Draft
Port and Modal Elasticity of Containerized Asian Imports via the Seattle-Tacoma Ports

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NOTE: The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein.

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EXECUTIVE SUMMARY

This study determines the economic viability and impact on demand for Puget Sound Port services from assessment of additional port user fees to fund improvements to transportation infrastructure aimed at ensuring efficient and environmentally sound access to the ports. This Port and Modal Elasticity Study analyzes the long-run elasticity of port demands as a function of access fees, determining what levels of fees would induce traffic diversion to other ports or induce shifts in modal shares (truck vs. rail) at the Puget Sound ports (the Ports of Seattle and Tacoma). These shifts also may depend upon the point in the overall logistics supply chain at which user fees are assessed.

Methodology and Observations:

1. A Long-Run Elasticity Model previously developed for studying the San Pedro Bay ports was applied to analyze imports at the Puget Sound ports with updated data.[1] This model allocates imports to ports and modes so as to minimize total inventory and transportation costs from the point of view of importers. Current capacities, contractual obligations and other short-run impediments to shifting traffic among ports and modes are not considered in the long-run model.
2. The long-run model was exercised for a single scenario in which fees on container loads imported from Asia are assessed at the Puget Sound ports without any improvements to access infrastructure. No new fees are assumed at any other ports. The entire volume of waterborne containerized imports from Asia to the continental United States was considered in the analysis.
3. Transportation service quality (measured in terms of mean and variance of container flow times) and transportation rates prevailing in mid-2007 are assumed. Landside channels considered include local dray and long-distance trucking of marine boxes, inland-point intermodal (IPI) rail movement of marine boxes, trans-loading from marine boxes to domestic truck trailers at a trans-loading facility in the hinterland of the port of entry, and trans-loading from marine boxes to domestic rail containers at a trans-loading facility. Supply-chain strategies that are considered include direct shipment of marine containers to regional distribution centers, and consolidation-deconsolidation strategies wherein shipments to several regional distribution centers are pooled as far as a trans-load facility or import warehouse located in the hinterland of the port of entry.

It is concluded that:

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[1] The development of the Long-Run Elasticity Model and its application to analysis of the elasticity of imports via the San Pedro Bay ports is detailed in "Port and Modal Elasticity Study," prepared by Leachman & Associates LLC for the Southern California Association of Governments in September, 2005. The report is available at http://www.scag.ca.gov/goodsmove/pdf/FinalElasticityReport0905rev1105.pdf. An academic presentation of the methodology made be found in "Port and Modal Allocation of Waterborne Containerized Imports from Asia to the United States" by Robert C. Leachman, appearing in *Transportation Research Part E*, **44** (2), P. 313 – 331. The academic article may be purchased from http://dx.doi.org/10.1016/j.tre.2007.07.008.

1. Puget Sound import volume is very elastic with respect to potential container fees. If unmatched by new fees at other ports, even relatively small fees of $60 per FEU or less would render supply-chain channels using other ports more economically attractive for imports to be consumed in most markets located east of the Rockies.
2. For imports routed via the California ports vs. the Puget Sound ports to most points east of the Rockies and north of the Mason-Dixon Line, total transportation costs for both supply chains featuring direct shipping of marine boxes to inland market regions and supply chains featuring consolidation – deconsolidation are very competitive. Total transportation costs for direct shipping of marine boxes to certain inland US regions also are very competitive between Canadian West Coast ports and Puget Sound ports. These factors make imports quite elastic to potential fees at Puget Sound.
3. As fees are instituted at other West Coast ports, the Puget Sound ports may choose to match them to maintain market share, or, if unmatched, gain market share.

The analyses and conclusions expressed herein are solely those of the consultant and do not necessarily reflect the views of the Puget Sound ports, other agencies sponsoring this project, nor any stakeholder in Asian – US maritime trade.

1. OVERVIEW

To explain and ultimately predict the allocation of containerized imports to ports and landside modes, it is useful analyze the economics of both inventory and transportation from the importers' points of view. The vast majority of imports from Asia are consumer goods imported by US retailers or by the vendors of goods marketed by these retailers. It is thus appropriate to describe inventory and transportation economics for imports in terms of those faced by a retailer of imported goods.

Importers face two basic types of inventory costs sensitive to the choice of port of entry and to the choice of landside transportation mode. One is the cost of pipeline inventory for goods in transit from Asian factories to regional or national distribution centers that serve the importer's retail outlets in the United States. This cost is a linear function of the average transit time of the supply channel, the average declared value of the imports assigned to that channel, and the quantity routed via that channel. The other is the cost of safety stocks maintained at destination distribution centers. These stocks are established as a hedge against uncertainties in transit times and against potential errors in sales forecasts over the lead time from when the goods were ordered. This cost is a complex non-linear function of the variability in lead times and transit times of the shipping channels utilized, the volume assigned to each channel, and the statistical error in sales forecasts. It also is a function of whether shipments are made directly from Asian origin to destination distribution center, or whether shipments to multiple destinations are consolidated from Asian point of origin to a trans-loading warehouse located in the hinterland of the port of entry, then de-consolidated at that point and re-loaded in domestic containers or trailers for landside transport to the multiple destinations. Trans-loading (interchangeably described in this report as consolidation-deconsolidation) pools the variability in forecast errors across the various destination regions and pools the variability in transit time from the factory in Asia to the port of entry across the shipments that are consolidated. When many destinations are consolidated, trans-loading enables a substantial reduction in destination safety stocks. Mathematical formulas to calculate required destination safety stocks for the cases of direct shipping and trans-loading are applied in this study. The required safety stocks are sensitive to the distribution of sales forecast errors. The required safety stocks also are very sensitive to the mean and standard deviation of transit times. Such parameters were estimated by the consultant for various ports of entry, destination cities, and alternative transportation channels.

It was found that, for many importers, the cost of their safety stocks is comparable to or even larger than the cost of their pipeline stocks. Moreover, for importers of high-value goods, the total cost of their pipeline and safety stock inventories can be larger than the total cost of transporting their goods from Asia to their destination distribution centers.

Both types of inventory costs are linear functions of the value of the goods imported. Differences between inventory costs for direct-shipping and trans-loading options are relatively small for importers of low-value goods but relatively large for importers of high-value goods. For this reason it was important for this study to establish the distribution of values of goods imported from Asia. 2005 data from the World Trade Atlas (WTA) was furnished to the consultant by the Port of Long Beach. The WTA reports the total value declared to US customs for imports from Asia for 99 commodity types. The Port of Long Beach also furnished the consultant with 2005 PIERS data on TEU volumes imported from Asia by commodity type. The PIERS data for each of the commodity types was joined to the WTA data to establish a distribution of imports by declared value per TEU. This in turn was joined to data from the Pacific Maritime Association concerning the mix of marine container types (20ft, 40ft, 45ft) that are imported and the consultant's estimates concerning the mix of standard and hi-cube 40-foot containers in order to estimate the average declared value per cubic foot for each commodity type. Grouping commodities by similar declared values, an overall distribution of import volume vs. declared value was obtained. This distribution is displayed in Figure S-1. The maroon bars are directly derived from the WTA and PIERS data; this raw distribution is much lumpier than reality because a single average declared value has been associated with each commodity type. The light blue bars represent the consultant's smoothing of the data.[2] This distribution suggests a declared value of about $9 per cubic foot to be the most common one, with steadily declining volumes as the declared value extends up to a maximum of $72 per cubic foot.

[2] As may be seen in the figure, the shape portrayed by the blue bars suggests a Pareto distribution.

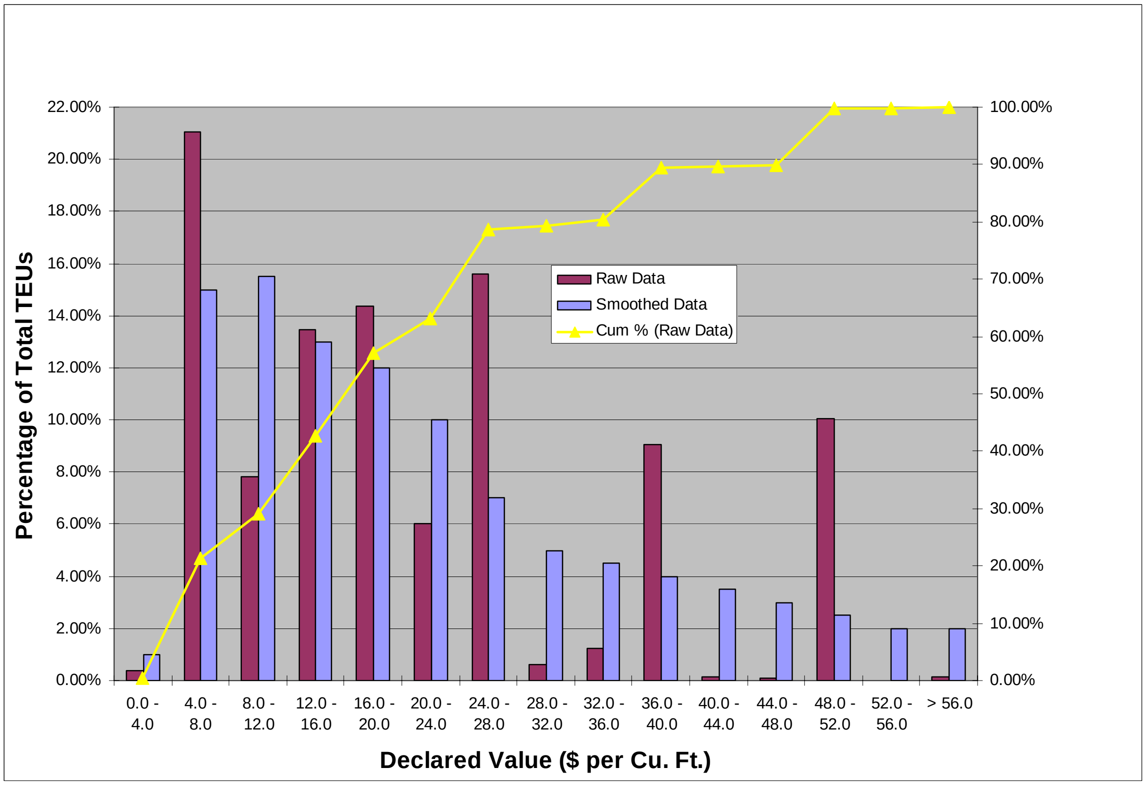

Figure S-1. Distribution of Declared Values for 2005 Asian Imports Through US West Coast Ports

Inventory and transportation costs for the top 83 importers of containerized Asian goods were specifically modeled in this study.[3] An average declared value for each of these importers was estimated by the consultant based on the types of commodities imported. 2004 PIERS import volumes reported in the Journal of Commerce for these importers were scaled by the consultant to more realistic figures for their imports from Asia.[4] The consultant estimates that these importers accounted for about 32% of total containerized Asian imports to the US. To account for the other 68% of imports, 19 categories of so-called "proxy miscellaneous" importers were defined at $4 increments in declared value from $2 up to $70 so as to fill out the above distribution of declared values. Inventory and transportation costs also were analyzed for these proxy miscellaneous importers. To estimate total nation-wide logistics costs for containerized Asian imports, it was assumed that every modeled importer (i.e., the 83 large importers and the 19 proxy miscellaneous ones) is nation-wide in its distribution of imported goods, with the geographical distribution of its import volume proportional to the distribution of purchasing power across the Continental United States.

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[3] In May, 2005, the *Journal of Commerce* published a list of the top 100 importers of goods in ocean-borne containers, derived from PIERS data. Seventeen of these importers were excluded from this analysis because their imports predominantly come from origins other than Asia.
[4] Volume statistics derived from PIERS data are low compared to actual volumes. Actual volumes for some importers were found to be as much as 33% higher than PIERS-reported volumes.

Alternative transportation channels available to importers include the following:

- Steamship Line or NVOCC[5] provides inland-point intermodal (IPI) service. Steamship Line arranges transfer of marine container from vessel to rail and rail line haul movement, all under one rate. Line/Carrier or customer may arrange dray from destination rail ramp to destination distribution center. In this report, we term this the "Direct Rail" channel.

- Steamship Line or NVOCC provides only transportation to port gate with container mounted on a chassis. Customer separately arranges for marine container to be transported from port gate to destination distribution center via long-haul truck or local dray. In this report, we term these the "Direct Truck" and "Direct Local Dray" channels.

- Steamship Line or NVOCC provides transportation to warehouse in the hinterland of the port of entry. Dray from port gate to warehouse may be arranged by Line or by customer. Customer contracts with a third-party logistics firm (sometimes a subsidiary of the Steamship Line or the NVOCC) to provide deconsolidation and trans-loading into domestic trailers or containers. Customer contracts with an intermodal marketing company (IMC) to provide dray from trans-load warehouse to rail ramp in port of entry hinterland, rail line haul and destination dray. In this report, we term this the "Trans-load Rail" channel.

- Same as immediately above as far as the trans-load warehouse. From that point, customer contracts for movement via long-haul truck or local dray to destination distribution center. We term these the "Trans-load Truck" and "Trans-load Local Dray" channels.

For the purposes of this study, 21 destination regions were defined encompassing the Continental United States, and a single destination city was selected within each region. The destination city so selected was one the consultant believes is representative as a locus for regional distribution centers operated by large retail importers. Rates charged as of mid-2007 by steamship lines, railroads, IMCs, trucking companies and dray companies to these destinations via ten major North American ports of entry (Vancouver, BC, Seattle-Tacoma, Oakland, Los Angeles – Long Beach), Houston, Savannah, Charleston, Norfolk and New York – New Jersey) were researched by the consultant. Many rates are confidential and vary by customer or service provider.. In some cases, an average of a basket of rates was utilized in this study. The data collected for the matrix of 10 ports and 21 destinations by channel was not complete. But enough data was available to infer a structure to the rates, and missing rates were estimated to fit this structure.

In this report, specific rates are not divulged. Only our estimates of the overall transportation charges per cubic foot of capacity are reported for the various channel-port-destination combinations.[6] It is important to note that transportation rates to inland

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[5] Non-vessel-operating common carrier.
[6] See Table 18 in Chapter 6.

points are in considerable flux. As their multi-year contracts with the railroads expire, steamship lines are facing rate increases in the range of 25-40% in new single-year contracts. At the time of this study, some lines still are enjoying legacy long-term contracts, while others bear the new burden of substantial rail rate increases. Market shares of the lines have shifted significantly over the last two years. In the course of this study, the consultant found considerable disparity in inland-point-intermodal (IPI) rates offered by the various lines, much more so than in 2005. This market turbulence will continue for several more years until the last of legacy contracts expires.

In general, we find that the total transportation and handling cost for the Trans-load Rail channels ranges $0.02 - $0.10 more per cubic foot of imports than for the Direct Rail channels from the West Coast ports and $0.25 - $0.30 more per cubic foot in lanes from East Coast ports. Trans-loading to truck is $0.60 - $0.80 more per cubic foot than Direct Rail in lanes from West Coast ports and $0.05 - $0.15 more per cubic foot in lanes from East Coast ports.

The trade-off of transportation and inventory costs leads to the result that small importers, importers with few destinations, and importers with low average values of their imports minimize their total inventory and transportation costs by using direct shipping channels. Importers that are nation-wide in scope (i.e., that ship imports to multiple destinations that may be consolidated as far as the port of entry), have moderate or high average values for their imports, and have sufficient overall volume minimize their total transportation and inventory costs by trans-loading their imports in the hinterlands of one or several ports of entry.

It is estimated that, in 2004, the largest of the 83 major importers (Wal-Mart) imported an average of 580 TEUs per week to each of the 21 destination regions defined in this study; the smallest shipped an average of only 10. The shipping volume for the smallest of the 83 major importers is marginally sufficient for practicing the trans-loading strategy. It was therefore assumed that all importers in the proxy miscellaneous categories are too small to practice trans-loading, i.e, we assumed all proxy miscellaneous importers solely utilize direct shipping channels.

The transportation cost matrix, the transit time matrix and the formulas computing pipeline and safety stocks were combined into an overall model termed the Long-Run Elasticity Model. For each importer and each alternative strategy for the allocation of imports to ports and channels, this model calculates the total transportation and inventory costs. For each of the 83 major importers and for each of the 19 proxy miscellaneous categories, the model was exercised to compute total costs for the following alternative import strategies:

- Direct shipping of marine containers to destinations using the least costly port-landside channel available. (This strategy is attractive to importers of low-valued commodities.)

- Direct shipping of marine containers to destinations using the least costly West Coast port and landside mode combination available. (This strategy is attractive to importers of moderate- and high-valued commodities but who are too small or too regional to utilize a consolidation – de-consolidation strategy.)

- Trans-loading of marine containers into domestic containers in the hinterlands of the four ports of Seattle-Tacoma, Los Angeles-Long Beach, Savannah and New York-New Jersey. Destinations are assigned to trans-load centers so as to roughly equalize volumes at each center. The least costly transportation channels from trans-loading centers to destinations are selected. (This strategy is attractive to importers of moderate-valued commodities who are large and nation-wide in scope.)

- Trans-loading of marine containers into domestic containers in the hinterlands of only one or several West Coast ports (Seattle-Tacoma, Oakland, LA-Long Beach). Destinations are assigned to trans-load centers so as to roughly equalize volumes at each center. The least costly transportation channels from trans-loading centers to destinations are selected. (This strategy is attractive to importers of high-valued commodities who are large and nation-wide in scope.)

Total costs were tallied for each alternative strategy for each importer and the best strategy was identified. Then total import volumes passing through the Puget Sound Ports were tallied across importers. This process was repeated assuming the application of a fee on loaded containers imported through the Puget Sound Ports. This fee was assumed to be borne by the importer. Reacting to such fees, direct-shipping supply chains may be adjusted to shift imports previously routed via the Puget Sound ports to either California or Canadian ports. Consolidation – de-consolidation supply chains may be adjusted to supply the Pacific Northwest region from California de-consolidation facilities. Fee values in increments of $30 from $0 to $1200 were tested in runs of the Model. Combining results, an elasticity curve of port demand vs. fee value was constructed.

Elasticity Results

The Long-Run Elasticity Model was applied to a single scenario assuming a fee is applied at the Puget Sound ports but no new fees are applied elsewhere. Results are summarized as follows. For a $0 fee, the best distribution strategies as a function of average declared value of imports are summarized in Table S-1.

The Model output suggests that a large nation-wide importer of furniture or building materials, such as Home Depot or Lowe's, should opt for direct shipping of their imports. It suggests that a large "big-box" department store importer such as Wal-Mart, K-Mart, or Target should trans-load imports at multiple ports, while an importer of high-value electronics such as Sony or Samsung should trans-load all its imports at only one West Coast port. By and large, these predictions are borne out by actual practice.

Table S-1.
Import Strategy as a Function of Declared Value – As-Is Scenario

Importer type	Declared Value Per Cubic Foot	Least-cost import strategy
Large importer	$0 – $13	Direct shipping using nearest port
Large importer	$13 – $20	Trans-load at multiple ports
Large importer	$20 and up	Trans-load only at LA-Long Beach
Small importer	$0 – $40	Direct shipping using nearest port
Small importer	$40 and up	Direct shipping using only West Coast ports

As an increasingly larger fee is imposed, the Model predicts that some importers are induced to change strategy. For example, an importer of high-valued goods currently trans-loading in both Southern California and the Kent Valley might be induced to begin trans-loading all inland volumes in Southern California and only handling Pacific Northwest traffic through the Seattle-Tacoma ports, once the fee is large enough. As the fee is progressively increased, eventually the importer will be induced to discontinue importing through the Puget Sound Ports altogether and truck or use rail to supply its Southern California distribution center from its trans-load warehouse in the hinterland of the Seattle-Tacoma or Oakland ports. The “break points” in fee value for each importer, i.e., where the importer has the economic incentive to change strategy, are calculated using the Long-Run Elasticity Model. At these points the importer’s volume through the Puget Sound Ports is predicted by the Model to be reduced.

Figure S-2 displays the resulting elasticity curves. Shown are curves for (1) total imported containers via the Puget Sound Ports vs. container fee and (2) total imported containers via the Puget Sound Ports containing inland cargoes that are trans-loaded vs. container fee. As may be seen, imports at the Puget Sound Ports are quite elastic even for very low fees. Trans-loading shipments have an economic incentive to re-route via California for even very small fees. For a fee of $60 per FEU, the model predicts trans-loaded volumes are by and large eliminated, while total volume drops by 30%. At a fee of $150, port volumes have dropped in half, and at about $450, the Model predicts that nearly all importers are driven away from the Puget Sound ports.

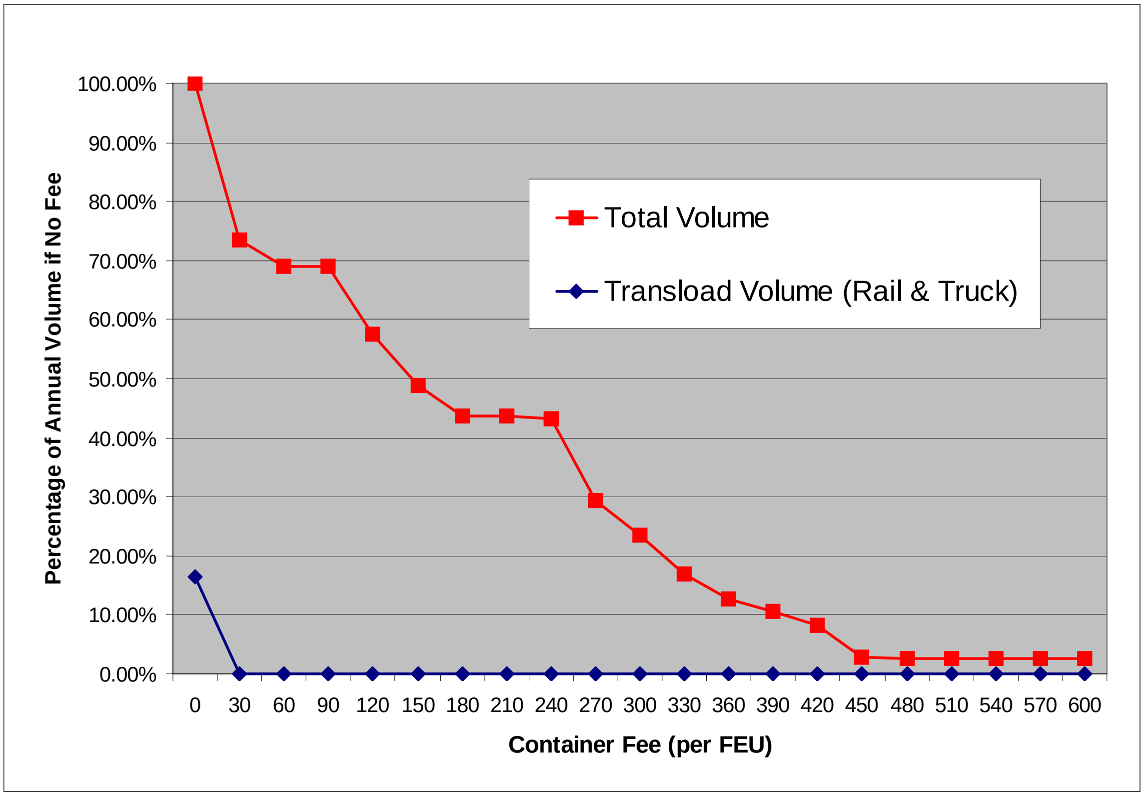

Figure S-2.
Elasticity of Imports via the Puget Sound Ports

Excluded Factors

Certain factors are excluded from the Long-Run Elasticity Model; their qualitative impacts are summarized as follows.

Some importers utilize port terminals as virtual warehouses (whereby the importers deliberately delay picking up goods not yet needed at their distribution centers). Others maintain warehouses in the hinterland of the port of entry specifically for this purpose. Economies afforded by these practices are not included in the Model. Qualitatively, these practices extend the economies of trans-loading; in effect, the break-point in the average value of imported goods for which trans-loading is more efficient than direct shipping is shifted downwards.

Rail transportation charges input to the Model do not include any surcharges for re-positioning equipment. What matters most in this regard is the relative cost of rail shipment of marine containers vs. cost of rail shipment of domestic containers. If these charges are comparable, the Model’s allocations of imports to channels will remain valid.

But if re-positioning charges per cubic foot for one of these types of equipment became much larger than for the other, model input parameters would need to be adjusted.

It is important to note that the diversification of supply chains as a hedge against port congestion risk is not considered in the model. After the congestion experienced at the San Pedro Bay Ports during the peak of the 2004 shipping season, many importers diversified their supply-chain strategies to feature increased use of the Puget Sound ports. Moreover, several steamship lines shifted vessel strings from Southern California to the Puget Sound ports for the 2005 shipping season; these actions increased the Puget Sound ports' shares of so-called discretionary imports, i.e., IPI shipments where choice of port is up to the steamship line. Congestion at the San Pedro Bay ports was much reduced during 2005, and so for the 2006 season, those vessel strings moved back to Southern California.

The value of risk mitigation perceived by importers and by steamship lines may well exceed relatively small values for container fees assessed at the Puget Sound ports. This consideration suggests an increase in the Puget Sound port volumes above values calculated by the Model, especially for small fee values.

Short-Run vs. Long-Run: Proper Interpretation of Model Results

In the short run, there are many factors inhibiting the shifting of imports to other ports or alternative channels. There are multiple dimensions of capacity constraining the channel volumes: vessel frequencies and capacities, available transit slots through the Panama Canal, lift capacities at port and rail terminals, available draymen, available trans-loading warehouses, and line-haul capacities of rail and truck channels in the various lanes. Moreover, steamship lines are committed to relatively long-term port contracts whose fee structures provide the incentive for the lines to tender large volumes and mandate stiff penalties for premature withdrawal. In turn, rates paid by large importers to steamship lines, often involving volume guarantees, are negotiated annually.

The Long-Run Elasticity Model analyzes transportation and handling rates, values of goods, and transit time statistics faced by importers to determine the least costly allocation of imports to ports and channels. Transit time statistics are exogenously supplied to the model and are not updated if the Model shifts substantial traffic volumes between ports or modes. The Model results should be interpreted as indicating the fee points at which importers would experience an economic incentive to reduce import volumes through the Puget Sound Ports.

Given a scenario in which there is economic incentive to shift imports between modes or between ports, there will be inertia inhibiting such shifts. Major shifts in import traffic may require considerable time to implement. Thus, in the short run, Puget Sound Ports' traffic will be significantly more inelastic than the predictions of the Long-Run Model. However, given strong economic incentives for importers to shift traffic, one may expect *in the long run* that desired terminal and line haul capacities will get built, new port and importer contracts will be negotiated, vessel strings will be adjusted, new trans-loading warehouses will be erected, and dray forces will be adjusted.

The Long-Run Elasticity Model is intended to inform the public policy dialogue concerning potential container fees. It also could be used to assess potential major investments in access infrastructure for the Puget Sound Ports. Such infrastructure may require up to a decade to build, and financing instruments may require up to three decades to retire the principal. It seems very unwise to rely solely on estimations of short-run elasticity to justify such investments. Investment of large sums of public monies in long-term infrastructure should be confirmed to be sound on the basis of long-run elasticity calculations.

Conclusions

Puget Sound import volume is very elastic with respect to container fees. Total inland transportation charges via Puget Sound ports vs. other West Coast ports are very competitive to many destinations east of the Rockies for most types of imports.

Lacking improvements in access infrastructure that improve transit times or otherwise improve the economics from the importer's point of view, and without offsetting fee increases at other West Coast ports, in the long run even a small container fee at Puget Sound may drive significant amounts of traffic away from the Puget Sound ports. The Long-Run Elasticity Model predicts that a $60 per FEU fee on inbound loaded containers at the Puget Sound ports would cut total import volume at the Puget Sound ports by approximately 30%. The model predicts a fee of $150 would cut traffic in half. These estimates of volume reductions are likely somewhat larger what would actually happen, given the value of diversification of supply chains perceived by large importers.

Institution of container fees without offsetting fees at other West coast ports seems unwise. However, as fees are instituted at the California ports, they may be matched at Puget Sound in order to create a revenue source for infrastructure improvement and environmental impact mitigation without loss of market share, or, if unmatched, market share at the Puget Sound ports may be grown.

2. INVENTORY COSTS BORNE BY IMPORTERS

The choice of transportation mode and route by importers of Asian goods depends on a number of factors. Clearly, transportation charges for the alternative modes and routes are important. But other factors play an important role as well. Differences in transit time, in required inventory levels, and in labor required for labeling, repackaging, and other handling may result in substantial differences in inventory costs, handling costs and sometimes even significant differences in sales revenues. The economics of these factors therefore must be jointly analyzed with transportation costs.

In this chapter, economic models are described that analyze inventory and distribution costs arising from these factors. Analytical methodology and supporting data are presented to compute the value to shippers of transit time, inventory and logistics factors as a function of commodity values.

Also discussed in this chapter are other factors that influence logistics decision-making, including re-packaging and labeling services by trans-loaders, the supply of 53-foot containers at various ports, the desire on the part of importers to diversify risks of delays from congestion arising in specific shipping channels or at specific ports.

Types of Inventory

Alternative strategies for goods imported from Asian vendors to U.S. demand points typically feature differences in the mean and standard deviation of transit time, as well as differences in the opportunity for consolidation and de-consolidation of shipments serving multiple demand points. These differences impact the inventory costs of the importer.

The vast majority of imports from Asia are retail goods. The origins for imports are typically factories in China and elsewhere in Asia, and the destinations are regional distribution centers (RDCs) that supply the importer's retail outlets or retail customers within the region. Differences in inventory costs resulting from use of alternative supply channels typically extend only as far as the RDC, not to the store or customer level.

There are two types of inventory costs influenced by the choice of supply channel. One is the working capital required to finance goods in transit (so-called "pipeline stock"). The other is working capital required to finance stocks of goods at destination RDCs. The overall stocks of goods at destination RDCs may be subdivided into what is called "cycle stock" and what is called "safety stock."

Average pipeline stock is simply the product of the average transit time and the average shipment size. Larger pipeline stocks result from using supply channels with longer transit times

At any given time, cycle stock at a shipment destination is the unused portion of the stock that arrived in the previous replenishment. This stock level equals the amount of the shipment just after a shipment arrives, then steadily drops to zero just before the next shipment arrives. Its average value is therefore equal to one half of the average shipment quantity.

Safety stock is required by retailers who strive to have stock on hand to service customer demands without delay. This stock level is maintained as a hedge against potential delays to shipments and potential errors in sales forecasts upon which the shipment quantities were based. That is, if customer demands are to be met without backorder, safety stocks are necessary to buffer against unpredictable surges in demand while replenishment orders are in transit and against unpredictable extensions in transit times for replenishments. Use of supply channels that entail a longer transit time and/or a more unreliable transit time result in the need for larger safety stocks at destinations.

As noted above, the vast majority of imports from Asia are retail goods. It is therefore important to understand the impact of the choice of supply channel on safety stock. Let us first consider the simplest case of a single destination for imported goods. Suppose the frequency of shipments from Asia is once every R time periods. Suppose the lead time between ordering goods from Asia and receipt at destination has mean value L and standard deviation σ_L. Further, suppose the mean absolute percentage error in sales forecasts made one period ahead is $MAPE$. The mean absolute deviation in forecast errors is defined as $MAD = MAPE * D$ where D is the expected (forecasted) demand per period. It is well-known that the standard deviation is related to the mean absolute deviation by

$$\sigma = (1.25)(MAD) = (1.25)(MAPE)(D) .$$ [7]

Considering the replenishment lead time and the frequency of replenishments, sales must be forecasted over an interval of length $(L+R)$ in order to determine the proper quantity to be ordered from the Asian supplier. To analyze the impact of differences in lead time, the growth of forecast errors as a function of lead time must be characterized. Mathematically, the standard deviation of forecast errors grows with lead time according to the general model

$$\sigma_{R+L} = (L+R)^c \, \sigma_D$$

where c is a constant that depends on the correlation of week-to-week sales (i.e., does higher-than-expected sales last week imply higher-than-expected sales this week) and σ_D is the standard deviation of errors in one-period-ahead forecasts. Perfectly correlated sales would imply c=1. We shall assume in this analysis that c=0.5, which has been found to be accurate for household consumer products.[8] That is, to good approximation,

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[7] Any of the many academic texts on production and inventory control would serve as a useful reference for the mathematics in this chapter. See, for example, *Decision Systems for Inventory Management and Production Planning*, E.A. Silver and R. Peterson, John Wiley & Sons, 1985.
[8] See "Optimal Planning and Control of Consumer Products Packaging Lines," in *Optimization in Industry*, T. A. Ciriani and R. C. Leachman, John Wiley & Sons, 1993.

forecast error grows as the square root of the time interval over which sales are forecasted. Hence the standard deviation of forecast errors over (L+R) is

$$\left(\sqrt{L+R}\right)\sigma_D \ .$$

As a function of the standard deviations of the transit time and the sales forecasting errors, the required level of safety stock ss may be expressed as

$$ss = k\sqrt{(L+R)\sigma_D^2 + D^2\sigma_L^2}$$

where R denotes the time between replenishments, L denotes the average transit time, σ_L denotes the standard deviation of transit time, D denotes the average shipment quantity per replenishment, σ_D denotes the standard deviation of forecast errors and k is a safety factor corresponding to the desired probability of no stockout.

To illustrate, suppose $k = 2$; this value corresponds to a 98% probability of no stockout, a typical value chosen for the safety factor. Suppose $\sigma_L = 2.5$ days, $D = 1000$ cases per day, $\sigma_D = 200$ cases, $R = 3$ days and $L = 7$ days. Then the required safety stock is

$$ss = 2\sqrt{(10)(40{,}000) + (1{,}000{,}000)(6.25)} = 5{,}158 \ .$$

The average cycle stock at the destination is

$$(R)(D)/2 = (3)(1000)/2 = 1{,}500 \ ,$$

and the pipeline stock is

$$(L)(D) = 7{,}000 \ .$$

Thus, in this case, the safety stock at the destination is much larger than the cycle stock and equal to about 74% of the pipeline stock.

If the variability in transit time were reduced to $\sigma_L = 1.0$ days, the safety stock level would drop to $ss = 2{,}366$, i.e., a reduction of more than fifty percent. If in addition the mean lead time were reduced to 5 days, the safety stock level would drop to $ss = 1{,}131$, or about 22% of the required safety stock for the original data. The pipeline stock would drop to 5,000, i.e., $5/7^{\text{ths}}$ or about 71% of the required pipeline stock for the original data.

From this small example, one can conclude that (1) cycle stock is independent of the selection of a supply chain channel, (2) pipeline stock is linear in the average transit time, and (3) safety stock is non-linear and highly sensitive to the average and standard deviation of transit time.

Inventory Holding Costs

Typically, the cost of working capital is expressed as an interest rate times the amount of capital invested per unit inventory times the average inventory level. For the simple example above, the relevant inventory costs per unit time are expressed as

$$(i)(V_P)(L)(D) + (i)(V_{RDC})(ss)$$

where i is the interest rate, V_P is the amount of capital tied up in a unit of pipeline stock, $(L)(D)$ is the average pipeline inventory level, V_{RDC} is the amount of capital tied up in a unit of RDC safety stock, and ss is the level of safety stock at the RDC. (We have omitted the cost of cycle stock because that cost is independent of supply channel alternative.)

As imports move through the supply chain, they accumulate more cost. First, the vendor in Asia must be paid to procure the goods. Next, the local transportation in Asia and the steamship transit must be paid for. If other vendors are involved for North American landside handling, they must be paid. Finally, handling at the importer's own destination RDC entails more accumulated cost.

One index to the amount of capital tied up is the value declared to US customs. This value typically includes the cost of purchase of the goods from the Asian vendor plus the cost of transportation and logistics services up to the termination point for the importing carrier. If from that point onwards additional carriers or logistics providers are utilized to move the goods to the RDC, those costs are not included in the declared value. Costs of handling at the destination RDC also are not included.

For the purposes of this study, we shall make the assumption that pipeline inventories are valued by importers at 125% of the value declared to Customs. We shall further assume that RDC inventories are valued at 150% of the value declared to Customs.

The appropriate interest rate to apply depends on a number of factors. If the goods represent replenishment of goods with long-term demand, then an interest rate reflecting the cost of working capital for the importer is appropriate. A reasonable value for this is assumed to be 20 percent.

A higher interest rate is more appropriate if retail prices are declining with time or if the products experience rapid obsolescence, such as is the case for technology goods, style goods and goods for special sales events. For example, prices of many electronics products such as personal computers, video games, hand-held devices, etc., decline as much as fifty percent in the first year they are marketed and become completely obsolete within 2-3 years. Style goods are even more extreme, some having a selling season of only several months. In such cases, larger requirements for pipeline stocks and safety stocks result in revenue loss, and such losses should be accounted for in inventory costs. For such cases, a more appropriate value for the interest rate is 50 percent.

The sales of most retailers are a mixture of event items and standard items. We shall assume a simple average of the two cases, i.e., an interest rate of 35 percent is assumed for the purposes of costing pipeline and safety stocks. In the case of electronics and fashion item importers, we assume an interest rate of 50 percent.

Distribution of Values of Asian Imports

Inventory costs associated with both transit time and the location of mixing/distribution warehousing depend crucially on the values of the cargoes shipped. The best logistics strategy for merchants of, say, electronics or fashion apparel may be quite different than that for merchants of, say, furniture or textiles.

The consultant therefore undertook an effort to determine the distribution of declared values of containerized imports from Asia. Year 2005 customs data for U.S. West Coast ports, as summarized by PIERS and by the World Trade Atlas (WTA), were provided by the Port of Long Beach to the consultant. The PIERS data provided total TEUs imported from Asian origins through US West Coast ports, broken out by 100 commodity codes. The WTA data provided total declared values for the Asian imports passing through US West Coast ports, again broken out by the 100 commodity codes. The PIERS summarization of customs data includes logic to allocate Code 00, Miscellaneous Manufactured Goods, among other more specific categories, based on its reading of the description of the shipment contents on each bill of lading; the WTA summarization does not. In order to match PIERS and WTA data, the consultant therefore made a judgment to express Category 00 as a weighted combination of other commodity codes. This enabled the consultant to determine the average declared value per TEU for each of the 99 other (more specific) commodity codes.

Next, data from the Pacific Maritime Association web site was downloaded concerning the mix of 20-foot (12.3%), 40-foot (80.3%) and 45-foot containers (7.4%) carrying imports through West Coast ports during 2003. A further breakdown of 40-foot containers into standard (40%) and high-cube (60%) was assumed. Usable cubic capacities for these four sizes of marine containers are as follows:

20-foot: 1,169 cu. ft.
40-foot standard: 2,395 cu. ft.
40-foot high-cube: 2,684 cu. ft.
45-foot: 3,026 cu. ft.

The weighted-average cubic capacity per TEU works out to be 1,274.4 cu. ft. This in turn led to an estimate of the average declared value per cubic foot of shipping capacity for each commodity code. Table 1 displays the fifteen highest-volume commodity codes imported from Asia through US West Coast ports in 2005. The table also displays the average declared value per cubic foot of usable container capacity. As may be seen, furniture and bedding is the highest-volume commodity, with an average declared value of only $7.87 per cubic foot. Next highest is electronics and electrical equipment, with an average declared value of $39.24 per cubic foot, and so on.

Table 1
Total Volume and Average Declared Value by Commodity
For 2005 Asian Imports Through US West Cost Ports

Commodity	**TEUs (1000s)**	**Average declared value ($ per Cu Ft)**
Furniture & Bedding	2,069	7.87
Electronics & Elec Eqpt	1,001	39.24
Machinery	970	51.08
Toys, Games & Sports Eqpt	902	16.57
Motorcycles & Auto Parts	734	24.65
Plastic goods	600	14.63
Apparel - not knitted	586	25.60
Steel goods	471	15.43
Footwear	426	24.91
Rubber goods	399	14.37
Leather goods	290	16.14
Wooden goods	280	8.24
Misc manufactured goods	253	22.94
Apparel – knitted	241	59.93
Ceramic goods	215	6.34
All other	2,669	

Source: PIERS, WTA and PMA data

The commodity codes were then grouped by ranges of declared values, resulting in a distribution of total shipment volume vs. average declared value. The results are graphed in Figure 1. The maroon bars correspond to the raw data derived from PIERS, WTA and PMA databases. Because a single average declared value is associated with each of the 99 commodity codes in lieu of the actual range of declared values for each code, the depicted distribution is lumpier than reality. The real distribution of declared values must exhibit a Pareto-like shape. The light blue bars in the figure represents the consultant's smoothing of the raw data into a more realistic distribution. As may be seen, the distribution of declared values reaches a peak at the low end of the spectrum ($8-$12 per cubic foot of container capacity), with the distribution extending up to $175 per cubic foot in steadily declining volumes.

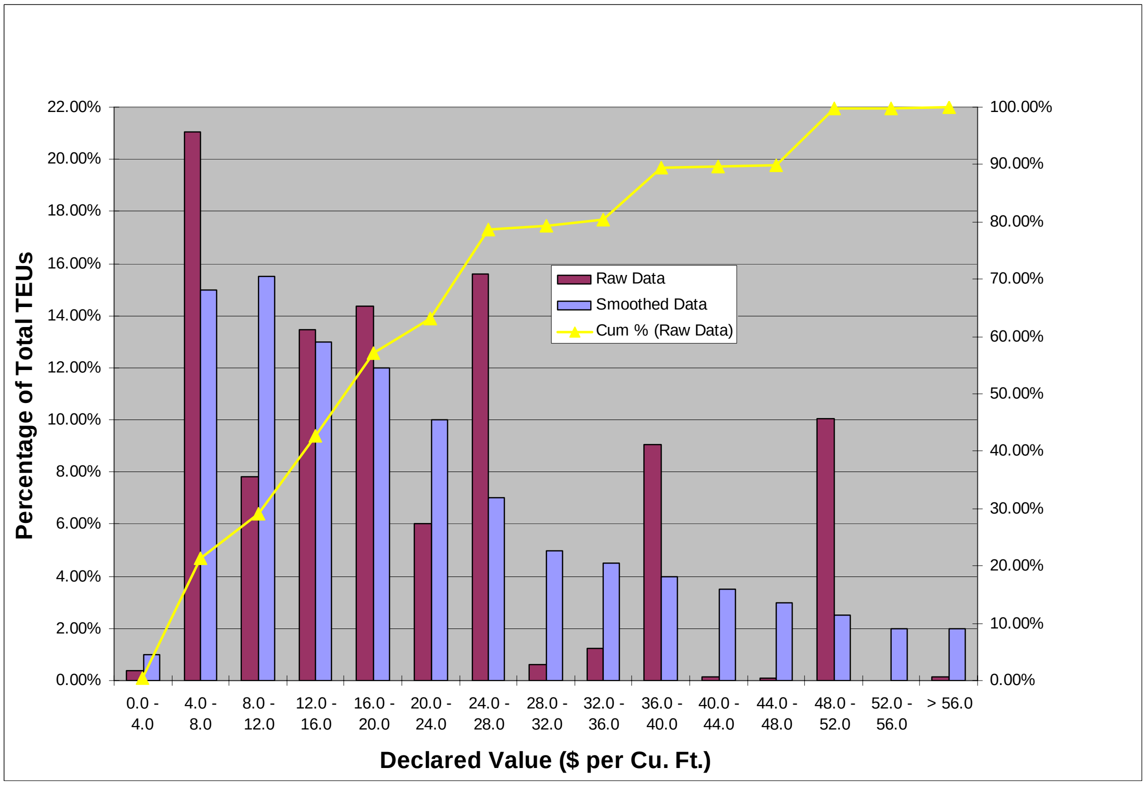


Figure 1.
Distribution of Declared Values for 2005 Asian Imports
Through US West Coast Ports

It should be kept in mind that Figure 1 displays the value per cubic foot of container capacity and not the value per cubic foot of the actual cargo within the container. Anecdotal evidence received from trans-loaders suggests that, while shippers strive to fully utilize the available space, sometimes the full cubic capacity can not be utilized because of inability to stack cargoes, need for handling space, racking or blocking and bracing, etc. Moreover, some shipments, such as steel manufactured goods, may reach weight limits before cube limits.

A second factor to keep in mind is that the declared values reflect the manufactured or purchased cost of the goods in Asia rather than their retail values in North America. Retail values are roughly double the declared values.

Large Retail Merchant Importers

A different view of the PIERS data is a break-down by importer. The May 30, 2005 issue of the *Journal of Commerce* published a list of the top 100 US importers via ocean container transport. The consultant adopted this list, less 17 companies (all food and beverage, paper or chemical companies) who the consultant believes are not major importers of Asian goods. The remaining 83 are all large retailers or vendors of goods such as tires, electronics or appliances that are ready for retail marketing. While the imports these companies make are not solely sourced from Asia, the consultant believes the vast majority are. Moreover, the PIERS data is known to be very incomplete. For example, the *JOC* article lists Target Corp. as importing 202,700 TEUs in 2004. In contrast, Target Corp. advises the consultant that in 2004 it actually imported from Asia 315,766 TEUs, i.e., the PIERS figure for Target is low by more than a third.

Table 2 displays the resulting list of large retail merchant importers. Shown are the consultant's estimate for the average declared value of imports, the PIERS-reported volume, the volume inflated by 10% (a level that in the consultant's judgment is a suitable assumption for the merchant's import level from Asia, for the purposes of this study). Also shown is the average off-peak weekly volume to one of 21 equal-size demand regions spanning the continental United States. This is derived assuming 50% of the annual shipping is concentrated in three peak months of late summer and early fall.

Table 2
Largest US Importers of Asian Goods Via Ocean Container Transport

Importer	Type	Assumed avg. value per cu. ft. for Asian imports	PIERS 2004 Import Volume (TEUs)	Actual 2004 Asia Volume (TEUs)	Assumed 2004 Asia Volume (TEUs)	TEUs per week per region (off-peak)
Wal-Mart	Big box	$15	576,000		633,600	387
Home Depot	Furniture	$9	301,200		331,320	202
Target	Big box	$20	202,700	315,766	222,970	136
Sears (K-Mart)	Big box	$20	186,000		204,600	125
Ikea	Furniture	$9	100,000		110,000	67
Lowe's	Furniture	$9	100,000		110,000	67
Costco	Big box	$20	66,400		73,040	45
Ashley Furniture	Furniture	$9	63,800		70,180	43
Payless ShoeSource	Shoes	$25	54,200		59,620	36
Samsung	Electronics	$40	52,800		58,080	35
Matsushita	Electronics	$40	52,100		57,310	35
Toyota	Auto parts	$20	52,000		57,200	35
GE	Appliances	$25	51,800		56,980	35
Williams-Sonoma	Appliances	$25	50,000		55,000	34
Mattel	Toys	$17.50	49,300		54,230	33
Pier 1 Imports	Big box	$10	48,100		52,910	32
Nike	Shoes	$25	47,900		52,690	32
Sony	Electronics	$40	47,100		51,810	32
Michelin	Tires	$15	46,100		50,710	31
J C Penney	Big box	$20	45,000		49,500	30
LG	Electronics	$40	43,300		47,630	29
Bridgestone	Tires	$15	42,500		46,750	29

Limited Brands	Big box	$30	41,300	45,430	28
Dollar General	Big box	$15	40,000	44,000	27
Toys R Us	Toys	$17.50	39,300	43,230	26
Big Lots	Big box	$10.00	36,300	39,930	24
Ford	Auto parts	$20	29,700	32,670	20
Dorel	Furniture	$9	28,700	31,570	19
Nissan	Auto parts	$20	28,500	31,350	19
Yamaha	Auto parts	$20	27,300	30,030	18
Philips	Electronics	$40	27,200	29,920	18
Michaels Stores	Big box	$10	27,100	29,810	18
Whirlpool	Appliances	$25	26,800	29,480	18
Canon	Electronics	$40	26,200	28,820	18
Walgreen	Big box	$10	25,500	28,050	17
Rooms to Go	Furniture	$9	24,200	26,620	16
Thomson	Electronics	$40	24,200	26,620	16
Federated	Big box	$25	23,700	26,070	16
Emerson	Elec Eqpt	$40	22,600	24,860	15
Marubeni	Machinery	$50	21,800	23,980	15
Jarden	Appliances	$25	21,800	23,980	15
Reebok	Shoes	$25	20,600	22,660	14
Hankook	Tires	$15	20,400	22,440	14
Dollar Tree	Big box	$10	20,000	22,000	13
Natuzzi	Furniture	$9	19,654	21,619	13
Goodyear	Tires	$15	19,400	21,340	13
Family Dollar	Big box	$10	19,300	21,230	13
Retail Ventures	Big box	$15	18,800	20,680	13
TJX (T J Maxx)	Big box	$20	18,200	20,020	12
Sharp	Electronics	$40	17,900	19,690	12
Conair	Appliances	$25	17,800	19,580	12
Liz Claiborne	Apparel	$40	17,500	19,250	12
Toyo	Tires	$15	16,900	18,590	11
Toyota	Auto parts	$20	16,000	17,600	11
JoAnn Stores	Textiles	$20	15,900	17,490	11
FoxConn	Electronics	$40	15,400	16,940	10
Caterpillar	Machinery	$50	15,300	16,830	10
Gap	Apparel	$40	14,800	16,280	10
DaimlerChrysler	Auto parts	$20	14,600	16,060	10
May	Big box	$18	14,500	15,950	10
TPV International	Electronics	$40	14,500	15,950	10
Best Buy	Electronics	$40	14,400	15,840	10
Bombay	Furniture	$9	14,300	15,730	10
Fuji	Film	$80	14,300	15,730	10
BMW	Auto parts	$20	14,200	15,620	10
Haier	Appliances	$25	14,200	15,620	10
Hasbro	Toys	$17.50	14,200	15,620	10
Salton	Appliances	$25	14,100	15,510	9
Suzuki	Auto parts	$20	13,700	15,070	9
Linens 'n Things	Textiles	$20	13,600	14,960	9
OfficeMax	Big box	$12	13,400	14,740	9
Epson	Electronics	$40	13,400	14,740	9

Coaster of America	Furniture	$9	13,300	14,630	9
Staples	Big box	$12	13,200	14,520	9
Yazaki	Auto parts	$20	12,900	14,190	9
Ricoh	Electronics	$40	11,600	12,760	8
Brother	Electronics	$40	11,600	12,760	8
Applica	Appliances	$20	11,100	12,210	7
Adidas-Solomon	Shoes	$25	10,800	11,880	7
Footstar	Shoes	$25	10,500	11,550	7
Hamilton Beach	Appliances	$25	10,400	11,440	7
Honda	Auto parts	$20	10,300	11,330	7
CVS (Eckerds)	Big box	$10	10,200	11,220	7
Avg. value per cu ft		$18.79			
Total TEUs			3,447,654	3,792,419	
Subtotals:					
Big box			1,445,700	1,590,270	
Furniture			665,154	731,669	
Electronics			371,700	408,870	
Appliances			218,000	239,800	
Auto parts			219,200	241,120	
Tires			145,300	159,830	
Shoes			144,000	158,400	
Toys			102,800	113,080	
Elec eqpt			22,600	24,860	
Machinery			37,100	40,810	
Textiles			29,500	32,450	
Apparel			32,300	35,530	
Film			14,300	15,730	

As may be seen, the volume towards the end of the list is quite low; Eckerds was importing on average only 215.7 TEUs per week. If the Continental US were divided into 21 distribution regions, this would be only about 10 TEUs per week per region. The off-peak weekly volume per region is only 7 TEUs. For such merchants the transloading strategy is marginally feasible from a volume point of view, quite apart from whether or not it is economically attractive.

For the purposes of this study, the major importers listed above are considered to be the only candidates for transloading. As will be discussed in Chapter 5, these importers were subjected to an economic analysis to determine what import strategy (trans-load at one port, trans-load at multiple ports, direct shipping via nearest port, direct shipping via West Coast ports) is economically best.

The remaining total import volume from Asia is assumed to be confined to direct shipping and assumed to have cargo values distributed such that distribution of total imports fills out the light blue bars in Figure 1.

The Economic Impact of Consolidation and De-consolidation

The amount of safety stock required among several RDCs can be reduced if their shipments are consolidated for a portion of the overall lead time for replenishment, then de-consolidated according to updated demand forecasts. Because fluctuations in sales served by the various RDCs are partially off-setting, and because the impact of an extended transit time for one or several containers may be shared across the RDCs, much less safety stock is required at the destinations.

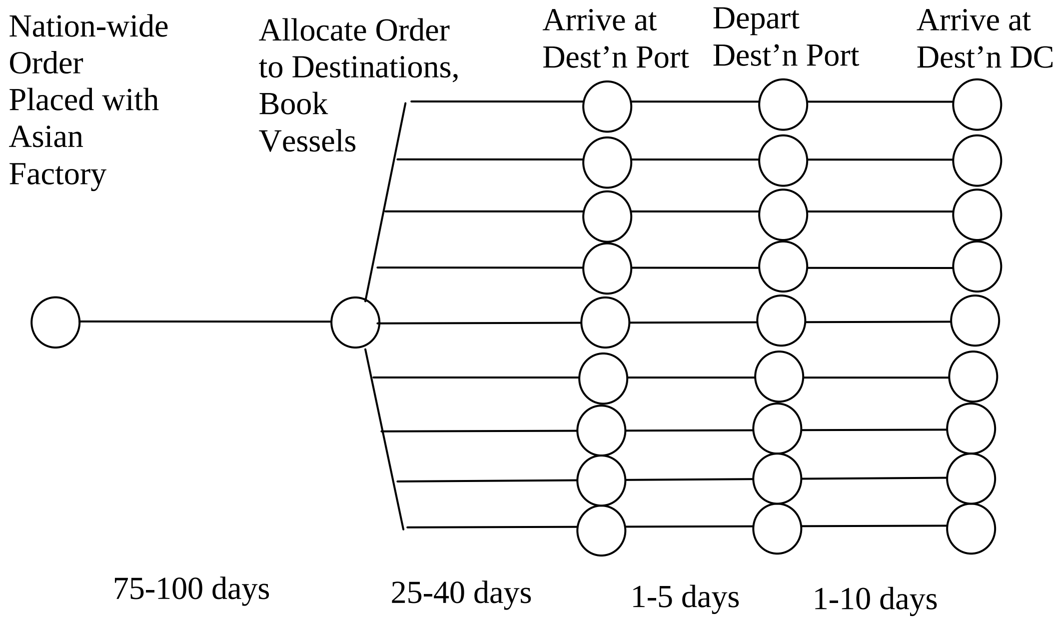
For example, suppose there are ten RDCs, each serving the same amount of retail demand. Suppose ten containers of goods are ordered each week, one for each RDC. If sales are 10% higher than expected at 5 RDCs but 10% lower at the other 5 RDCs, then no safety stock is required to meet demands if the ten shipments were consolidated. Further, suppose one of the 10 containers gets delayed by customs in Asia and misses its scheduled vessel and must transit on the next vessel one week later. If the ten shipments were pooled, each RDC could receive 90% of what was ordered. If not, one RDC would receive nothing. In the former case, a 10% safety stock is adequate; in the latter a 100% safety stock is required.

The consolidation-deconsolidation strategy is implemented by large, nationwide retailers as follows. Rather than shipping direct from Asia to its North American RDCs, shipments are made from Asian suppliers to de-consolidation facilities located in the hinterland of one or several North American ports of entry. Blanket orders covering nation-wide demands are issued to the vendors in Asia, typically on the order of 90 days before the desired shipment date. Not until shortly before vessel bookings are secured is the blanket order subdivided by port of entry, typically about 14 days before vessel departure. Total transit time to the North American port of entry, from the time containers are tendered at the origin port until the time containers can be picked up at the destination port, ranges from 14 to 30 days. Three days before arrival of a vessel at a destination port, the decision is made as to how to allocate the total shipment on the vessel among RDCs served by the port of entry, and this decision is electronically transmitted to the de-consolidation facility.

The importer conducting direct shipping from Asia to RDCs also can furnish its Asian vendors with blanket orders covering nationwide demands, but it must decide the RDC destination before booking vessels for departure from Asia. This avoids the extra handling cost and lead time of de-consolidation at the ports of entry, but it exposes the RDCs to forecast errors over a longer lead time and it denies the RDCs the opportunity to pool transit time risks.

The lead times for direct shipping and consolidation – deconsolidation are diagrammed in Figure 2. Under either alternative, blanket nation-wide orders may be placed with Asian suppliers, so that variations in demands across the importer’s regional distribution centers are pooled. Under the direct shipping alternative, the order must be allocated to destination distribution centers before vessels are booked, resulting in 26 – 55 days of lead time exposure during which destination demands are not pooled. Under the trans-

Direct Shipping:



Transloading:

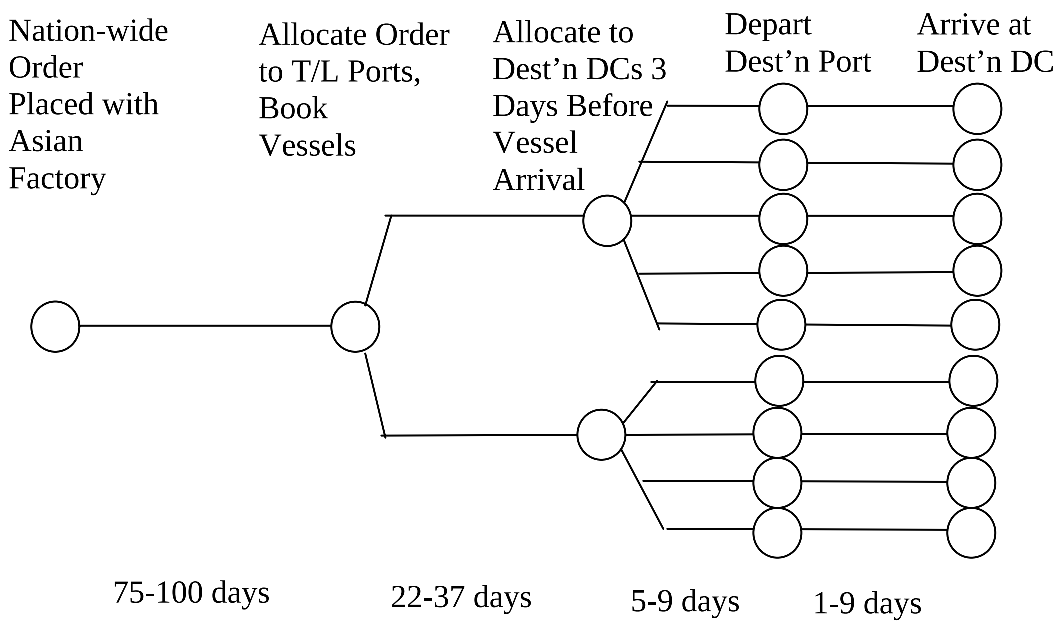


Figure 2
Structure of Ordering Lead Times
for Direct Shipping and Transloading Alternatives

loading alternative, only the trans-load port is selected before vessel booking, and demands of distribution centers serviced by a single trans-load port are still pooled. Three days before vessel arrival at destination port, allocations are made to destination distribution centers, resulting in only 6 – 18 days of lead time exposure during which destination demands are not pooled.

Differences in transit time between the alternatives are explained as follows. From arrival at port of entry to departure from port of entry, the trans-loading alternative takes 2-3 days longer considering the priority given to inland-point intermodal shipments when unloading vessels and releasing boxes for pickup at marine terminals, the time to dray to the deconsolidation warehouse, the time to sort and trans-load goods, and the time to dray to the domestic rail ramp and await the next rail departure. From departure from port of entry to arrival at destination DC, transit time for the direct shipping alternative is 0-1 days longer because in many lanes marine stack trains have slower schedules than domestic container trains. Specific transit time assumptions by port and lane are provided in Tables 3 and 4.

To more easily quantify the safety stock savings from the consolidation-deconsolidation strategy, we first develop the mathematical formulas for safety stocks for the direct shipping and the consolidation-deconsolidation strategies for the simplified case of N equal-demand RDCs and M de-consolidation facilities each serving M/N RDCs.

Notation for Parameters:

D - nation-wide average sales volume per week (in physical units, not dollars).
$MAPE$ – mean absolute percentage error (expressed as a fraction of one) in one-week-ahead forecasts of nation-wide sales.
N – number of RDCs. The sales volume per week served by each RDC is initially assumed to be D/N. (We relax this assumption later on.)
M – number of ports carrying out trans-load de-consolidation of Asian shipments. Each such trans-load facility is assumed to supply N/M RDCs. (We generalize this later on.)
R – time between replenishment orders (from Asian suppliers). R is assumed to be 1 week for all importers.
L_{AO} – mean lead time (expressed in weeks) from when order is placed until port of entry for shipment is selected.
L_{AW} – mean lead time (expressed in weeks) from when port of entry for shipment is selected until shipment completes over-water transport from Asia and commences land transport from North American POE to RDC. In the case of trans-loading L_{AW} includes the time to trans-load the goods at a POE trans-loading facility.
L_W – mean lead time (expressed in weeks) from departure from point of origin until shipment commences land transport from POE to RDC. In the case of trans-loading L_W includes the time to trans-load the goods at a POE trans-loading facility.
L_{NA} – mean lead time (expressed in weeks) from when shipment commences land transport from POE until processed through the RDC.
$\sigma_{L_{AW}}$ – standard deviation of L_{AW}.
$\sigma_{L_{NA}}$ – standard deviation of L_{NA}.
k – safety factor determining the level of safety stocks at RDCs. (Choosing k = 2 implies approximately a 98% probability of no stock-out.)

Formula for Pipeline Stock

The total in-transit inventory is simply

$$(L_W + L_{NA})(D)\ . \qquad (1)$$

Formulas for Safety Stocks

The standard deviation of errors in one-week-ahead forecasts of nation-wide sales is approximately given by

$$\sigma_D = (1.25)(MAPE)(D)\,.$$

Assuming independence of forecast errors across RDCs, the standard deviation of errors in one-week-ahead forecasts of sales served by a single RDC is

$$\sigma_D / \sqrt{N}\ .$$

The formulas for nation-wide safety stocks are different for the case of direct shipping from Asia to the RDCs and the case of de-consolidation of bulk shipments from Asia at a trans-load facility near the port of entry. We develop the formulas for these two cases as follows.

Direct Shipping

We assume uncertainties in water-side and land-side lead times are independent. We further assume errors in sales forecasts grow as the square root of lead time. If there were only a single RDC with demand rate D and variance of forecast errors σ_D^2, the generic formula for the required safety stock is

$$k\sqrt{L_{AO}\sigma_D^2 + (L_{AW} + L_{NA} + R)\sigma_D^2 + D^2(\sigma_{L_{AW}}^2 + \sigma_{L_{NA}}^2)}\ .$$

Considering the fleet of N RDCs each with demand rate D/N and variance of forecast errors σ_D^2/N, the required total nation-wide safety stock is

$$(k)\sqrt{L_{AO}\sigma_D^2 + N^2(L_{AW} + L_{NA} + R)(\sigma_D^2 / N) + N^2(D/N)^2(\sigma_{L_{AW}}^2 + \sigma_{L_{NA}}^2)}$$

or

$$(D)(k)\sqrt{[L_{AO} + (N)(L_{AW} + L_{NA} + R)](1.25)^2(MAPE)^2 + (\sigma_{L_{AW}}^2 + \sigma_{L_{NA}}^2)}\ . \qquad (2)$$

De-consolidation at Trans-load Facilities

We assume each of the *M* trans-load facilities serves *N*/*M* RDCs. Fluctuations in demands among these RDCs over the lead time L_{AW} may be pooled. The generic formula for the total safety stock across *N* RDCs served by an individual trans-load facility is[9]

$$(k)\sqrt{(L_{AO})\sigma_D^2 + (L_{AW})\sigma_D^2 + (N)^2(L_{NA}+R)(\sigma_D^2/N) + (N)^2(D/N)^2(\frac{\sigma_{L_{AW}}^2}{N} + \sigma_{L_{NA}}^2)} \ .$$

The total nation-wide safety stock in the case of *M* trans-load facilities each serving *N/M* RDCs is then

$$(k)\begin{bmatrix} L_{AO}\sigma_D^2 + (M)^2(L_{AW})\sigma_D^2/M \\ + N^2(L_{NA}+R)\sigma_D^2/N \\ + (N)^2(D/N)^2(\frac{M}{N}\sigma_{L_{AW}}^2 + \sigma_{L_{NA}}^2) \end{bmatrix}^{1/2}$$

or

$$(D)(k)\sqrt{\left[L_{AO} + (M)(L_{AW}) + (N)(L_{NA}+R)\right](1.25)^2(MAPE)^2 + (\frac{M}{N}\sigma_{L_{AW}}^2 + \sigma_{L_{NA}}^2)} \ . \qquad (3)$$

Note that if $M = N$, then (3) reduces to (2) (the formula for the case of direct shipping), as expected.

Numerical Examples

Suppose $N = 21$, $M = 3$, $D = 6{,}072$ TEUs per week, $MAPE = 0.06$, $L_{AO} = 7$, $L_{AW} = 4$, $L_W = 2$, $L_{NA} = 1$, $R = 1$, $\sigma_{L_{AW}} = 5/7$, $\sigma_{L_{NA}} = 1/7$ and $k= 2$. (These are believed to be fairly realistic data for a large US "big-box" retailer.)

Applying formula (1), the total pipeline inventory is

(2 + 1)(6,072) = 3*D* = 18,216 TEUs.

Next, we calculate safety stocks. Applying formula (2), direct shipping results in total nation-wide safety stock equal to

[9] The derivation of this formula for the case of $M = 1$ and no variance in lead times is provided in "Centralized Ordering Policies in a Multi-Warehouse System with Lead Times and Random Demand," by Gary Eppen and Linus Schrage, in *Multi-Level Production/Inventory Control Systems: Theory and Practice*, L. B. Schwarz, Editor, North Holland, 1981, pp. 51-68.

$(6{,}072)(2)\,[(7 + (21)(4+1+1))(1.25)^2(0.06)^2 + (5/7)^2 + (1/7)^2\,]^{½} = 2.262D = 13{,}733$ TEUs.

Applying formula (3), de-consolidation of Asian imports at three trans-load facilities results in a nation-wide safety stock equal to

$(6{,}072)(2)\,[(7 + (3)(4) + (21)(1+1))(1.25)^2(0.06)^2 + (1/7)(5/7)^2 + (1/7)^2\,]^{½} = 1.321D = 8{,}023$ TEUs.

Note that the trans-loading option reduces RDC safety stocks by (2.262 – 1.321) = 0.941 weeks of demand. Put another way, the retailer's supply chain is reduced by about 7 days.

Let's suppose the investment in landed imports is $20 per cubic foot, assume 1,250 usable cubic feet per TEU, and assume an inventory carrying cost of 20% per year.

For direct shipping, the total inventory cost is

(18,216 + 13,733)(1,250)($20)(0.20/52) = $3,072,019 per week

or about $159.7 million per year.

The savings in nation-wide safety stock from de-consolidation at the POEs is calculated as

(13,733 – 8,023)(1,250)($20)(0.20/52) = $549,038 per week

or about $28.6 million per year.

Expressed a different way, the de-consolidation savings per cubic foot of imports is

($549,038) / [(6,072)(1,250)] = $0.0723

This savings is linear in the total import volume, the value of the imports and in the assumed inventory carrying cost, but it is non-linear in the numbers of RDCs and POEs, the forecast error, and the standard deviations of the lead times. Advantages from de-consolidation grow with

- Increasing import volume (linearly)
- Increasing import value (linearly)
- Increasing inventory carrying cost (linearly)
- Increasing numbers of RDCs (square root function)
- Decreasing numbers of POEs (square root function)
- Avg. forecast error (square root function)

To illustrate, if we reduce N to 7 but keep $M = 3$, the savings declines to $0.0379 per cubic foot. i.e., abut half. Even if M is reduced to 1 (while N is 7), the savings is reduced to $0.0561 per cubic foot. This suggests that de-consolidation is much more attractive to relatively large retailers with a nation-wide or nearly nation-wide market. In particular, de-consolidation offers no savings at all to the retailer with only one nation-wide distribution center (as there is nothing to consolidate).

If we keep N = 21 but reduce M to 1, the savings grows from $0.0732 to $0.0839, i.e., by about a penny per cubic foot. This suggests that if the total of transportation plus pipeline inventory costs is significantly lowered by using multiple ports of entry, then it is efficient to carry out trans-loading and de-consolidation at several ports situated to take advantage of land transportation economies (e.g., Los Angeles, Seattle and Norfolk) rather than at just one (e.g., Los Angeles).

Finally, if we again consider the case of N = 21 and M = 1 but set $MAPE$ = 0.09 (as might be the case for new electronics or style goods), the savings from transloading is $0.0988. This suggests that for such kinds of items, consolidation-deconsolidation is extremely valuable, as it is essential to be able to control inventories as tightly as possible.

The Impact of Congestion

Suppose the trans-loading channel suffers congestion (e.g., a severe shortage of draymen), while the direct-shipping channel does not (e.g., it uses on-dock rail). We retain the original example data except we suppose for the trans-loading channel that L_{NA} = 2, and $\sigma_{L_{NA}}$ = 4/7. That is, transit times to pass through the POE rise by a week, and the standard deviation grows by three days. In this situation, the savings in nation-wide safety stock for the trans-loading option over the direct shipping option drops to $0.0312 per cubic foot. If the standard deviation was even worse, e.g., $\sigma_{L_{NA}}$ = 7/7, then the cost of safety stock becomes $0.0201 *more* per cubic foot than that for the direct shipping option. It is clear that the impact of congestion is economically very severe for retailers, to the point that it may become necessary for them to abandon de-consolidation in favor of direct shipping, if that is the only way that the congestion can be avoided.

Generalization for Varying Lead Times and Volumes

The general case is where there are multiple North American ports of entry and multiple destination RDCs. The different combinations have different lead times. Moreover, the volumes at the various RDCs are not necessarily equal. The complex formulas for the general case are provided in the appendices.

Assumed Values of Lead Time Parameters

Lead time parameters for assessing inventory costs were assumed as follows:

L_{AO} – 60 days

L_{AW} – 24.5 days plus vessel transit time plus port-to-ramp time for inland rail intermodal shipments of marine containers
L_{AW} – 24.5 days plus vessel transit time plus port-to-gate time for truck or local dray shipments of marine containers
L_{AW} – 24.5 days plus vessel transit time plus port-to-warehouse transit time for deconsolidation/trans-load shipments
L_{NA} – truck transit time for inland truck shipment of marine containers
L_{NA} – rail transit time plus one day for inland rail intermodal shipments of marine containers
L_{NA} – one day for local delivery of marine containers
L_{NA} – two days plus rail transit time for trans-loaded inland rail intermodal shipments
L_{NA} – truck transit time for inland truck shipment of trans-loaded cargo
L_{NA} – one day for local delivery of trans-loaded cargo

Port-related transit time parameters were assumed as shown in Table 3.

Table 3
Assumed Lead Time Parameters

Port	**Asia to Port**		**Port to Mount** (on-dock rail)		**Port to Gate** (off-dock rail and truck)		**Port to T/L Whse**	
	Mean	Std Dvn	Mean	Std Dvn	Mean	Std Dvn	Mean	Std Dvn
Vancouver – Prince Rupert	15	5	2	2	3	2	3	2
Seattle-Tacoma	15	5	2	2	3	2	3	2
Oakland	15	5	2	2	3	2	3	2
LA-Long Beach	14	5	2	2	3	2	3	2
Houston	22	5	2	2	3	2	2	2
Savannah	28	5	2	2	3	2	2	2
Charleston	27	5	2	2	3	2	2	2
Norfolk	28	5	2	2	3	2	2	2
NY-NJ	26	5	2	2	3	2	3	2

In addition to the above, direct rail movement of marine containers was assumed to have a standard deviation of 3 days. Rail movement of trans-loaded cargo (in domestic containers) was assumed to have a standard deviation of 1 day. Truck and local dray movements were assumed to have a standard deviation of 0.25 days.

Transit Times for Inland Movements

The mean transit times for inland truck and rail movements depend on origin-destination pairs. Average transit time parameters, expressed in days, were established for each channel from each port to each destination. For rail movements, rail schedules (showing total hours from cut-off at origin ramp to release at destination ramp and showing frequency of service) were obtained from various rail and service web sites. Generally, an extra day at destination was added to allow for drays to and from rail ramps. For transcontinental, inter-railroad movements of marine carriers, the consultant sometimes added an extra day or two based on our experience. For truck movements, the consultant estimated transit times directly. These transit times are summarized in Table 4.

Table 4
Assumed Mean Transit Times for Inland Truck and Rail Movement (Days)

Port	Destination	Rail - 40ft Container	Rail 53ft Container	Direct Truck
Charleston	Atlanta	2	2	1
Charleston	Baltimore	3	1	2
Charleston	Boston	4	3	3
Charleston	Charleston	NA	NA	NA
Charleston	Charlotte	3	NA	1
Charleston	Chicago	4	4	3
Charleston	Cleveland	5	5	2
Charleston	Columbus	5	5	2
Charleston	Dallas	4	3	3
Charleston	Harrisburg	5	4	2
Charleston	Houston	6	6	3
Charleston	Kansas City	7	6	3
Charleston	Los Angeles	NA	NA	6
Charleston	Memphis	3	3	2
Charleston	Minneapolis	5	5	4
Charleston	New York	4	2	2
Charleston	Norfolk	3	2	1
Charleston	Oakland	NA	NA	7
Charleston	Pittsburgh	6	5	2
Charleston	Savannah	3	2	1
Charleston	Seattle-Tacoma	NA	NA	7
Charleston	Toronto	7	7	3
Houston	Atlanta	5	4	2
Houston	Baltimore	6	5	3
Houston	Boston	7	6	4
Houston	Charleston	6	6	3
Houston	Charlotte	6	6	3
Houston	Chicago	4	4	3
Houston	Cleveland	5	4	3

Houston	Columbus	5	4	3
Houston	Dallas	2	1	1
Houston	Harrisburg	6	5	4
Houston	Houston	NA	NA	NA
Houston	Kansas City	4	4	2
Houston	Los Angeles	7	7	4
Houston	Memphis	3	3	2
Houston	Minneapolis	7	7	3
Houston	New York	7	7	4
Houston	Norfolk	7	6	3
Houston	Oakland	NA	NA	5
Houston	Pittsburgh	6	5	4
Houston	Savannah	7	6	3
Houston	Seattle-Tacoma	NA	NA	6
Houston	Toronto	8	8	5
LA-Long Beach	Atlanta	8	6	6
LA-Long Beach	Baltimore	9	7	7
LA-Long Beach	Boston	9	7	8
LA-Long Beach	Charleston	10	8	6
LA-Long Beach	Charlotte	9	8	6
LA-Long Beach	Chicago	6	5	4
LA-Long Beach	Cleveland	8	6	5
LA-Long Beach	Columbus	8	6	5
LA-Long Beach	Dallas	6	4	3
LA-Long Beach	Harrisburg	9	7	6
LA-Long Beach	Houston	6	4	4
LA-Long Beach	Kansas City	6	4	3
LA-Long Beach	Los Angeles	NA	NA	NA
LA-Long Beach	Memphis	6	5	4
LA-Long Beach	Minneapolis	8	7	4
LA-Long Beach	New York	9	7	7
LA-Long Beach	Norfolk	9	8	7
LA-Long Beach	Oakland	NA	NA	1
LA-Long Beach	Pittsburgh	8	6	6
LA-Long Beach	Savannah	10	8	6
LA-Long Beach	Seattle-Tacoma	4	3	3
LA-Long Beach	Toronto	8	7	6
Norfolk	Atlanta	3	3	2
Norfolk	Baltimore	4	4	1
Norfolk	Boston	5	5	2
Norfolk	Charleston	3	2	2
Norfolk	Charlotte	2	2	1
Norfolk	Chicago	4	3	2
Norfolk	Cleveland	4	4	2
Norfolk	Columbus	4	4	2
Norfolk	Dallas	5	5	3
Norfolk	Harrisburg	4	4	1
Norfolk	Houston	6	6	3
Norfolk	Kansas City	6	5	3
Norfolk	Los Angeles	NA	NA	7

Norfolk	Memphis	4	3	2
Norfolk	Minneapolis	7	4	3
Norfolk	New York	4	4	1
Norfolk	Norfolk	NA	NA	NA
Norfolk	Oakland	NA	NA	7
Norfolk	Pittsburgh	4	4	2
Norfolk	Savannah	4	3	2
Norfolk	Seattle-Tacoma	NA	NA	7
Norfolk	Toronto	6	5	2
NY-NJ	Atlanta	4	2	2
NY-NJ	Baltimore	NA	NA	1
NY-NJ	Boston	NA	NA	1
NY-NJ	Charleston	5	5	2
NY-NJ	Charlotte	4	4	2
NY-NJ	Chicago	3	2	2
NY-NJ	Cleveland	3	3	2
NY-NJ	Columbus	3	3	2
NY-NJ	Dallas	6	5	4
NY-NJ	Harrisburg	NA	NA	1
NY-NJ	Houston	8	6	4
NY-NJ	Kansas City	5	4	3
NY-NJ	Los Angeles	NA	NA	7
NY-NJ	Memphis	5	4	3
NY-NJ	Minneapolis	5	3	4
NY-NJ	New York	NA	NA	NA
NY-NJ	Norfolk	3	2	1
NY-NJ	Oakland	NA	NA	7
NY-NJ	Pittsburgh	3	3	1
NY-NJ	Savannah	5	5	3
NY-NJ	Seattle-Tacoma	NA	NA	7
NY-NJ	Toronto	4	3	2
Oakland	Atlanta	9	7	6
Oakland	Baltimore	10	7	7
Oakland	Boston	10	7	8
Oakland	Charleston	11	9	7
Oakland	Charlotte	9	9	7
Oakland	Chicago	7	5	5
Oakland	Cleveland	9	6	6
Oakland	Columbus	9	7	6
Oakland	Dallas	7	5	3
Oakland	Harrisburg	10	8	7
Oakland	Houston	7	5	3
Oakland	Kansas City	7	5	3
Oakland	Los Angeles	NA	NA	1
Oakland	Memphis	7	5	4
Oakland	Minneapolis	8	7	5
Oakland	New York	10	8	7
Oakland	Norfolk	10	7	7
Oakland	Oakland	NA	NA	NA
Oakland	Pittsburgh	9	7	6

Oakland	Savannah	11	9	7
Oakland	Seattle-Tacoma	NA	NA	2
Oakland	Toronto	9	8	7
Savannah	Atlanta	1	1	1
Savannah	Baltimore	3	2	2
Savannah	Boston	3	3	3
Savannah	Charleston	NA	NA	1
Savannah	Charlotte	3	3	1
Savannah	Chicago	4	3	3
Savannah	Cleveland	5	4	3
Savannah	Columbus	4	4	3
Savannah	Dallas	4	4	4
Savannah	Harrisburg	5	4	3
Savannah	Houston	5	4	4
Savannah	Kansas City	6	4	4
Savannah	Los Angeles	NA	NA	6
Savannah	Memphis	3	3	2
Savannah	Minneapolis	7	4	4
Savannah	New York	4	2	3
Savannah	Norfolk	3	2	2
Savannah	Oakland	NA	NA	6
Savannah	Pittsburgh	5	4	3
Savannah	Savannah	NA	NA	NA
Savannah	Seattle-Tacoma	NA	NA	7
Savannah	Toronto	7	7	5
Seattle-Tacoma	Atlanta	9	7	5
Seattle-Tacoma	Baltimore	9	7	5
Seattle-Tacoma	Boston	9	8	5
Seattle-Tacoma	Charleston	11	8	5
Seattle-Tacoma	Charlotte	10	9	5
Seattle-Tacoma	Chicago	6	5	3
Seattle-Tacoma	Cleveland	8	6	4
Seattle-Tacoma	Columbus	8	6	4
Seattle-Tacoma	Dallas	8	8	4
Seattle-Tacoma	Harrisburg	9	7	5
Seattle-Tacoma	Houston	10	7	5
Seattle-Tacoma	Kansas City	8	6	3
Seattle-Tacoma	Los Angeles	4	3	2
Seattle-Tacoma	Memphis	8	7	4
Seattle-Tacoma	Minneapolis	5	4	3
Seattle-Tacoma	New York	9	7	5
Seattle-Tacoma	Norfolk	9	8	5
Seattle-Tacoma	Oakland	NA	NA	2
Seattle-Tacoma	Pittsburgh	9	6	4
Seattle-Tacoma	Savannah	11	11	6
Seattle-Tacoma	Seattle-Tacoma	NA	NA	NA
Seattle-Tacoma	Toronto	8	7	4
Vancouver, BC[10]	Atlanta	9	8	5

[10] Vancouver lead time data is assumed to apply to Prince Rupert.

Vancouver, BC	Baltimore	10	8	5
Vancouver, BC	Boston	10	8	5
Vancouver, BC	Charleston	11	10	5
Vancouver, BC	Charlotte	10	9	5
Vancouver, BC	Chicago	7	5	3
Vancouver, BC	Cleveland	9	7	4
Vancouver, BC	Columbus	9	7	4
Vancouver, BC	Dallas	9	9	4
Vancouver, BC	Harrisburg	10	8	5
Vancouver, BC	Houston	12	9	5
Vancouver, BC	Kansas City	9	8	3
Vancouver, BC	Los Angeles	NA	NA	2
Vancouver, BC	Memphis	7	6	4
Vancouver, BC	Minneapolis	6	5	3
Vancouver, BC	New York	10	8	5
Vancouver, BC	Norfolk	10	9	5
Vancouver, BC	Oakland	NA	NA	2
Vancouver, BC	Pittsburgh	10	7	4
Vancouver, BC	Savannah	11	11	6
Vancouver, BC	Seattle-Tacoma	NA	NA	1
Vancouver, BC	Toronto	6	5	4

3. TRANSPORTATION CHARGES

There are many individual transportation charges assessed by various parties concerning the movement of containerized imports. Some of these charges are specifically billed to importers, some are absorbed by carriers and covered by their overall rate charged to the importer. Table 5 documents various land-side charges and distinguishes those billed to the customer vs. those absorbed by the carrier. Three types of carriers are shown: steamship line, non-vessel-owning common carrier, and intermodal marketing company.

For the purposes of this study, a matrix of transportation and handling charges as faced by importers was developed for specific ports of entry and alternative modes of transport as follows.

Alternative Ports of Entry

Nine major groupings of North American ports of entry were included in the analysis, as follows:

* Vancouver – Prince Rupert, BC. Consolidation – deconsolidation to US points via Canadian ports of entry is assumed to be infeasible because of assessment of both Canadian and US duties on imports. Only direct shipping via these ports is analyzed.

* Seattle – Tacoma, WA. Assumed trans-load warehouse site is Fife, WA.
* Oakland, CA. Assumed trans-load warehouse site is Tracy, CA.
* Los Angeles – Long Beach, CA. Assumed trans-load warehouse site is Ontario, CA.
* Houston, TX. Assumed trans-load warehouse site is Baytown, TX.
* Savannah, GA. Assumed trans-load warehouse site is Garden City, GA.
* Charleston, SC. Assumed trans-load warehouse site is Summerville, SC.
* Hampton Roads, VA (referred to as Norfolk throughout this report). Assumed trans-load warehouse site is Suffolk, VA.
* Port of New York – New Jersey. Assumed trans-load warehouse site is 50% East Brunswick, NJ and 50% Allentown, PA.

There are other ports handling Asian imports to North America, but in much smaller volumes than handled by the above ports. There also are prospects or potential for future volumes of Asian cargoes to US destinations through the Ports of Manzanillo and Lazaro Cardenas and a proposed new port near Ensenada, all on the West Coast of Mexico. However, US-destined volume via the Mexican ports at this time is negligible, and rate quotations are scarce.

Destinations

The typical large US importer/retailer operates regional distribution centers that restock retail stores located within an overnight driving distance. Typically, on the order of 15-30 regional centers are required to service all the retail outlets within the continental United States and Canada. This suggests that a reasonable approximation of import trade flows may be made by considering a comparable number of destination zones, each with one regional distribution center as a destination for Asian imports.

To model inland transportation costs, the continental United States was divided into 21 destination regions. It was assumed that a regional distribution center (RDC) located in a suburb of a major city within each region was the destination for all imported goods consumed within the region, as detailed below. Transportation costs for alternative modes/channels for Asian imports via alternative potential ports of entry to these distribution center sites were developed.

The destination regions and assumed site of the RDC within the region are as follows:[11]

Seattle Region – including Washington, Oregon, Idaho and Montana. Regional distribution center assumed to be in Fife, WA.
Oakland Region – including Wyoming, 50% of Colorado, 67% of Utah, 34% of California, and 33% of Nevada. Regional distribution center assumed to be in Tracy, CA.

[11] A percentage specified for a state defines the portion of import volume terminating in that state that is assumed to be assigned to a distribution center in the named region. For example, 50% of imports terminating in Pennsylvania are assumed to be served from an importer's Harrisburg Region distribution center, and 50% are assumed to be served from the importer's Pittsburgh Region distribution center.

Los Angeles Region – including Arizona, New Mexico, 66% of California, 67% of Nevada, 33% of Utah, and 50% of Colorado. Regional distribution center assumed to be in Ontario, CA.
Dallas Region – including Oklahoma and 50% of Texas. Regional distribution center assumed to be in Midlothian, TX.
Houston Region – including Louisiana, Mississippi and 50% of Texas. Regional distribution center assumed to be in Baytown, TX.
Memphis Region – including Arkansas, Tennessee and Kentucky. Regional distribution center assumed to be in Millington, TN.
Kansas City Region – including Kansas, Nebraska, Iowa and Missouri. Regional distribution center assumed to be in Lenexa, KS.
Minneapolis Region – including North Dakota, South Dakota, Minnesota and 50% of Wisconsin. Regional distribution center assumed to be in Rosemount, MN.
Chicago Region – including Illinois, Indiana, Michigan 50% of Wisconsin. Regional distribution center assumed to be in Joliet, IL.

Table 5
Transportation Costs – Charges Separately Billed to Customer vs. Charges Absorbed by Carrier
("Yes" indicates charge is separately billed to customer by carrier,
"No" indicates charge is absorbed by carrier and must be covered by overall rate)

	Carrier Type		
Type of Charge	SSL on through B/L	NVOCC on through B/L	IMC B/L
Terminal gate charge for truck/dray	No, always paid by SSL		
JPA terminal gate charge (Alameda Corr.)	No, always paid by SSL/collected by RR		
PierPass charge for truck/dray	Yes - surcharge always paid by customer		
Dray to warehouse in Port of Entry hinterland	Yes for Group 4 rate	Yes for Port B/L	
Trans-load from marine container to domestic trailer or domestic container	Not involved	Yes	
Truck line-haul of marine container	Yes for Group 4 rate	Yes for Port B/L	
Truck line-haul of domestic trailer	Not involved	Yes	
Dray of domestic trailer or container from warehouse to origin rail ramp	Not involved	Yes	
Rail line-haul of marine container	No for MLB/IPI	Yes for SSL Port B/L No for SSL IPI B/L	Yes for Third Party International (TPI)
Destination dray of marine intermodal container	Yes for SDD B/L No for CY	Yes for SDD B/L No for CY B/L	

	B/L		
Rail line-haul of domestic trailer or container	Not involved	In some cases – but most likely not	Yes
Destination dray of domestic intermodal trailer or container			
Third party booking fee (IMC) for rail intermodal movement			

Abbreviations: B/L – bill of lading, SSL – steamship line, NVOCC – non-vessel-owning common carrier, IMC – intermodal marketing company, MLB – mini-land-bridge, IPI – inland point intermodal, SDD – store-door delivery, CY – container yard pick-up by customer, Group 4 rate – applies to store-door delivery in the Port of Entry hinterland.

Columbus Region – including 50% of Ohio. Regional distribution center assumed to be in Springfield, OH.
Cleveland Region – including 50% of Ohio and 25% of New York. Regional distribution center assumed to be in Chagrin Falls, PA.
Pittsburgh Region – including West Virginia and 50% of Pennsylvania. Regional distribution center assumed to be in Beaver Falls, PA.
Harrisburg Region – including 50% of Pennsylvania. Regional distribution center assumed to be in Allentown, PA.
Atlanta Region – including Alabama, Georgia and 50% of Florida. Regional distribution center assumed to be in Duluth, GA.
Savannah Region – including 50% of Florida. Regional distribution center assumed to be in Garden City, GA.
Charleston Region – including 50% of South Carolina. Regional distribution center assumed to be in Summerville, SC.
Charlotte Region – including North Carolina and 50% of South Carolina. Regional distribution center assumed to be in Salisbury, SC.
Norfolk Region – including Virginia. Regional distribution center assumed to be in Suffolk, VA.
Baltimore Region – including Maryland, DC and Delaware. Regional distribution center assumed to be in Frederick, MD.
New York Region – including New Jersey, Connecticut and 75% of New York. Regional distribution centers are assumed to be located 50% in East Brunswick, NJ and 50% in Allentown, PA.
Boston Region – including Rhode Island, Massachusetts, New Hampshire, Vermont and Maine. Regional distribution center assumed to be in Milford, MA.

The Journal of Commerce PIERS database is a summarization of US customs data concerning containerized imports. Tabulations are available by port, commodity code, shipper, destination and quantity of containerized imports. The Port of Long Beach supplied the consultant with PIERS data for the West Coast ports for the 2005 calendar year. MARAD supplied the consultant with a summarization of PIERS data concerning imports from Asia through all US ports for the 2005 calendar year.

Unfortunately, many types of aggregate statistics derived from PIERS are unreliable. MARAD advised the consultant that only about 20% of the import records have correctly filled out destination records, and it cautioned against using the PIERS data as a base for analyzing the geographical distribution of imports.[12]

The consultant believes the vast majority of containerized imports from Asia to the United States are retail goods. It is reasonable to expect that the geographical distribution of destinations for retail imports should be the same as the geographical distribution of retail sales. Furthermore, it is reasonable to expect that retail sales may be indexed to purchasing power in each region, i.e., average income times population in each region.

The consultant obtained population and personal income data by state from U.S. Dept. of Commerce web sites. For the purposes of the elasticity analysis in Chapter 5, the distribution of import volumes by destination region was assumed to be proportional to total purchasing power in each region. Data on per-capita personal incomes by state and state populations were obtained by the consultant from US Dept. of Commerce web sites, then aggregated into the regions as defined above. The results are displayed in Table 6. This distribution is assumed to apply to all of the 83 major importers as well as every category of proxy miscellaneous importer.

Transportation Modes

When considering the shipment of containerized Asian imports to North America there are various options available to importers:

- Alternative vessel operating common carriers and non-vessel operating common carriers (NVOCCs), and alternative ports of entry.
- Through movement of marine containers from port of entry to inland destination via local dray (“Direct Dray”) or long-haul truck (“Direct Truck”).
- Through movement of marine containers from port of entry to inland destination via rail double-stack train and final dray from rail terminal to destination. An initial dray from port terminal to origin rail terminal is required if the rail terminal is not on-dock (“Direct Rail”).
- Dray of marine containers from port of entry to a transloading warehouse in the hinterland of the port of entry, transloading to the goods to a 53-foot trailer for truck movement to inland destination or local dray (“Trans-load Truck” or “Local Trans-load”).
- Dray of marine containers from port of entry to a transloading warehouse in the hinterland of the port of entry, transloading to the goods to a 53-foot trailer, dray to origin rail terminal, rail movement of the 53-foot trailer via premium

[12] To illustrate the uselessness of destination data with PIERS, the most common destination shown for imports through the Port of Los Angeles was “Unknown”. Next was California, and third most common was “Puerto Rico”(!).

intermodal train service, and final dray from rail terminal to destination ("Trans-load Rail Trailer").

- Dray of marine containers from port of entry to a transloading warehouse in the hinterland of the port of entry, transloading to the goods to a 53-foot container, dray to origin rail terminal, rail movement of the 53-foot container via double stack train, and final dray from rail terminal to destination ("Trans-load Rail Container").

The portions of the overall movement of each vehicle type (marine container, 53-foot trailer or 53-foot container) may be procured separately from multiple vendors, or they may be purchased as a bundled service from a single service provider. The vendors may be carriers or they may be third parties such as NVOCCs or intermodal marketing companies (IMCs).

Table 6
Assumed Distribution of Import Volumes by Destination Region

Region	Percentage of total imports
Seattle-Tacoma	4.024
Oakland	6.629
Los Angeles	11.782
Dallas	4.572
Houston	5.576
Memphis	3.765
Kansas City	4.219
Minneapolis	3.262
Chicago	10.990
Cleveland	3.807
Columbus	1.888
Pittsburgh	2.653
Atlanta	6.915
Savannah	2.811
Charleston	0.597
Charlotte	3.220
Harrisburg	2.161
Norfolk	2.740
Baltimore	2.870
New York	11.229
Boston	4.290
Total	100.000

Further complexity arises because many rates are contractual and confidential, with different rates applying to different customers.

The consultant was able to view rates offered by various vendors. The costs reported herein are based on averages across baskets of rates charged by various vendors to various customers and therefore do not necessarily reflect the specific rates of any individual contract or individual carrier.

Components of Transportation Costs

Costs components that were estimated include the following:

- All modes/channels: steamship line rate from Shanghai to dockside at each port of entry for a 40-foot container, plus wharfage and landing charges absorbed by the line
- Direct Rail: Weighted average of JPA gate charge, dray to near-dock rail ramps and dray to off-dock rail ramps
- Direct Rail of 40-foot container: Rail line haul rate (Note: This is an estimation of the difference between steamship rate for store-door delivery at a warehouse site near port of entry and steamship rate for inland point intermodal.)
- Direct Rail of 40-foot container: Destination dray
- Direct Truck or Direct Dray of 40-foot container: Truck line haul rate or local dray rate
- All trans-load modes: Dray from port to site of trans-load warehouse plus trans-loading fee
- Trans-load Rail Container: Dray from trans-load warehouse to domestic rail ramp
- Trans-load Rail Container: Rail line haul rate
- Trans-load Rail Container: Destination dray
- Trans-load Rail Container: Third-party (e.g., IMC) booking fee
- Trans-load Truck or Local trans-load: Truck line haul rate or local dray rate

In certain cases, weighted-averages of charges serve as the basis for costs, such as weighted averages of dray rates to near-dock terminals, to off-dock terminals, and mount charges for loading on-dock rail, or weighted averages of destination drays from rail ramps operated by different railroads.

As indicated above, many transportation rates are part of confidential contracts. For reasons of confidentiality, costs that are reported reflect the average of a basket of rates from multiple carriers rather than the specific rates of any particular contract or carrier. To further protect confidentiality, we report only total costs per cubic foot for each channel.

Domestic and marine vehicles have different cubic capacities. International cargo moves in 20-foot, 40-foot and 45-foot containers and has done so for many years. In contrast, the vehicles utilized for U.S. domestic freight have become progressively larger. Nowadays, the domestic truck fleet consists almost entirely of 53-foot trailers. Domestic containers and trailers used in rail intermodal service also have grown in size, from 40-foot trailers used in the early 1970s to 48-foot and 53-foot boxes today.

Domestic freight vehicles are not only longer than international containers, they are also taller and wider. The usable cubic space thus grows faster than the increment in length. Table 7 displays the useable cubic space of various vehicles. Note that a standard 53-foot domestic container offers about 60% more useable space than a standard international 40-foot container; a 53-foot truck offers about 71% more useable space.

The vast majority of Asian imports are cube freight, in the sense that cubic capacities are reached before weight capacities are reached. To properly compare transportation costs, it is therefore necessary to express costs on a cost per cubic foot basis. For the purposes of this analysis, we have assumed shipments in 40-foot marine containers are 60% in high-cube 40-foot boxes and 40% in standard 40-foot boxes, leading to the weighted average cubic capacity shown in Table 7. Shipments trans-loaded into domestic containers for rail intermodal movements are assumed to utilize hi-cube 53-foot containers. For cube freight, this means the contents of five marine (40-foot) containers may be stuffed into three domestic (53-foot) trailers or high-cube containers.

Table 7. Space Capacities of Containers and Trucks

Vehicle Type	Usable Space for Lading (cubic feet)	Space as a % of Avg 40ft Space
20ft standard container	1,163	45.29%
40ft standard container	2,395	93.26%
40ft hi-cube container	2,684	104.52%
Wtd. Avg. 40ft container	2,568	100.00%
45ft standard container	3,026	117.83%
48ft standard container	3,471	135.16%
53ft standard container	3,830	149.14%
53ft hi-cube container	3,955	154.01%
53ft truck	4,090	159.27%

Note: The equipment specifications shown above represent those most commonly found in the industry. Actual specifications vary from carrier to carrier and across carrier fleets.

Transportation Unit Costs

Table 8 provides the estimated rates per cubic foot for shipment from Shanghai to the selected North American destinations via the alternative ports of entry listed above. It is assumed that freight shipped is cube freight, and that the cubic space of transportation vehicles is fully utilized. Not all port-destination pairs are shown; unreasonable combinations, such as Vancouver – Houston or New York – Dallas are omitted. All figures are expressed in dollars per cubic foot. The total transportation cost ranges from $1.40 up to $3.00 per cubic foot of vehicle capacity, depending on the destination, choice of port and choice of mode.

Table 8
Transportation Rates Per Cubic Foot,
Shanghai – Selected North American Destinations

Port	Destination	Direct Rail	Transload Rail 53ft Container	Direct Truck	Transload 53ft Truck	Direct Dray
Charleston	Atlanta	1.65	1.95	1.61	1.80	NA
Charleston	Baltimore	1.79	2.05	1.83	1.94	NA
Charleston	Boston	NA	2.16	2.11	2.13	NA
Charleston	Charleston	NA	NA	NA	NA	1.50
Charleston	Charlotte	NA	NA	1.55	1.76	NA
Charleston	Chicago	1.79	2.00	2.09	2.12	NA
Charleston	Cleveland	1.77	2.07	1.95	2.02	NA
Charleston	Columbus	1.76	2.05	1.89	1.98	NA
Charleston	Dallas	NA	2.11	2.22	2.21	NA
Charleston	Harrisburg	NA	2.12	1.93	2.01	NA
Charleston	Houston	NA	2.10	2.19	2.19	NA
Charleston	Kansas City	NA	1.99	2.24	2.22	NA
Charleston	Los Angeles	NA	NA	3.29	2.92	NA
Charleston	Memphis	1.69	1.94	1.93	2.01	NA
Charleston	Minneapolis	NA	2.14	2.41	2.33	NA
Charleston	New York	NA	2.11	1.98	2.04	NA
Charleston	Norfolk	1.67	2.10	1.73	1.88	NA
Charleston	Oakland	NA	NA	3.54	3.09	NA
Charleston	Pittsburgh	1.88	2.10	1.89	1.98	NA
Charleston	Savannah	NA	1.94	1.61	1.80	NA
Charleston	Seattle-Tacoma	NA	NA	3.63	3.14	NA
Charleston	Toronto	NA	2.37	2.35	2.29	NA
Houston	Atlanta	1.65	1.91	1.85	1.91	NA
Houston	Baltimore	NA	2.22	2.37	2.23	NA
Houston	Boston	NA	2.33	2.69	2.45	NA
Houston	Charleston	NA	1.96	2.09	2.05	NA
Houston	Charlotte	NA	1.95	2.07	2.04	NA
Houston	Chicago	1.72	1.83	2.12	2.07	NA
Houston	Cleveland	NA	1.98	2.29	2.18	NA
Houston	Columbus	NA	1.95	2.18	2.11	NA
Houston	Dallas	NA	NA	1.45	1.62	NA
Houston	Harrisburg	NA	2.21	2.44	2.28	NA
Houston	Houston	NA	NA	NA	NA	1.33
Houston	Kansas City	1.59	1.81	1.84	1.88	NA
Houston	Los Angeles	NA	1.99	2.49	2.31	NA
Houston	Memphis	1.52	NA	1.70	1.79	NA

Houston	Minneapolis	1.76	2.07	2.19	2.12	NA
Houston	New York	NA	2.16	2.53	2.35	NA
Houston	Norfolk	NA	2.07	2.33	2.21	NA
Houston	Oakland	NA	NA	2.78	2.51	NA
Houston	Pittsburgh	NA	2.17	2.34	2.22	NA
Houston	Savannah	NA	1.94	2.07	2.04	NA
Houston	Seattle-Tacoma	NA	NA	3.20	2.79	NA
Houston	Toronto	NA	2.18	2.55	2.36	NA
LA-Long Beach	Atlanta	1.73	1.80	2.45	2.23	NA
LA-Long Beach	Baltimore	1.80	1.88	2.80	2.47	NA
LA-Long Beach	Boston	1.85	2.03	3.11	2.69	NA
LA-Long Beach	Charleston	1.74	1.90	2.68	2.39	NA
LA-Long Beach	Charlotte	1.74	1.82	2.61	2.34	NA
LA-Long Beach	Chicago	1.48	1.59	2.34	2.15	NA
LA-Long Beach	Cleveland	1.60	1.67	2.59	2.33	NA
LA-Long Beach	Columbus	1.58	1.68	2.49	2.25	NA
LA-Long Beach	Dallas	1.51	1.60	1.85	1.81	NA
LA-Long Beach	Harrisburg	1.73	1.92	2.77	2.45	NA
LA-Long Beach	Houston	1.58	1.60	1.96	1.89	NA
LA-Long Beach	Kansas City	1.47	1.56	1.98	1.90	NA
LA-Long Beach	Los Angeles	NA	NA	NA	NA	0.90
LA-Long Beach	Memphis	1.52	1.57	2.16	2.02	NA
LA-Long Beach	Minneapolis	1.54	1.82	2.20	2.05	NA
LA-Long Beach	New York	1.80	1.92	2.91	2.55	NA
LA-Long Beach	Norfolk	1.76	1.87	2.83	2.49	NA
LA-Long Beach	Oakland	NA	NA	1.08	1.27	NA
LA-Long Beach	Pittsburgh	1.70	1.91	2.63	2.36	NA
LA-Long Beach	Savannah	1.74	1.86	2.63	2.36	NA
LA-Long Beach	Seattle-Tacoma	1.24	1.48	1.64	1.66	NA
LA-Long Beach	Toronto	1.65	1.89	2.76	2.44	NA
Norfolk	Atlanta	1.71	2.08	1.83	1.97	NA
Norfolk	Baltimore	NA	NA	1.58	1.80	NA
Norfolk	Boston	1.85	2.09	1.84	1.98	NA
Norfolk	Charleston	1.70	1.99	1.74	1.90	NA
Norfolk	Charlotte	1.63	1.96	1.64	1.84	NA
Norfolk	Chicago	1.72	2.06	2.07	2.12	NA
Norfolk	Cleveland	1.74	2.01	1.79	1.94	NA
Norfolk	Columbus	1.72	2.00	1.83	1.97	NA
Norfolk	Dallas	NA	2.32	2.43	2.37	NA
Norfolk	Harrisburg	1.73	2.03	1.65	1.84	NA
Norfolk	Houston	NA	2.30	2.43	2.37	NA
Norfolk	Kansas City	NA	2.11	2.29	2.27	NA
Norfolk	Los Angeles	NA	NA	3.45	3.05	NA
Norfolk	Memphis	1.75	2.05	2.07	2.13	NA
Norfolk	Minneapolis	NA	2.20	2.34	2.31	NA
Norfolk	New York	1.76	2.02	1.68	1.87	NA
Norfolk	Norfolk	NA	NA	NA	NA	1.52
Norfolk	Oakland	NA	NA	3.69	3.21	NA
Norfolk	Pittsburgh	1.76	2.05	1.72	1.89	NA

Norfolk	Savannah	1.72	2.07	1.95	2.05	NA
Norfolk	Seattle-Tacoma	NA	NA	3.61	3.15	NA
Norfolk	Toronto	NA	2.15	2.06	2.12	NA
NY-NJ	Atlanta	1.89	2.12	2.09	2.22	NA
NY-NJ	Baltimore	NA	NA	1.58	1.88	NA
NY-NJ	Boston	NA	NA	1.61	1.90	NA
NY-NJ	Charleston	NA	2.14	2.03	2.18	NA
NY-NJ	Charlotte	NA	2.11	1.94	2.12	NA
NY-NJ	Chicago	1.80	2.06	2.04	2.19	NA
NY-NJ	Cleveland	1.70	2.01	1.78	2.02	NA
NY-NJ	Columbus	1.68	2.02	1.85	2.06	NA
NY-NJ	Dallas	NA	2.31	2.63	2.58	NA
NY-NJ	Harrisburg	NA	NA	1.49	1.82	NA
NY-NJ	Houston	NA	2.29	2.67	2.61	NA
NY-NJ	Kansas City	NA	2.10	2.38	2.41	NA
NY-NJ	Los Angeles	NA	NA	3.57	3.21	NA
NY-NJ	Memphis	NA	2.10	2.28	2.35	NA
NY-NJ	Minneapolis	NA	2.23	2.37	2.41	NA
NY-NJ	New York	NA	NA	NA	NA	1.60
NY-NJ	Norfolk	NA	2.11	1.72	1.97	NA
NY-NJ	Oakland	NA	NA	3.66	3.27	NA
NY-NJ	Pittsburgh	1.74	2.04	1.72	1.97	NA
NY-NJ	Savannah	NA	2.14	2.24	2.32	NA
NY-NJ	Seattle-Tacoma	NA	NA	3.62	3.24	NA
NY-NJ	Toronto	1.79	2.13	1.81	2.04	NA
Oakland	Atlanta	1.79	1.83	2.69	2.39	NA
Oakland	Baltimore	1.84	1.86	2.95	2.56	NA
Oakland	Boston	1.89	2.11	3.20	2.72	NA
Oakland	Charleston	1.80	2.08	2.97	2.57	NA
Oakland	Charlotte	1.80	1.88	2.88	2.51	NA
Oakland	Chicago	1.52	1.61	2.46	2.23	NA
Oakland	Cleveland	1.64	1.75	2.69	2.39	NA
Oakland	Columbus	1.62	1.76	2.66	2.36	NA
Oakland	Dallas	1.59	1.73	2.14	2.02	NA
Oakland	Harrisburg	1.77	2.00	2.92	2.54	NA
Oakland	Houston	1.66	1.76	2.28	2.11	NA
Oakland	Kansas City	1.51	1.59	2.22	2.07	NA
Oakland	Los Angeles	NA	NA	1.12	1.33	NA
Oakland	Memphis	1.56	1.67	2.42	2.21	NA
Oakland	Minneapolis	1.54	1.80	2.38	2.18	NA
Oakland	New York	1.84	1.98	3.04	2.62	NA
Oakland	Norfolk	1.82	1.88	3.11	2.66	NA
Oakland	Oakland	NA	NA	NA	NA	0.98
Oakland	Pittsburgh	1.74	1.98	2.79	2.45	NA
Oakland	Savannah	1.80	1.89	2.88	2.51	1000.00
Oakland	Seattle-Tacoma	NA	NA	1.44	1.55	NA
Oakland	Toronto	1.68	1.87	2.87	2.51	NA
Savannah	Atlanta	1.62	1.95	1.57	1.77	NA

Savannah	Baltimore	1.78	1.98	2.03	2.08	NA
Savannah	Boston	NA	2.09	2.38	2.31	NA
Savannah	Charleston	NA	NA	1.60	1.79	NA
Savannah	Charlotte	NA	1.93	1.57	1.77	NA
Savannah	Chicago	1.79	1.97	2.11	2.13	NA
Savannah	Cleveland	1.77	2.06	1.97	2.03	NA
Savannah	Columbus	1.76	2.05	1.94	2.01	NA
Savannah	Dallas	NA	2.08	2.17	2.17	NA
Savannah	Harrisburg	NA	2.05	1.94	2.01	NA
Savannah	Houston	NA	2.13	2.17	2.17	NA
Savannah	Kansas City	NA	1.97	2.18	2.18	NA
Savannah	Los Angeles	NA	NA	3.24	2.88	NA
Savannah	Memphis	1.67	1.89	1.89	1.98	NA
Savannah	Minneapolis	NA	2.10	2.42	2.34	NA
Savannah	New York	NA	2.04	2.18	2.18	NA
Savannah	Norfolk	1.66	2.02	1.93	2.01	NA
Savannah	Oakland	NA	NA	3.44	3.02	NA
Savannah	Pittsburgh	1.88	2.09	1.95	2.02	NA
Savannah	Savannah	NA	NA	NA	NA	1.49
Savannah	Seattle-Tacoma	NA	NA	3.62	3.13	NA
Savannah	Toronto	NA	2.37	2.56	2.43	NA
Seattle-Tacoma	Atlanta	1.81	1.87	2.87	2.43	NA
Seattle-Tacoma	Baltimore	1.84	1.86	2.93	2.47	NA
Seattle-Tacoma	Boston	1.87	2.02	3.15	2.61	NA
Seattle-Tacoma	Charleston	1.82	1.93	3.05	2.55	NA
Seattle-Tacoma	Charlotte	1.80	1.85	3.01	2.52	NA
Seattle-Tacoma	Chicago	1.48	1.59	2.39	2.11	NA
Seattle-Tacoma	Cleveland	1.60	1.67	2.64	2.27	NA
Seattle-Tacoma	Columbus	1.60	1.69	2.62	2.26	NA
Seattle-Tacoma	Dallas	1.86	1.78	2.45	2.15	NA
Seattle-Tacoma	Harrisburg	1.75	1.93	2.87	2.43	NA
Seattle-Tacoma	Houston	1.87	1.80	2.68	2.30	NA
Seattle-Tacoma	Kansas City	1.59	1.60	2.24	2.01	NA
Seattle-Tacoma	Los Angeles	1.33	1.49	1.68	1.63	NA
Seattle-Tacoma	Memphis	1.59	1.59	2.60	2.25	NA
Seattle-Tacoma	Minneapolis	1.45	1.55	2.08	1.90	NA
Seattle-Tacoma	New York	1.80	1.90	2.99	2.51	NA
Seattle-Tacoma	Norfolk	1.82	1.85	3.02	2.53	NA
Seattle-Tacoma	Oakland	NA	NA	1.44	1.47	NA
Seattle-Tacoma	Pittsburgh	1.74	1.92	2.75	2.35	NA
Seattle-Tacoma	Savannah	1.82	1.93	3.05	2.55	NA
Seattle-Tacoma	Seattle-Tacoma	NA	NA	NA	NA	0.90
Seattle-Tacoma	Toronto	1.66	1.87	2.80	2.38	NA
Vancouver, BC	Atlanta	NA	1.81	2.95	2.52	NA
Vancouver, BC	Baltimore	1.84	1.95	3.01	2.56	NA
Vancouver, BC	Boston	1.95	2.00	3.22	2.70	NA
Vancouver, BC	Charleston	NA	2.07	3.13	2.64	NA
Vancouver, BC	Charlotte	NA	1.85	3.08	2.61	NA
Vancouver, BC	Chicago	1.50	1.56	2.47	2.20	NA

Vancouver, BC	Cleveland	1.62	1.65	2.72	2.37	NA
Vancouver, BC	Columbus	1.60	1.65	2.69	2.35	NA
Vancouver, BC	Dallas	NA	1.81	2.53	2.24	NA
Vancouver, BC	Harrisburg	1.84	1.93	2.95	2.52	NA
Vancouver, BC	Houston	NA	1.83	2.76	2.39	NA
Vancouver, BC	Kansas City	NA	1.74	2.32	2.10	NA
Vancouver, BC	Los Angeles	NA	1.63	1.76	1.72	NA
Vancouver, BC	Memphis	1.58	1.66	2.68	2.34	NA
Vancouver, BC	Minneapolis	1.47	1.58	2.16	1.99	NA
Vancouver, BC	New York	1.84	1.94	3.07	2.60	NA
Vancouver, BC	Norfolk	NA	1.85	3.10	2.62	NA
Vancouver, BC	Oakland	NA	NA	1.51	1.56	NA
Vancouver, BC	Pittsburgh	NA	1.85	2.82	2.44	NA
Vancouver, BC	Savannah	NA	2.05	3.13	2.64	NA
Vancouver, BC	Seattle-Tacoma	NA	NA	0.99	1.15	NA
Vancouver, BC	Toronto	1.70	1.85	2.88	2.47	NA
Prince Rupert, BC	Atlanta	NA	NA	NA	NA	NA
Prince Rupert, BC	Baltimore	1.84	NA	NA	NA	NA
Prince Rupert, BC	Boston	1.95	NA	NA	NA	NA
Prince Rupert, BC	Charleston	NA	NA	NA	NA	NA
Prince Rupert, BC	Charlotte	NA	NA	NA	NA	NA
Prince Rupert, BC	Chicago	1.50	NA	NA	NA	NA
Prince Rupert, BC	Cleveland	1.62	NA	NA	NA	NA
Prince Rupert, BC	Columbus	1.60	NA	NA	NA	NA
Prince Rupert, BC	Dallas	NA	NA	NA	NA	NA
Prince Rupert, BC	Harrisburg	1.84	NA	NA	NA	NA
Prince Rupert, BC	Houston	NA	NA	NA	NA	NA
Prince Rupert, BC	Kansas City	NA	NA	NA	NA	NA
Prince Rupert, BC	Los Angeles	NA	NA	NA	NA	NA
Prince Rupert, BC	Memphis	1.58	NA	NA	NA	NA
Prince Rupert, BC	Minneapolis	NA	NA	NA	NA	NA
Prince Rupert, BC	New York	1.84	NA	NA	NA	NA
Prince Rupert, BC	Norfolk	NA	NA	NA	NA	NA
Prince Rupert, BC	Oakland	NA	NA	NA	NA	NA
Prince Rupert, BC	Pittsburgh	1.76	NA	NA	NA	NA
Prince Rupert, BC	Savannah	NA	NA	NA	NA	NA
Prince Rupert, BC	Seattle-Tacoma	NA	NA	NA	NA	NA
Prince Rupert, BC	Toronto	1.70	NA	NA	NA	NA

Transportation Cost Comparison

As may be seen in Table 8, overall handling and transportation costs to trans-load to 53-foot containers are generally a little more from West Coast ports than total costs for direct rail movement in marine containers and sometimes even less, generally ranging $0.02 - $0.10 per cubic foot more. For reverse intermodal movements from East Coast ports, overall handling and transportation costs to trans-load to 53-foot containers generally range $0.25 - $0.30 per cubic foot more than that for direct rail movement of marine containers. Trans-loading to a domestic truck is generally cheaper than direct trucking of the marine box, if any significant distance is involved. Trucking generally ranges $0.60 - $0.80 more per cubic foot than that for direct rail movement from West Coast ports, and generally ranges $0.05 - $0.15 more per cubic foot that that for direct rail movement from East Coast ports. Short-haul truck is sometimes comparable or even less than rail.

These comparisons set the stage for the overall economic allocation of imports to channels. As will be shown, low-value goods are most cheaply handled in the direct channels. Moderate-value and high-value goods that are shipped in enough volumes and distributed over wide enough areas to be amenable to trans-loading are more cheaply handled in the trans-loading channels.

Transloading vs. Direct Shipment

The opportunity at de-consolidation to trans-load into the larger domestic vehicles enables importers to partially defray the added expenses of the side trip to a de-consolidation warehouse in the hinterland of the port of entry. That is, the reduction in line haul transportation costs (per cubic foot of cargo) partially offsets the added costs associated with one extra lift and two extra drays, the costs for the transloading/deconsolidation activity itself, and the increment in pipeline inventory.

While there are some heavy cargoes in Asia – U.S. trade such as imported steel, it is our impression that the vast majority of containerized imports consist of relatively light cargoes that reach space limits before reaching weight limits. We estimate typically 48 hours (two days) is lost for cargo that is to be immediately de-consolidated and trans-loaded to domestic containers or trucks. Thus transloading entails up to two additional days of pipeline inventory for the importer and corresponding additional inventory carrying costs.[13] At the same time, the opportunity for mixing and reallocation of cargoes at a transloading warehouse in the port of entry hinterland offers the opportunity to reduce safety stocks at destinations with corresponding reductions in inventory carrying costs, as analyzed above.

Thus deconsolidation/transloading vs. direct shipping is a trade-off between added transportation expenses and reduced inventory expenses. As will be discussed in Chapter 7, a certain minimum volume and a nation-wide fleet of RDCs are required for an importer to potentially benefit from the transloading strategy. Among those with such a scale and scope, it turns out that for low-value goods the transloading strategy does not pay. For moderate-value and high-value goods, it pays off.

Growth of the Domestic Container Fleet

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[13] Domestic stack train schedules are often faster than marine stack train schedules. The overall increment in pipeline inventory is less than two days in some lanes.

The feasibility of the transloading strategy depends upon an adequate supply of domestic vehicles. Tracing the growth and mix of domestic intermodal container fleet over the last several years, we are able to confirm a substantial increase in the supply of 53-foot containers. Table 9 documents this growth. In 1998, only 14% of the domestic container fleet consisted of 53-foot boxes. But by 2002, 53-foot boxes accounted for almost half of the fleet. Considering expiration dates of current leases and anticipated retirements, we project that by 2007 more than 85% of the fleet will consist of 53-foot boxes.

Table 9
Domestic Container Fleet, 1998 to 2007

	1998	**2000**	**2002**	**2007 Projected**
48 foot	76,112	77,670	65,124	24,045
53 foot	12,500	34,758	56,686	138,436
Total	**88,612**	**112,428**	**121,810**	**162,481**
53ft % of total	***14.1%***	***30.9%***	***46.5%***	***85.2%***

	48 foot Containers			**53 foot Containers**		
Carrier	***1998***	***2000***	***2002***	***1998***	***2000***	***2002***
UP	11152	12823	11723	0	6436	8936
BNSF	16000	16000	13500	0	1500	4004
NS	6020	6004	5800	0	4997	4921
CSX	6550	6498	8030	0	0	4750
CP	5200	5100	5100	0	1000	2600
CN	4600	4550	4500	0	500	1400
KCS	1050	1045	1496	0	100	100
PACER SS	17990	17950	13000	0	5725	9200
JB HUNT	7550	7500	1500	12500	14500	20500
TFM	0	200	475	0	0	0
FXE	0	0	0	0	0	275
TOTAL	**76,112**	**77,670**	**65,124**	**12,500**	**34,758**	**56,686**

Note: Some small operators with fleets of less than 500 units may have been omitted.
Some carriers contribute to pools (e.g., NACS, EMP). Ownership shown here by carrier.

These figures confirm that the supply of 53-foot domestic containers became adequate in recent years to support the West Coast distribution warehousing and transloading strategies pursued by large importers in recent years. Considering that the fleet size of 53-

foot containers will continue to grow, we expect continued growth in transloading volumes.

An important point concerning transloading is that Southern California is by far the largest West Coast market for inbound domestic freight. It would be more difficult for the Bay Area, Seattle/Tacoma or Vancouver to develop transloading traffic to the extent that has happened in Southern California, simply because the supply of domestic 53-foot containers is smaller (reflecting the smaller amounts of westbound domestic freight traffic). To the extent that West Coast distribution and transloading is economically attractive to importers of Asian-manufactured goods, the SPB Ports have a competitive advantage for this traffic, owing to Southern California's more generous supply of 53-foot containers. Nonetheless, as the fleet size of 53-foot containers enlarges, we anticipate the levels of transloading activity at other West Coast ports to increase.

4. INTANGIBLE FACTORS

In Chapter 5 we introduce a Long-Run Elasticity Model that calculates allocations of Asian imports to ports and supply channels based on the economics of transportation and inventory from the importers' point of view. There are a number of important intangible factors not incorporated in the quantitative analyses of the Model, summarized as follows.

Port Terminals as Virtual Warehouses

Some importers deliberately delay pick-up of containers from port terminals. If demand at destination has slowed compared to forecasts made when the goods were ordered, and so the goods in the container are not yet needed, such importers use the port terminal as a virtual warehouse. Certain very large importers have negotiated with the steamship lines for very large amounts of free time[14] for their containers awaiting dray pick-up at the port terminals.

This has several effects. First, this creates greater opportunity for trans-loading importers to re-direct imported goods where they are most needed, thereby reducing safety stock requirements at destination distribution centers. This enhances the value of the trans-loading channel in a way that is not included in the formulas developed in Chapter 2.[15] Second, it increases congestion and decreases throughput at port terminals. More acreage is required as the terminal has in effect been converted into a virtual import warehouse. Third, the steamship lines observe that the average dwell time at port terminals for "store-door" (i.e., local and trans-load) import boxes is much larger than for inland-point intermodal boxes. In order to maximize box utilization, they tend to prioritize inland point intermodal boxes in the way they stow cargo on their vessels and the way they

[14] Reportedly, 21 days in one case.
[15] The same is true if the importer implements a port-hinterland warehouse (as opposed to merely deconsolidating and immediately cross-docking and re-shipping all imports).

unload the vessels. This has the result that the average transit time from vessel arrival to rail interchange for the Direct Rail channel (AKA inland point intermodal) is one to three days less than the average transit time from vessel arrival to local warehouse delivery for boxes moving in the Trans-load channels. This is ironic, in that shippers of high-value goods, for whom managing inventories tightly is most important, are allocated the longest lead times.

Diversification of Congestion Risk

During the summer of 2004, serious congestion (which the industry press – and many customers – termed a "meltdown") was experienced at the San Pedro Bay Ports. Many vessels were greatly delayed from unloading, and unloaded containers were further delayed awaiting dray or rail pick-up because of shortages of staff and equipment. In interviews with 3PL firms and carriers, we were advised that many shippers were unable to divert substantial cargoes to other ports, as they did not have adequate redundancy engineered into their logistics systems. We are advised there is now widespread recognition among importers of the need to diversify their logistics strategy, to have alternatives readily available in case a meltdown develops in one particular shipping channel or at one particular port. We have received considerable anecdotal evidence that shippers have increased their arrangements for transloading services at ports other than San Pedro Bay.

To the extent that importers divert traffic purely for the purpose of diversifying the port channels utilized, this factor suggests the Long-Run Elasticity Model may be too high in its predictions of volume through the SPB Ports.

Other Cost Factors

Third-party logistics firms providing transloading services to importers sometimes are hired to perform other services besides sorting-by-destination and transloading the imported goods. Commonly provided outbound distribution services include piece-count and/or manifest verification by SKU (stock-keeping unit), and attaching bar codes. Other services sometimes provided include stretch-wrapping or palletization, and, much less often, short-term storage.

We are advised by 3PL firms that the vast majority of containerized imports from Asia are simply floor-loaded in the container. All of the above types of tasks need to be completed before the goods may be handled through mechanized regional distribution centers. That is, piece-counts must be made, the goods need to be stretch-wrapped, and bar codes need to be attached. If these activities were not done at the transloading warehouse in the port hinterland, they would have to be done upon arrival at the inland regional distribution center itself or else at a mixing center in Asia before sea shipment. Stretch-wrapping in Asia would entail a loss of usable cubic capacity in the container. If labor costs at inland distribution centers are higher than at the port hinterland warehouses, there is an economic incentive to perform these activities in the port hinterland.

These factors may enhance the attractiveness of the trans-loading option compared to the cost calculations made using the formulas developed in Chapter 2.

Regional Importers

In the Long-Run Elasticity Model we assume the top 83 Asian importers are nation-wide in the scope of their distribution operations. If any are regional in nature, their eligibility for trans-loading may be sharply curtailed compared to the assumptions of the Model.

The Model also assumes that “generic” importers that account for the rest of Asia – U.S. imports are not eligible for trans-loading (because they are too small or too regional). Moreover, it is assumed that, in aggregate, for all levels of declared value, the geographical dispersion of their destinations is proportional to the geographic dispersion of purchasing power in the United States.

If any of the “generic” importers actually practice trans-loading, the Model misses this. If in aggregate the destinations of generic importers are distributed differently from the distribution of purchasing power, the Model misses this, too.

Taken together, these factors are off-setting and do not suggest a major bias in Model calculations.

Short Run Vs. Long Run Factors

The Long-Run Elasticity Model exercised in Chapter 5 analyzes given transportation rates, values of goods, and transit time statistics faced by importers to determine the least costly allocation of imports to ports and channels. Transit time statistics are exogenously supplied to the model and are not updated if the Model shifts substantial traffic volumes between ports or modes. The Model results should be interpreted as indicating the fee levels at which importers would experience an economic incentive to reduce import volumes through the SPB Ports.

In the short run, there are many factors inhibiting the shifting of imports to other ports or alternative channels. There are multiple dimensions of capacity constraining channel volumes. Moreover, steamship lines may be committed to relatively long-term port contracts whose fee structures provide the incentive for the lines to tender large volumes and mandate stiff penalties for premature withdrawal. Given a scenario in which there is economic incentive for importers to shift their import volumes between modes or between ports, there will be inertia inhibiting such shifts. Major shifts in import traffic may require considerable time to implement. In the short run, San Pedro Bay Ports traffic will be significantly more inelastic than predictions derived using the Long-Run Model.

Notwithstanding these factors, given strong economic incentives for importers to shift traffic, one may expect *in the long run* that desired terminal and line haul capacities will get built, new port contracts will be negotiated, vessel strings will be adjusted, new trans-loading warehouses will be erected, and dray forces will be adjusted. For that reason, the evaluation of potential major investments in ports access infrastructure, requiring many years to construct and many more years to recoup the investment, is best done considering the long-run elasticity of port demand.

Nonetheless, the short-run evolution of ports traffic is of considerable interest. The most prominent short-run factors inhibiting the shifting of port and channel volumes in the short run are therefore discussed in more detail below.

Capacity and Congestion

The Long-Run Elasticity Model described in Chapter 5 does not include any capacity constraints. Imports are assigned to channels based on minimization of the importers' costs – including transportation charges in each channel, and inventory costs resulting from the pre-specified transit times and opportunities for consolidation/deconsolidation.

Transit time parameters used in Model calculations are exogenously supplied by the user and remain fixed during the Model's calculations. In reality, the mean and standard deviation of transit time both increase dramatically as utilization of a channel is increased to high percentages of its capacity. (What happened in the summer of 2004 at the SPB Ports is an obvious case in point.) Moreover, it is likely that service providers using congested channels may be motivated to increase their charges or curtail service.

Most North American ports are operating close to their current capacities during peak shipping season. If there were to be massive diversion of traffic away from the SPB Ports, it is doubtful this traffic could be accommodated without substantial infrastructure investments in other port regions.

In the analysis of current traffic volumes and current costs, the Elasticity Model predicts feasible allocations of imports to channels. In analyzing scenarios with marginal changes in costs or volumes, the Model can be expected to provide reasonable predictions of short-run behavior. At issue is the analysis of scenarios with added costs (e.g., container fees) that entail a major departure from current costs. The Model's traffic calculations in that case may be very inconsistent with the existing available capacity. Moreover, transportation rates are likely to change in such a scenario.

Thus in cases where the Long-Run Elasticity Model responds to strong economic incentive by calculating major traffic shifts, there is the question of whether sufficient capacity exists (or can be created) to allow such a shift. The interpretation of Long-Run Elasticity Model results for scenarios very different from current economics must therefore be tempered.

There are numerous examples of this, some discussed below.

Panama Canal

The Panama Canal is an example of a capacity-constrained channel. The Canal is reported to be operating very close to capacity. Importers report that securing space on vessel strings transiting the Canal is becoming increasingly difficult.

In some scenarios it could be called upon to analyze, the Long-Run Elasticity Model's calculations may call for higher levels of utilization of the Canal, perhaps even infeasible volume levels through the Canal.

One might expect that if there is very strong demand for increased Canal capacity, investment in its expansion would follow. Indeed, in 2006, the Government of Panama held a referendum among the populace asking whether or not the Country should build a third set of locks – and supply the water necessary to operate them – in order to accommodate post-Panamax vessels, a multi-billion-dollar undertaking. This referendum was approved. It is estimated that a decade or more will be required to complete the project.

Larger Vessels

Another aspect of the Panama Canal capacity issue is the fleet mix of the steamship lines. Some lines are investing heavily in post-Panamax vessels with capacities on the order of 10,000 TEUs. A number of lines already operate 8,000 TEU vessels. Such large vessels are confined to service in Asia – Europe or Trans-Pacific lanes. While the introduction of such vessels displaces older Panamax vessels that can be re-deployed in strings passing through the Panama Canal, the overall fleet capacity has a declining fraction that is eligible for that type of service.

Deconsolidation Capacity

The consultant has heard estimates to the effect that, considering the total warehouse capacity suitable for deconsolidation activity in the hinterlands of all North American ports of entry, 65% is located in Southern California. Displacing a large fraction of the trans-loading activity in Southern California is simply not feasible without more investment in warehouse capacity in other port regions. How "large" is infeasible is at present not quantified. By how much trans-loading capacities can be increased (and at what cost) at the various ports is at present not quantified.

Port Capacities

Capacities at ports are multi-dimensional. One aspect of capacity concerns dock labor to unload and re-load vessels and transfer containers onto chasses and rail well cars. Another aspect concerns the supply of dray labor to haul boxes from the port gate to off-dock rail terminals and warehouses in the region. A third aspect concerns the ability of rail terminals and rail lines to handle increased traffic.

All of these aspects of capacity were severely strained in 2004 peak season in Southern California. Many shippers responded by shifting some of their 2005 import volumes to Seattle-Tacoma and, to a lesser extent, to Oakland. Several steamship lines shifted selected vessel strings from San Pedro Bay to Puget Sound for the 2005 shipping season. Because congestion in Southern California was much abated in 2005, these strings were shifted back to San Pedro Bay for the 2006 season.

A Long-Run Elasticity Model calculation that calls for a large shift of volume from one port to another must be judged in light of the multi-dimensional capacity of that port.

Productivity Differences Among Ports

Throughput rates (measured in lifts per hour or TEUs per acre or vessel moves per quay foot) vary among ports. Certain East Coast ports exhibit better numbers than West Coast ports. Certain Asian ports exhibit number even better than the best US East Coast ports.

Where a port lags the performance of others, this suggests there is an opportunity to improve and thereby increase capacity. Improvements may involve labor issues, technology or both. Thus capacity at the ports is a moving target.

There is a chicken-and-egg phenomenon here: The incentive to improve productivity increases dramatically as the volume is increased. Thus current “capacity” limits at each port might not be the real limits. Instead, as volumes are pushed towards those limits, efforts to improve productivity will accelerate and “capacity” will be increased.

Vessel Operator-Port Contracts and Other Inertia

Steamship lines enter into long-term contracts with ports. The rents are a function of volume; generally, the lines have an economic incentive to sustain high volume at the port (thereby decreasing the port charges per container). A Long-Run Elasticity Model calculation that calls for a large shift of volume from one port to another must be judged in light of the contractual disincentive.

Many importers enter into contracts with steamship lines. These contracts often entail volume commitments by origin – destination pair. Once an economic incentive exists for an importer to switch from direct shipping to inland points to trans-loading in the hinterland of the port of entry, such contracts may delay or impede the transition.

Every importer must make considerable effort to develop a supply-chain management system. A Model calculation that calls for major shifts in supply-chain strategy (e.g., switch from trans-load to direct-ship) may in turn trigger the need for re-engineering the supply-chain management system. Thus there may be some inertia or time lag on the part of importers to change their supply-chain strategy, even when economic incentive exists to do so.

Container Repositioning Surcharges

Traditionally, merchandise traffic in lanes between central or eastern US points on the east end and West Coast points at the west end was heavier westbound than eastbound. (Westbound traffic was termed the "headhaul" and eastbound traffic was termed the "backhaul".)

The growth in Asian imports has changed that; eastbound traffic is now greater, much greater during peak shipping season. There is considerable upward pressure on eastbound rates for domestic containers and trailers, especially during peak shipping seasons. As a result, in some lanes at certain times of the year, equipment repositioning surcharges are being assessed.

Similarly, there is upward pressure on rates for direct inland movement of marine containers. At present, as a rough average, there is one export load for every three-to-four import loads. Most marine containers moved to inland points are returned to the ports empty. This average is declining, and in certain lanes the steamship lines are applying surcharges to inland point intermodal rates because of the dearth of backhaul business in those lanes.

A Long-Run Elasticity Model calculation that predicts either a large increase in trans-loading or a large increase in direct inland point movement of marine containers must be interpreted with caution. A large swing in the relative demands for domestic vs. marine containers would likely entail a commensurate change in the relative re-positioning charges for those types of equipment. Transportation rates input to the Model may require adjustment.

5. ELASTICITY CALCULATIONS

Modeling Procedure

The transportation costs developed in Chapter 3 and the inventory cost formulas developed in Chapter 2 were combined to compute total costs for importers. The 83 major importers listed in Table 2 were subjected to these calculations. We assume each importer applies a single homogenous supply-chain strategy to handle all of its imported goods at the least overall cost for the assumed average declared value of its imports (as specified in Table 2). The importer's total assumed volume (also shown in Table 2) was allocated among the destination regions defined in Chapter 3 in proportion to the purchasing power in each region (Table 6).

To account for the remaining import volume, a set of "proxy miscellaneous" importer categories were generated, not eligible for transloading, stratified along the value distribution of Figure 1 in value increments of $4 per cubic foot from a low of $2 to a high of $70. The relative total volumes in each value category, including both large importers and proxy miscellaneous importers, are displayed in Table 10.

Table 10
Assumed Distribution of Import Volumes by Declared Values

Declared Value Per Cubic Foot	Fraction of Total Misc. Imports	Declared Value Per Cubic Foot	Fraction of Total Misc. Imports
$2	0.010	$38	0.040
$6	0.150	$42	0.035
$10	0.155	$46	0.030
$14	0.130	$50	0.025
$18	0.120	$54	0.020
$22	0.100	$58	0.010
$26	0.070	$62	0.005
$30	0.050	$66	0.003
$34	0.045	$70	0.002

The total amount of proxy miscellaneous imports was calibrated so that sum of proxy miscellaneous imports and major-shipper imports added to the total imports from Asia to the USA. The volumes for each proxy miscellaneous value category also were allocated to destination regions in proportion to the purchasing power in each region (as defined in Table 6).

Elasticity Analysis

For each importer, total costs for alternative strategies were computed to deduce the least-cost strategy for each type of importer. The alternative strategies so tested are as follows:

- Direct shipping via nearest port to each region
- Direct shipping via least-cost West Coast ports to each region (least cost considering all transportation and inventory costs)
- Trans-load only at LA – Long Beach, then least-cost shipping
- Trans-load Los Angeles Region imports at LA – Long Beach, but trans-load everything else at Seattle-Tacoma, then least-cost shipping

- Trans-load only at Seattle-Tacoma, then least-cost shipping
- Trans-load only at Oakland, then least-cost shipping
- Trans-load only at Seattle/Tacoma and LA – Long Beach, then least-cost shipping
- Trans-load at Seattle/Tacoma, LA – Long Beach and Norfolk, then least-cost shipping
- Trans-load at Seattle/Tacoma, LA – Long Beach, Savannah and New York, then least-cost shipping

Total costs were tallied for each alternative strategy for each importer and the best strategy identified. For major importers, the break points in value and the corresponding optimal supply-chain strategy were found to be as summarized in Table 11.

Table 11
Efficient Supply-Chain Strategies as a Function of Avg. Declared Value for Large Nation-Wide Importers – As-Is Scenario

Value Range ($ per cu ft)	Strategy
0 – 13	Direct shipping using least-cost port-landside channel
13 – 20	Trans-load at multiple ports
20 and up	Trans-load only at LA – Long Beach

For the proxy generic importers (those lacking the scale and/or scope for transloading), the optimal supply-chain strategies were found to be as summarized in Table 12.

Table 12
Efficient Supply-Chain Strategies as a Function of Avg. Declared Value for Regional and Small-Scale Importers – As-Is Scenario

Value Range ($ per cu ft)	Strategy
0 – 40	Direct shipping using cheapest port-landside channel
40 and up	Direct shipping using least-cost West Coast port

This analysis was repeated with the addition of a variable container fee assessed on all containers entering through the Puget Sound ports. Fee values expressed in increments of $30 per 40-foot container ranging from $0 to $1,200 were tested. The direct and trans-load volumes via Puget Sound were then totaled for each fee value in order to construct curves of volume vs. container fee.

As the value of the fee was increased from zero, certain importers would be induced to change strategies in order to minimize total cost. For example, trans-load importers might be induced to shift trans-loading to other West Coast ports or open up trans-load centers at East Coast ports. Direct shippers might be induced to ship solely using other ports.

As a concrete example, consider a large, nation-wide importer with an average declared value of $14 per cubic foot. Its optimal policy for Puget Sound fee values between $0 and $29 is to trans-load imports using facilities in the hinterlands of ports on both Coasts, including a facility in the Kent Valley. For fee values between $29 and $57, its optimal policy changes to direct-shipping via the cheapest port-landside channel; its traffic through the Puget Sound ports is reduced to only imports destined to the importer's Pacific Northwest regional distribution center. For a fee at Puget Sound greater than $330, the importer's optimal policy is to abandon the Puget Sound ports entirely, and truck its PNW RDC volume from the Port of Vancouver.

As another concrete example, consider a direct shipper with an average declared value of $10 per cubic foot. With no fee, its optimal policy is to direct ship to each of its RDCs using the least-cost port and landside channel. All of its volume to the PNW and Minneapolis RDCs and about half of the volume to the Chicago RDC are supplied via the Puget Sound ports. For fees in the range of $0 to $120, the optimal policy is to supply all of the Chicago RDC volume via the San Pedro Bay ports. The PNW and Minneapolis RDCs continue to be supplied via the Puget Sound ports for a fee in this range. For fees in the range $120 to $269, only traffic local to the PNW is routed through the Puget Sound ports. For a fee greater than $269, the Puget Sound ports are abandoned entirely, and PNW RDC volume is trucked down from Vancouver.

Figure 3 displays the elasticity results. This can be construed to represent the case where container fees are assessed but are not used to pay for improvements to the ports and port access infrastructure. Shown are curves for the total inbound Asian import volume (in FEUs) via Puget Sound as well as the portion of inbound volume that passes through deconsolidation warehouses (i.e., trans-load volume). The elasticity curves are somewhat "lumpy" because so many importers share the same average declared value of imports and so it is optimal for many of them to reduce Puget Sound volumes at the same point on the fee scale.

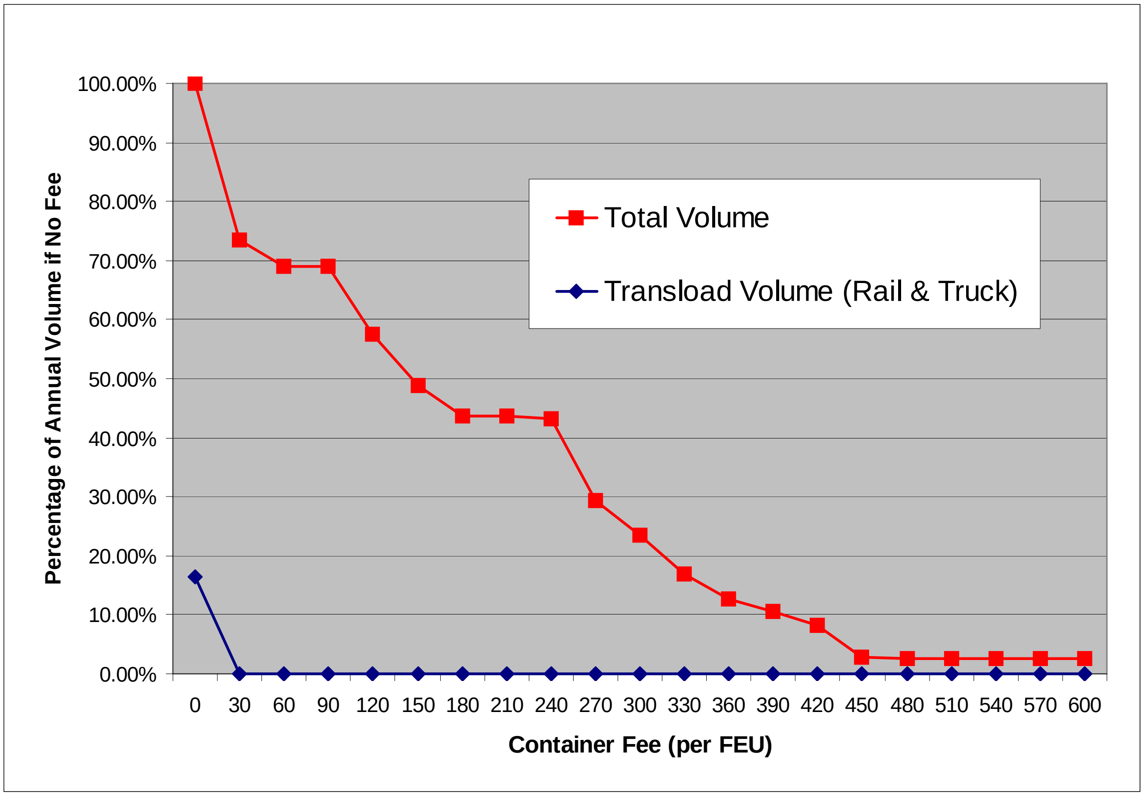

Figure 3.
Elasticity of Imports via the Puget Sound Ports, As-Is Scenario

Note that the model predicts that, at present, about 17% of imports through the Puget Sound Ports pass through deconsolidation centers.

As may be seen, imports routed via the Puget Sound ports are quite elastic, even for very low fees. Fees in the range of $30 - $90 per FEU provide incentive to shift to other ports 30% of imports currently routed via Puget Sound. A fee of about $150 renders about 50% of imports cheaper to re-route via other ports.

Model Limitations and Proper Interpretation of Results

As discussed in Chapter 4, there are important limitations to the Long-Run Elasticity Model. Most importantly, the model includes no capacity limitations in any channel or at any port. Transit time statistics are exogenously supplied to the model and are not updated if the Model shifts traffic between ports or modes. Limitations on available warehouse space for trans-loading activity are not considered.

The model results should be interpreted as indicating the points at which importers would experience an economic incentive to reduce import volumes through the Puget Sound ports. Whether it is actually feasible in the short run for them to do so, considering capacity limitations, increased congestion at other ports, contract commitments, etc., is beyond the scope of the Long-Run Elasticity Model. Moreover, the Long-Run Model tacitly assumes capacity improvements will be made at other ports and in landside channels emanating form those ports so as to accommodate any projected diversions of traffic now handled via the Puget Sound ports.

Given a scenario in which there is economic incentive to shift imports between modes or between ports, there will be inertia inhibiting such shifts. Major shifts in import traffic may require considerable time to implement. Thus, in the short run, Puget Sound ports' traffic will be significantly more inelastic than the predictions of the Long-Run Model. However, given strong economic incentives for importers to shift traffic, one may expect *in the long run* that desired terminal and line haul capacities will get built, new port contracts will be negotiated, vessel strings will be adjusted, new trans-loading warehouses will be erected, and dray forces will be adjusted.

The Long-Run Elasticity Model is intended to inform public policy concerning potential fees and potential major investments in access infrastructure for the Puget Sound ports. Such infrastructure may require up to a decade to build, and financing instruments may require up to three decades to retire the principal. It seems very unwise to rely solely on estimations of short-run elasticity to justify such investments. Investment of large sums of public monies in long-term infrastructure should be confirmed to be sound on the basis of long-run elasticity calculations.

6. CONCLUSIONS

Puget Sound import volume is very elastic with respect to container fees. Total inland transportation charges via Puget Sound ports vs. other West Coast ports are very competitive to many destinations east of the Rockies for most types of imports.

Lacking improvements in access infrastructure that improve transit times or otherwise improve the economics from the importer's point of view, and without offsetting fee increases at other West Coast ports, in the long run even a small container fee at Puget Sound may drive significant amounts of traffic away from the Puget Sound ports. The Long-Run Elasticity Model predicts that a $60 per FEU fee on inbound loaded containers at the Puget Sound ports would cut total import volume at the Puget Sound ports by approximately 30%. The model predicts a fee of $150 would cut traffic in half. These estimates of volume reductions are likely somewhat larger what would actually happen, given the value of diversification of supply chains perceived by large importers.

Institution of container fees without offsetting fees at other West coast ports seems unwise. However, as fees are instituted at the California ports, they may be matched at Puget Sound in order to create a revenue source for infrastructure improvement and environmental impact mitigation without loss of market share, or, if unmatched, market share at the Puget Sound ports may be grown.

APPENDICES.

Safety Stock Formulas for the General Case of Lead Times and Volumes Varying by Region

The general case is where there are multiple North American ports of entry and multiple regional distribution center (RDC) destinations. The different combinations have different lead times. Moreover, the volumes at the various RDCs are not necessarily equal. We add the index *n* for RDC and the index *m* for POE. The parameters are generalized as follows:

D - nation-wide average sales volume per week (in physical units, not dollars).
MAPE – mean absolute percentage error (expressed as a fraction of one) in one-week-ahead forecasts of nation-wide sales.
D_n = amount of sales distributed from RDC *n*. We assume $\sum_n D_n = D$ and the proportion of nation-wide sales handled by each RDC is fixed.
D_{mn} = amount of imports en route to RDC *n* that are passed through port *m*. We assume $\sum_m D_{mn} = D_n$.
R – time between replenishment orders (from Asian suppliers). R is assumed to be 1 week for all importers.
L_{AO} – mean lead time (expressed in weeks) from when order is placed until port of entry for shipment is selected.
$L_{AW}(m)$ – mean lead time (expressed in weeks) for a shipment from point of origin to port of entry *m*, measured from when port of entry for shipment is selected until RDC is selected for land transport from POE *m*.
$L_W(m)$ – mean lead time (expressed in weeks) from departure from point of origin until RDC is selected for land transport from POE *m*.
$L_{NA}(m,n)$ – mean lead time (expressed in weeks) from when RDC *n* is selected for land transport from POE *m* until processed through the RDC *n*.
$\sigma_{L_{AW}}(m)$ – standard deviation of $L_{AW}(m)$.
$\sigma_{L_{NA}}(m,n)$ – standard deviation of $L_{NA}(m,n)$.
k – safety factor determining the level of safety stocks at RDCs. (Choosing *k* = 2 implies approximately a 98% probability of no stock-out.)

Formula for Pipeline Stock

The total in-transit inventory is expressed as

$$\sum_{m,n} \left(L_W(m) + L_{NA}(m,n) \right) D_{mn} \, . \qquad (4)$$

Expression (4) is the generalization of expression (1).

Formulas for Safety Stock

In the direct shipping case, the total nation-wide safety stock is expressed as

$$(k)\left[\begin{array}{l} L_{AO}(1.25)^2(MAPE)^2 D^2 \\ +\left(\sum_n \left(\frac{\sum_m D_{m,n}\sqrt{L_{AW}(m)+L_{NA}(m,n)+R}}{D_n}\right)\sqrt{\frac{D_n}{D}}(1.25)(MAPE)D\right)^2 \\ +\left(\sum_{m,n} D_{m,n}\sqrt{\sigma^2_{L_{AW}}(m)+\sigma^2_{L_{NA}}(m,n)}\right)^2 \end{array}\right]^{1/2} \qquad (5)$$

Expression (5) is the generalization replacing expression (2).

In the de-consolidation case, the total nation-wide safety stock is expressed as

$$(k)\left[\begin{array}{l} L_{AO}(1.25)^2(MAPE)^2 D^2 \\ +\left(\sum_m \sqrt{\sum_n \left(\frac{D_{m,n}L_{AW}(m)}{D_n}\right)\left(\frac{D_n}{D}\right)(1.25)^2(MAPE)^2 D^2}\right)^2 \\ +\left(\sum_n \left(\frac{\sum_m D_{m,n}\sqrt{L_{NA}(m,n)+R}}{D_n}\right)\sqrt{\frac{D_n}{D}}(1.25)(MAPE)D\right)^2 \\ +\left(\sum_{m,n} D_{m,n}\sqrt{\frac{\sum_m D_{m,n}}{\sum_n D_{m,n}}\sigma^2_{L_{AW}}(m)+\sigma^2_{L_{NA}}(m,n)}\right)^2 \end{array}\right]^{1/2} \qquad (6)$$

Expression (6) is the generalization replacing expression (3).