marine Log, Maritime Reporter and Engineering News*, and *Waterways Journal*). As with other costs, costing for international operations should consider the effect of currency exchange rates when appropriate.

Voyage and port inputs are specific to a particular use of a vessel, varying by trade route and commodity market. The vessel itinerary dictates many of the cost and time factors and is defined by the specific port calls, the voyage length, and the time or distance under low-speed operations (e.g., canal transit). Vessel itineraries frequently change, sometimes requiring a definition of a prototypical voyage for analysis.

A tramp operation will typically assume a direct route between the load and discharge ports at full operating speed unless a lower speed is appropriate based on fuel economy. In many cases, tramp operations will include a deadhaul (e.g., empty) leg from the discharge port to the next voyage's load port, some portion of which may be allocated to the previous voyage.

Costing for liner operations is typically based on the entire itinerary rather than specific port pairs. A liner operation following a fixed schedule may operate at a lower-than-maximum speed which can be calculated based on available sea time (i.e., round-trip voyage time minus port and other delays).

Transit time for inland barge operations may include delays for lock processing which often represents a large portion of total transit time. Lock delays can be measured from historical data or approximated using models which combine lock-processing efficiency with traffic-flow and tow-arrival patterns.

Port characteristics may be estimated for each port or within general categories (e.g., domestic and foreign). Operating factors include berthing delays (in fixed hours or days per voyage), vessel berthing time (based on vessel size and berth type), and cargo handling time (based on load characteristics, equipment type and stevedoring practices). The term "port delay" is typically used to denote an unusual circumstance (e.g., berth congestion) which extends the port time, but may be applied to the entire port time in some cases.

Costs which are specific to a voyage itinerary include vessel tolls and port-related charges applied to the vessel (often based on size) and the cargo transferred (mostly based on type and volume). Vessel-related port costs include dockage and pilotage, while cargo-related costs include wharfage and cargo handling costs. Some port costs are fees assessed by the port as reimbursement for use of public facilities. Most cargo handling costs in deep-sea trades are charged by private stevedores based on the required manpower and equipment to load and discharge the vessel. Typical charges include stevedoring, terminal handling, equipment rental, and container stuffing and stripping. Practices for port charges may vary by U.S. coast and for foreign countries. Bulk and domestic barge operations typically utilize private terminals, often with no public port involved. Costs for these operations must be estimated from private sources.

Sources for voyage itineraries include Lloyd's on-line databases, the Journal of Commerce Shipcards and other service listings. Port operating characteristics and non-public cargo handling costs must typically be developed through private interviews; although, in most cases, costs and operating factors will be common by general cargo type over a particular port range. Fees charged by ports usually are available from port tariffs, although tariff rates may not apply to high-volume users. Worldwide port directories (e.g., *Lloyd's Ports of the World*) often include summary information on port tariffs, facilities and rules.

Cargo-specific inputs affecting cost and time factors include physical, market and packaging characteristics. The physical stowage and load characteristics determine the utilization of vessel and container capacity, while the handling and storage requirements dictate the type and cost of port facilities and equipment. The market characteristics include the balance of flow which determines port handling time and costs, as well as load factors for liner operations and required vessel size for tramp operations (including backhaul opportunities). When cargo is palletized or containerized, the cargo weight/unit relationship affects cargo handling factors.

The cost of container and pallet systems may also be included in the cost analysis. Pallet costs are based on an allocated share of the unit cost for reusable units and the total costs for one-way pallets. Container system costs can be estimated by calculating capital and operating costs for a fixed ratio of containers to available vessel capacity ("slots"). For example, a service of four vessels with a capacity of 800 twenty-foot equivalent container units (TEUs) might require three containers for every TEU of capacity or a total of 7,200 TEUs. The "additional" containers are either resting in a port or involved in the inland transit.

A final cargo-related cost which may be considered is the inventory cost which measures the financial cost of "holding" the commodity during the transit period. While this cost is not included in the transport rate or typically calculated at all, it provides a basis for measuring the impact of delays and changes in transit time, including changes resulting from changes in mode and/or route. Inventory costs can be calculated based on the average value per weight or container unit, combined with interest rate which reflects the cost of the capital required to hold the commodity for the period of transport.

Sources for cargo-related physical inputs include *Thomas' Stowage* (which provides weight-to-volume ratios on a commodity basis) and cargo flow statistics which cover both weight and volume data (e.g., PIERS and Census sources described in Appendix C). Data for major commodity flows may also be available through Drewry and other industry sources. Flow patterns can be measured from traffic statistics (available from PIERS, Census and individual ports). Other data must be generated from interviews or general commodity or water transportation sources.

The final category of costs is for inland transport which can be estimated using the appropriate modal costing methodology or assumed at a fixed unit cost if not influenced by the new facility. A key consideration for many general cargoes is the split between rail and truck flows. This information is not generally available but may be collected through a survey or interview process or approximated from a disaggregation by geographical region (i.e., rail vs. truck hinterlands).

Cost-Estimating Methods

Total and unit transport costs can be estimated by generating total capital and operating costs for an annual operation or single voyage, and then appropriately allocating the costs over the traffic flow. The first step is typically to calculate the total voyage time for use in generating time-based costs. Other cost factors are combined with the appropriate "use" factor (e.g., crew man-days or tons loaded and discharged). The allocation of annual costs on a voyage-basis requires the following steps:

- calculate total annual costs;
- estimate projected annual operating days (excluding maintenance and other downtime);
- calculate daily cost by dividing annual costs by operating days; and
- calculate voyage costs by multiplying daily costs by voyage days.

Fully allocated unit costs for bulk and breakbulk commodities are usually stated on a "per ton" basis, while containerized cargoes may be either per ton or per container or TEU. Costs may also be stated on a ton-mile basis, particularly if port and voyage costs are insignificant or measured separately. The unit costs can be calibrated against rate data if available.

Some key issues which often apply to water transport costing include:

- *Capital Costs: Accounting or Economic* – The estimation of capital costs on an accounting basis (i.e., depreciation, principal and interest) may skew results when comparing services with different fleet compositions. The true "economic" costs can be estimated based on an amortization of the current sale value over the expected lifetime minus scrap value.
- *Allocation of Fixed Costs* – The volatility of water transportation markets often creates a disparity between rates and fully allocated costs due to the method for allocating fixed costs. It is often useful to segregate marginal and fixed costs in the analysis, and also to consider current industry conditions.
- *Definition of Cargo Capacity* – While most capacities are stated in weight terms, volume-based restrictions apply for many breakbulk and containerized commodities. It is critical that vessel loading reasonably reflect the cargo mix, particularly when comparing different vessel types.
- *Allocation to Backhaul Flows* – Many waterborne services are designed for one-way movements of specific commodities (e.g., vehicles or bananas) or may have a natural imbalance in one direction. The backhaul leg is often considered secondary to the main cargo flow and

is often sold on a marginal cost basis. In such cases, an equal allocation of fixed costs among all traffic understates the costs in the headhaul direction. (The service would probably exist with no backhaul traffic, in which case, the headhaul traffic would be assigned all fixed costs). Various adjustments include assigning only the marginal costs of cargo handling to the backhaul or calibrating the assignment of fixed costs based on the relative market rates in each direction.

Typical Costs

Deep-Draft Vessels

Exhibit F.4 shows some typical costs for deep-draft vessels by type and vessel size. The costs per hour are a weighted average of fiscal year 1995 Corps of Engineers estimates for vessel costs at sea and in port and exclude port fees and tolls.[3] (The only difference between at-sea and in-port costs is fuel consumption, which represent less than ten percent of total costs.)

For tankers and dry-bulk vessels, costs per ton-mile were estimated by assuming an average load factor (ratio of cargo weight to deadweight tons) of 60 percent and that 20 percent of time is spent in port. For general cargo vessels, the corresponding assumptions were an average load factor of 75 percent and 40 percent of time in port. For containerships, costs per 20-foot equivalent container unit (TEU) mile were estimated assuming an 80 percent load factor (relative to TEU capacity) and 20 percent of time in port.

The cost estimates in Exhibit F.4 show very large cost advantages for foreign-flag vessels relative to U.S.-flag vessels and substantial economies of scale for the larger vessels (though large vessels, of course, are limited to routes generating high traffic volumes and serving harbors with adequate channel depth).

Inland Barges

Exhibit F.5 shows some typical costs for operating inland barges. The costs per hour for barges and towboats are fiscal year 1995 Corps of Engineers estimates.[4] The costs per ton-mile are derived assuming an overall average operating speed of 10 knots (upstream and downstream) and

[3] U.S. Army Corps of Engineers, Institute of Water Resources, *FY 1995 Planning Guidance: Deep Draft Vessel Costs*, Fort Belvoir, Virginia, December 1994.

[4] U.S. Army Corps of Engineers, Institute of Water Resources, *FY 1995 Estimated Towboat and Barge Costs*, Draft, Fort Belvoir, Virginia, no date.

Exhibit F.4 Deep-Draft Vessel Costs (1995 dollars)

		U.S. Flag		Foreign Flag	
Capacity (DWT Tons)	Speed (Knots)	Dollars per Hour	Cents per Ton-Mile[1]	Dollars per Hour	Cents per Ton-Mile[1]
		Tanker – Non-Double Hull			
20,000	14	$1,592	1.184¢	$639	0.475¢
50,000	14	1,953	0.581	815	0.243
90,000	14	2,270	0.375	975	0.161
150,000	14	2,625	0.260	1,162	0.115
265,000	14	3,128	0.176	1,440	0.081
		Tanker – Double Hull			
20,000	14	$1,452	1.080¢	$583	0.434¢
50,000	14	1,981	0.589	826	0.246
90,000	14	2,519	0.417	1,075	0.178
150,000	14	3,185	0.316	1,386	0.138
265,000	14	4,228	0.237	1,880	0.106
		Dry Bulk			
15,000	14	$1,093	1.084¢	$393	0.390¢
40,000	14	1,430	0.532	561	0.209
80,000	14	1,820	0.339	759	0.141
120,000	14	2,136	0.265	820	0.114
200,000	14	NA	NA	1,204	0.090
		General Cargo			
11,000	17	$1,059	1.259¢	$412	0.490¢
20,000	17	1,393	0.910	542	0.354
30,000	17	1,721	0.750	667	0.291
		Container			
Capacity (TEUs)	**Speed (Knots)**	**Dollars per Hour**	**Cents per TEU-Mile**	**Dollars per Hour**	**Cents per TEU-Mile**
600	17	$909	14.85¢	$544	8.88¢
1,200	17	1,154	9.43	768	6.28
2,000	18	1,517	7.02	1,101	5.10
2,800	19	1,984	6.22	1,527	4.78
4,000	20	2,293	4.78	1,811	3.77

[1] Excludes port fees and tolls.

Source: Study team estimates and data from U.S. Army Corps of Engineers, Institute of Water Resources, *FY 1995 Planning Guidance: Deep Draft Vessel Costs*, Fort Belvoir, Virginia, December 1994.

Exhibit F.5 Inland Barge Costs

Barge Type	Commodity	Dimensions (L x W x D) (Feet)	Capacity (Tons)	Operating Cost Per Day	Tow Characteristics				Cents per Ton-Mile[1]
					Horsepower	Operating Cost per Day	Barges per Tow	Load Factor	
Standard Dry Barge									
Deck Barge	General Cargo	130x35x10	750	$58.07	1,200	$2,717	1	62.5%	3.08¢
					1,500	3,109	4	62.5	0.93
		195x35x12	1,500	$89.66	1,200	$2,717	1	62.5%	1.56
					1,500	3,109	4	62.5	0.48
Open Hopper	General Bulk	195x35x12	1,500	$79.35	1,500	$3,109	4	62.5%	0.48
					5,600	7,677	15	62.5	0.38
Covered Hopper	General Bulk	195x35x12	1,500	$91.52	1,500	$3,109	4	62.5%	0.48
					5,600	7,677	15	62.5	0.34
Standard Liquid Barge									
Tank – Double Hull – with Coils	Petroleum Products	195x35x12	1,425	$256.70	1,500	$3,109	4	55%	0.69¢
					5,600	7,677	15	55	0.51
Single Skin Tank	Liquid Bulk	195x35x12	1,425	$210.86	1,500	$3,109	4	55%	0.66
					5,600	7,677	15	55	0.48
Chemical Tank (II) – Coils and Lined	Liquid Bulk	195x35x12	1,425	$323.90	1,500	$3,109	4	55%	0.73
					5,600	7,677	15	55	0.56
Specialized Barge									
Self-Unloader	Cement	195x35x12	1,410	$337.60	2,300	$4,077	2	50%	1.76¢
		290x50x12	3,300	770.20	4,200	6,152	2	50	1.21
Tank – Double Hull – with Coils	Petroleum Products	290x50x12	3,000	$524.51	4,200	$6,152	2	50%	1.25
Pressure Tank	Ammonia	278x50x12	2,500	$1,736.99	4,200	$6,152	2	50%	2.01
Pressure Tank	LPG	210x44x12	1,500	$1,129.96	2,300	$4,077	2	50%	2.20
Pressure Tank	Chlorine	195x35x12	1,000	$745.61	2,300	$4,077	2	50%	2.90

1 Excludes port fees and the effects of lock delays and transit times.

Source: Study team estimates and data from U.S. Army Corps of Engineers, Institute of Water Resources, *FY 1995 Estimated Towboat and Barge Costs*, Draft, Fort Belvoir, Virginia, no date.

tows underway 80 percent of the time. This last assumption is appropriate only for waterways without locks. For waterways with locks, an additional (waterway dependent) adjustment is necessary to reflect lock transit and delay times (decreasing the percentage of time underway and increasing costs per mile and per ton-mile).

Exhibit F.5 indicates that costs per ton-mile vary significantly with tow size and, to a more moderate extent, with barge type and commodity (which affects barge capacity) and with load factor. The load factors shown in the exhibit reflect assumed backhaul loads of 25 percent for dry barges, 10 percent for standard liquid barges, and zero percent for specialized barges. Four-barge tows are operated on several waterways, and 15-barge tows are operated on the Illinois and Ohio Rivers and on the upper Mississippi (and 30-barge tows are used on the lower Mississippi). Specialized barges usually are operated in dedicated service using small tow sizes.

For most commodities and tow sizes, the barge costs per ton-mile estimated in Exhibit F.5 are appreciably lower than the corresponding rail rates shown in Exhibit F.3 – in some cases by a factor of ten. However, as observed above, for most waterways, the barge costs require a further adjustment to reflect the effects of lock delay and transit times. Furthermore, if comparisons are to be made with rail rates, an additional adjustment is required to reflect the greater circuity of waterways. (Barge circuity is estimated to average about 17 percent more than rail circuity.[5])

■ F.4 Air Transportation

The secondary status of air freight in the air transport industry is indicated by the lack of data and techniques for cost analysis. While detailed unit costs are available for passenger transport, freight costs are typically stated as general "per pound" rates which are applied to entire markets (e.g., U.S. to North Europe). Although integrated air carriers have detailed internal costing methods, they do not file data that is comparable to that filed by passenger carriers and they use general tariff rates that are not easily correlated with specific traffic flows.

The following discussion addresses general cost elements used in air passenger costing as applied to air freight operations for a combination or charter carrier. (The dedicated closed systems of integrated carriers are not included in this analysis.) Air freight costs can be estimated based on the following categories of inputs:

[5] Jack Faucett Associates, *Goods-Movement Energy Efficiency: Overview*, prepared for the California Energy Commission, Sacramento, November 1982, p. 51.

- flight and airport operating characteristics;
- operating expenses (fuel and other);
- airport/station costs; and
- administrative costs.

Similar to water transport, air freight operations can be separated between scheduled round-trip services ("liner") and one-way charter flights ("tramp") often requiring an empty backhaul leg. In either case, the round trip distance and average operating speed for a particular aircraft can be used to calculate the round trip "block" hours which designate the period from when the blocks are removed prior to takeoff and when they are replaced after landing. (Flight distances between airports are available from a variety of sources including the U.S. DOT)

Costing methodologies for air passenger transport utilize detailed periodic costs for specific carriers, aircraft types and operating divisions as designated in the Department of Transportation Form 41 filings and reports. For example, Carrier A may file a report for all DC-8 aircraft for its Pacific Division. Unit costs per block hour can be estimated for personnel, equipment, insurance, taxes and other non-fuel operating expenses. Aircraft-related unit costs include maintenance and capital cost (depreciation, amortization and leases) also state per block hour. Fuel costs could also use Form 41 consumption rates per block hour, combined with the appropriate unit fuel cost for the airports involved. Total flight operating costs per round trip would combine the unit costs with estimated block hours.

Ground or "station" costs can be calculated on a trip basis, as most carriers use contract operators at non-hub airports (due to the limited number of daily flights). Ground costs include landing fees, aircraft and cargo handling, crew overnight costs, and miscellaneous airport charges. Landing fees are usually published rates available directly from the airports, although reductions and exemptions may apply. Aircraft and cargo handling costs depend on rates with the contract operator, but could be estimated from charter rate quotes. No published source is available for other ground costs.

Administrative overhead and profit estimates are also not available from public sources, but could be estimated based on general industry conditions or calibrated using current rate levels. There cost items are often stated as a percentage of all other costs.

The allocated unit cost per ton depends highly on the assumed load factor in both directions. Aircraft freight capacity for combination vessels can vary based on the service area (affecting fuel requirements) and passenger load (e.g., baggage load). Operating capacities are available from various aviation industry sources, as well as from the manufacturer. As with vessel operations, it is critical that the impact of volume-measured commodities on available capacity be considered.