Societal Full Marginal Costs of Port Expansion: The Case of NY

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ABSTRACT

Owing to its port, airports and economic stature, New York ranks among the most prominent gateway cities in North America. The region is expected to grow by additional 2 million people over the next 25 years. That translates into roughly 70 million more tons of goods to be delivered, challenging an already much constrained transportation network. Due to the lack of rail capacity, mainly trucks will haul this volume of freight; a substantial proportion of which travels to and from the Port of New York-New Jersey. What are the total costs, in particular, congestion, safety and emission, associated with this additional port related traffic? Addressing this question is critical to present planned expansion of the port’s capacity to handle projected growth in trade over the next several decades. This papers aims at empirically estimating the Full Marginal Costs (FMC) of additional truck traffic resulting from the further expansion the Port of NY/NJ.

1. INTRODUCTION

A global gateway city is defined here as a coastal metropolis with port access to the rest of the globe, which captures a substantial share of total regional and international trade volumes. Defined this way, and focusing on container traffic, of the four top US gateway cities three are on the West Coast (Los Angles, long Beach and Oakland) and only one New York/New Jersey (PNYNJ) is on the East Coast. A substantial proportion of the freight, which passes through these ports, is destined to hinterland destinations sometimes thousands of miles away. In the case of NY, rail captures a very small proportion of total freight traffic. Trucks constitute the main freight mode with some barge operations using coastal or inland waterways to haul bulk or fuel commodities.

The main advantage from being a gateway city is the economic development benefits that it confers on its respective metropolitan area in the form of enhanced employment, expanded output, efficient logistic chains, increased tax revenues and higher real estate values. In NY, for example, it has been estimated that port related freight activity contributes annually about $18 billion in economic activity and $2.2 billion in tax revenues. For these reasons decision makers, world wide, treat favorably plans aiming at expanding port and port related infrastructure, in order to capture a larger share of the international trade. For the past decade, international trade, mainly between the Far East and the US and Europe, has been
growing at an average rate of 7% annually. Hence, the payoff seems quite substantial, which explain present port policies and investment plans.

Against this reality it is necessary to also consider societal costs of port expansion and the traffic pattern it generates. These costs, which are shown to be quite substantial, can be clustered into three major categories: private (or internalized) costs, investment and maintenance costs, and social (or non-internalized) externality costs. Jointly, in this paper they are labeled as Full Marginal Costs (FMC) from additional truck traffic. The key argument is that these costs must be recognized and incorporated into the cost-benefit analysis of port investment plans. Thus, the main objectives of this paper are to identify and measure FMC associated with the additional traffic from the further development of the Port of New York/New Jersey. The paper further outlines possible ways to mitigate these costs through the use of alternative modes and adequate pricing policies.

The structure of this paper is as follows. Section 2 provides basic data on freight movements through the Port and the NY-NJ metropolitan area. Section 3 presents categories of FMC costs associated with increased truck traffic. The methodology used to estimate these costs is presented in Section 4. The data used in this study is discussed in Section 5 and major results are shown in Section 6. Section 7 outlines some possible policy approaches to reduce these costs. Summary and conclusions are in Section 8.

2. BASIC DATA ON FREIGHT MOVEMENT THROUGH THE PORT OF NY AND NJ

As shown in Table 1 the Port of New York-New Jersey (PNYNJ) is the third largest port in North America following Los Angeles and Long Beach.

Table 1: Ranking of North America Container Ports

<table>
<thead>
<tr>
<th>2005 Rank</th>
<th>Port (State/Province)</th>
<th>2005</th>
<th>2004</th>
<th>Absolute Change</th>
<th>Percent Change</th>
<th>2004 Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Los Angeles (CA)</td>
<td>7,484,624</td>
<td>7,321,440</td>
<td>163,184</td>
<td>2.2%</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Long Beach (CA)</td>
<td>6,709,818</td>
<td>5,779,852</td>
<td>929,966</td>
<td>16.1%</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>New York/New Jersey</td>
<td>4,792,922</td>
<td>4,478,480</td>
<td>314,442</td>
<td>7.0%</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Oakland (CA)</td>
<td>2,272,525</td>
<td>2,043,122</td>
<td>229,403</td>
<td>11.2%</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Seattle (WA)</td>
<td>2,087,929</td>
<td>1,775,856</td>
<td>312,073</td>
<td>17.6%</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Tacoma (CA)</td>
<td>2,066,447</td>
<td>1,797,560</td>
<td>268,887</td>
<td>15.0%</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>Charleston (SC)</td>
<td>1,986,586</td>
<td>1,863,917</td>
<td>122,669</td>
<td>6.6%</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>Hampton Roads (VA)</td>
<td>1,981,955</td>
<td>1,808,933</td>
<td>173,022</td>
<td>9.6%</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>Savannah (GA)</td>
<td>1,901,520</td>
<td>1,662,021</td>
<td>239,499</td>
<td>14.4%</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>Vancouver (BC)</td>
<td>1,767,379</td>
<td>1,684,906</td>
<td>102,473</td>
<td>6.2%</td>
<td>9</td>
</tr>
</tbody>
</table>
PNYNJ is the largest port on the US East Coast with the dollar value of all cargo moving through it exceeding $149 billion in 2006, surpassing the previous record of $132 billion\(^\text{12}\). Table 2 provides basic data on amount of cargo through the port of PNYNJ.

**Table 2: Basic Data on the Port of New York and New Jersey**

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2005</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship calls</td>
<td>5,577</td>
<td>5,321</td>
<td></td>
</tr>
<tr>
<td>Container Volume (loaded and empty) TEU</td>
<td>5,092,806</td>
<td>4,785,318</td>
<td>6.4</td>
</tr>
<tr>
<td>Total Imports and Export TEU</td>
<td>3,650,926</td>
<td>3,385,003</td>
<td>7.9</td>
</tr>
<tr>
<td>Loaded Imports TEU</td>
<td>2,599,554</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loaded Exports TEU</td>
<td>1,051,372</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empty TEU</td>
<td>1,441,880</td>
<td>1,400,315</td>
<td>2.9</td>
</tr>
<tr>
<td>Total General Cargo Volume (metric tons)(^a)</td>
<td>31,194,421</td>
<td>28,132,497</td>
<td></td>
</tr>
<tr>
<td>General cargo imports (metric tons)</td>
<td>22,126,272</td>
<td>20,236,519</td>
<td>9.3</td>
</tr>
<tr>
<td>General cargo export (metric tons)</td>
<td>9,068,149</td>
<td>7,895,978</td>
<td>14.8</td>
</tr>
<tr>
<td>Total Bulk Cargo (metric tons)(^b)</td>
<td>54,968,141</td>
<td>56,621,526</td>
<td>-2.9</td>
</tr>
<tr>
<td>Bulk cargo imports (metric tons)</td>
<td>49,168,042</td>
<td>53,449,638</td>
<td></td>
</tr>
<tr>
<td>Bulk cargo exports (metric tons)</td>
<td>5,800,099</td>
<td>3,171,888</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

\(^a\) Data from the U.S. Bureau of Census.  
\(^b\) The changes in bulk cargo imports and exports were due primarily to refined petroleum products.

**Source:** http://www.panynj.gov/

The top five containerized import commodities by volume were furniture, paper and paperboard, beer and ale, general cargo, and women and children’s clothing. The top five containerized export commodities by volume were paper and paperboard, automobiles, auto parts, general cargo and mixed metal scrap.

The top five trading partners in general cargo tonnage were China, Italy, India, Germany and Brazil. Top import trading partners in general cargo tonnage were China, Italy, Germany, India and Brazil. Top export trading partners in general cargo tonnage were China, India, Japan, United Kingdom and South Korea. Figure 1 shows projections of volume of containers through 2060.

Comparing these projections with actual figures for 2005 and 2006 (Table 2) shows that they have already been surpassed significantly. This reality has prompted the Port Authority of NY and NJ (PNYNJ) to plan $2 billion in seaport infrastructure investments in the next 10 years. They include marine terminal facilities and off-port thoroughfares and railways to improve the flow of cargo. Other projects include the 50-foot harbor deepening and the on-dock rail facilities (ExpressRail\(^3\)). Investments also are planned to develop Intelligent Transportation Systems for port operations\(^4\).

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\(^1\) In 2004, the total value of freight hauled in NY metropolitan area was $651.05 billion amounting to 392.34 million tons. It is expected to grow by 45% in 2025. These data comes from NYMTC *Regional Freight Plan.*

\(^2\) Data from the Port of New York and New Jersey (PANYNJ): http://www.panynj.gov/

\(^3\) Scheduled for completion in 2011, this rail investment month will double the capacity of ExpressRail Port Newark to more than 100,000 containers a year.

\(^4\) The budget includes investments to support third-party development of a parcel of land adjacent to the Howland Hook Marine Terminal on Staten Island for future terminal expansion.
These investments notwithstanding, for the next decade, the truck will be the predominant mode, carrying the largest proportion of freight volumes in the region, including to and from the Port. Waterborne modes, mainly barges, carry a sizeable share of bulk commodities such as fuel, oil products, and sand. The share of freight rail, on the other hand, will still remains rather low, mainly due to the region’s geography and lack of rail capacity investments. Table 3 provides the breakdown of total cargo movement in the New York-New Jersey metropolitan area by mode (2005).

Table 3: Freight Modal Share (by weight) in NY/NJ Metropolitan Area (2005)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Cargo</td>
<td>0.2</td>
</tr>
<tr>
<td>Waterway</td>
<td>18.3</td>
</tr>
<tr>
<td>Rail</td>
<td>0.8(^a)</td>
</tr>
<tr>
<td>Truck</td>
<td>80.7</td>
</tr>
</tbody>
</table>

Notes: \(^a\) ExpressRail, the Port Authority’s on-dock rail terminals in New Jersey, handled in 2006 338,882 containers, 11.8 percent more than in 2005
Source: New York Metropolitan Transportation Council (www.NYMT.C.org)

It is evident that a majority of the region’s freight movement is with the rest of the East Coast and from manufacturing centers in the mid-west. Trucks carry about 80% of all freight (measured in tons) in the region. Moreover, every mode of
freight transportation is tied to a truck trip. Intermodal rail and air cargo would not be possible without trucks. Even barge operations have a truck trip component. Truck freight is moved by thousands of common carriers and truck operators and scores of individual companies. Some operators are as small as a single vehicle, while others such as JB Hunt or Werner Transportation, operate thousands of trucks across the country.

In light of the planned capital investments, what is the likely additional truck traffic?

Accepting the modal share as in Table 3, and assuming that each truck carries one container, we can approximate the number of truck trips. Following the figures in Table 2 in 2006, there were total of 5,092,806 TEU containers (loaded and empty) traveling to and from the port of NY and NJ. Of these 72.8% were carried out by trucks, namely 3,661,698 annual tuck trips. While this port related truck movements might seem a small fraction of the overall metropolitan daily truck trips, it is nevertheless, has a quite significant impact on traffic. First, most of these trips are carried out on the densely traveled New Jersey highways. Second, these are 18-wheeler trucks with disproportionate impact on traffic and highway wear and tear costs. Third, these trips originate and concentrate in a specific location (the port), with major impact on congestion in strategic nodes. Forth, due to the geography of the region these truck trips must cross major tunnels and bridges with considerable impact on traffic flow.

Considering the present port capital investment plans and assuming that international trade will keep on growing at a rate of 4-5% per year, what are the expected societal costs from the additional truck trips?

3. SOCIETAL COSTS OF PORT RELATED TRAFFIC

3.1. Cost Categories

In estimating the FMC from additional truck traffic, the main cost categories are: (A) Private costs, which include vehicle operating costs and own congestion costs; (B) Investment costs, which include capital and maintenance costs; (C) Non-internalized externality or social costs, which include congestion externality costs, accident costs and environmental costs from noise and emission. Following Ozbay et al., (2001, 2007), these are defined as follows.

A. Private costs

1. Vehicle operating costs: These are costs borne by users. They include fuel and oil consumption, expected and unexpected maintenance, car wear and tear, insurance, parking fees and tolls, and automobile depreciation. Marginal vehicle operating costs are assumed to be a direct and linear function of “total miles traveled”, which, in turn, are highly correlated with the age of the vehicle. Additional truck traffic on the NY/NJ congested highway network is expected to lengthen car travel distances. That is, as traffic flow rises trip-makers are forced to switch to less congested but longer routers.

2. Own congestion costs: Congestion cost defined as the time-loss due to traffic conditions and drivers’ discomfort that trip makes endure, both of which are
a function of increasing volume to capacity ratios. In Graph 1, at traffic volume travel \( Q_1 \), the private congestion cost is \( P_1 \) (where the demand function \( D_1 \) intersects the average cost curve \( AC \)). When the demand function \( D_1 \) shifts to \( D_2 \) the new travel volume is \( Q_2 \) and the private congestion costs are now \( P_3 \).

**Graph 1: Private and Externality Costs of Traffic Congestion**

These costs are in units of time and are determined through the use of a travel time function (the AC function). Their magnitude depends on the distance between any OD pairs \( (d) \), traffic volume \( (Q) \) and roadway capacity \( (C) \). To transform travel time changes into monetary value we use of value of time (VOT) ($/hour). In this study two VOT figures were used: a 40% of the average hourly wage rate in NJ ($7.6 per hour) and 75% of the average wage rate in managerial jobs in NJ ($32.4 per hours).

**B. Investment costs**

1. **Infrastructure costs:** Roadway infrastructure costs are equated in this analysis with depreciation costs (3% per annum) and resurfacing costs. For lack of adequate data, below it was assumed that the marginal resurfacing cost equals the average cost.

**C. Non-internalized externality or social costs**

1. **Non-internalized congestion costs (congestion externality):** From Graph 1, at traffic volume \( Q_1 \) the non-internalized social congestion costs are given
by $P_2 - P_1$ (where the demand curve $D_1$ intersects the marginal social cost curve, MSC, less the private costs at this volume). When demand shifts to $D_2$ traffic volume increases to $Q_2$ and the social costs now are given by $P_4 - P_3$. Equation (3) below formalizes the measurements of these magnitudes.

2. Accident Costs: Accidents were categorized as fatality, injury and property damage accidents. Accident occurrence rate functions for each accident type were then developed. Historical data obtained from NJDOT shows that annual accident rates, by accident type, are closely related to intensity of traffic volume and roadway geometry. Thus, in this study both intensity of traffic volume and the geometry of the highway network were considered. Three accident occurrence rate functions were used one for each accident type and for each of three highway functional types. Hence, nine different functions were developed in total. Regression analyses have been used to estimate these functions.

3. Environmental Costs: Environmental costs due to highway transportation are categorized as air pollution and noise pollution costs. Air Pollution costs were estimated by multiplying the amount of pollutant emitted from vehicles by the unit cost values of each pollutant. The major pollutants including volatile organic compounds ($VOC$), carbon monoxide ($CO$), nitrogen oxides ($NO_x$) as directly emitted pollutants, and particulate matters ($PM_{10}$) as indirectly generated pollutant. Detailed explanation of the formulization of the air pollution cost function is given in Ozbay et al. (2001). Note that this function includes only the local effects, though air pollution has trans-boundary or even global attributes. Noise Costs are most commonly estimated as the depreciation in the value of residential units alongside the highways. Presumably, the closer a house to the highway the more its value will depreciate. While there are other factors that cause depreciation in housing values, “closeness” is most often utilized as the major variable explaining the effect of noise externality. The marginal noise cost function is specified so that whenever the ambient noise level at a certain distance from the highway exceeds 50 decibels, it causes a reduction in the value of houses that fall within this distance. Thus, the noise cost depends both on the noise level and on the house value. Detailed information is presented in Ozbay et al. (2001).

4. METHODOLOGY FOR MEASURING THE FMC OF PORT RELATED TRUCK TRAFFIC

To estimate Full Marginal Social Costs from additional truck traffic, it is necessary to define specific cost function models for the above cost categories. Beginning with congestion costs, equation (1) defines the cost of a trip between each specific OD pair:

$$C_n = F(V_j, q)$$  \hspace{1cm} (1)
In (1) \( q \) denotes travel volume between the OD pair \( r \) and \( s \), and \( F(V,q) \) is the average cost function, where \( V_j \) is a set of supply variables (e.g., capacity). Total Cost (\( FTC \)) of providing transportation between any OD pair for \( q \) trips is:

\[
FTC_{rs} = q \cdot (C_n) = q \cdot F(V_j;q) \tag{2}
\]

Marginal Costs (\( MC \)) for each OD pair, within a given time period, is:

\[
MC_{rs} = \frac{\partial (q \cdot F(V_j;q))}{\partial q} = F(V_j;q) + q \cdot \frac{\partial F(V_j;q)}{\partial q} \tag{3}
\]

This function defines the cost of an additional trip in the system. The first term represents the private average costs (\( P_2 - P_1 \), in Graph 1). The second term in equation (3), \( q \cdot (\partial F(V_j;q)/\partial q) \), represents the externality congestion cost (\( P_4 - P_3 \), in Graph 1). Faced with traffic congestion, trip makers select routes and time of travel (and mode), given the network's attributes, so as to minimize their individual travel costs. Thus, if travel demand between a given OD pair is increased, travel patterns on all routes in the network will change. As a result, all of the other cost components discussed above, will also change. Thus, to correctly estimate the magnitude of effects measurements must be made at the network level using appropriate assignment algorithm (see below).

Given the above notation, Table 4 below summarizes the various cost functions used in this study.

### Table 4: Marginal Cost Functions

<table>
<thead>
<tr>
<th>Cost</th>
<th>Total &amp; Marginal Cost Function</th>
<th>Variable Definition</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Operating</td>
<td>( C_{opr} = 7208.73 + 0.12(m/a) + 2783.3a + 0.143m )</td>
<td>( a ): Vehicle age (years)</td>
<td>AAA (2003), USDOT (1999), KBB (2006)</td>
</tr>
<tr>
<td>Congestion</td>
<td>( C_{cong} = \begin{cases} \frac{Q}{V_s} f_1 + \frac{0.09}{C} \frac{Q}{V_s} VOT &amp; \text{if } Q &lt; C \ \frac{Q}{V_s} f_1 + \frac{0.09}{C} \frac{Q}{V_s} VOT + 0.6 \frac{Q}{V_s} \frac{VOT}{2} &amp; \text{if } Q &gt; C \end{cases} )</td>
<td>( Q = ) Volume (veh/hr) ( d = ) Distance (mile) ( C = ) Capacity (veh/hr) ( VOT = ) Value of time (S/hr) ( V_o = ) Free flow speed (mph)</td>
<td>Mun (1994) Small and Chu (2003)</td>
</tr>
<tr>
<td>Accident(^{(1)})</td>
<td><strong>Category 1:</strong> Interstate-freeway</td>
<td>( C_{acc} = 127.5Q^{0.37}M^{0.76}L^{0.51} + 114.75Q^{0.69}M^{0.73}L^{0.49} + 198.9Q^{0.37}M^{0.54}L^{0.45} )</td>
<td>( Q = ) Volume (veh/day) ( M = ) Path length (miles) ( L = ) no of lanes</td>
</tr>
</tbody>
</table>
### Category 2: Principal Arterial

| FMC = 98.18Q^{0.28}M^{0.76}L^{0.55} + 97.53Q^{0.15}M^{0.23}L^{0.46} + 33,813Q^{-0.83}M^{-0.42}L^{0.45} |

### Category 3: Arterial-Collector Local Road

| FMC = 178.5Q^{0.58}M^{0.68}L^{0.45} + 18,359Q^{0.45}M^{0.65}L^{0.47} + 103.5Q^{0.62}M^{0.69}L^{0.44} + 8,261.5Q^{-0.55}M^{-0.63}L^{0.47} |

### Air Pollution

\[ T_{CA_{ir}} = Q(0.01094 + 0.2155F) \]
\[ MC_{CA_{ir}} = 0.01094 + 0.2155 \left( F + \frac{\delta E}{\delta Q} \right) \]
\[ F = 0.0723 - 0.00312V + 5.403x10^{-5}V^2 \]

### Noise

\[ C_{noise} = 2 \int_{r_{min}}^{r_{max}} \left( L_{eq} - 50 \right) \frac{D_{avg}R}{5280} dr \]
\[ MC_{noise} = \frac{D_{avg}R}{264} \left( \frac{\delta Q}{\delta r} \log Q + \log K - \ln r_2 - 4.88 \right) + \frac{1}{\ln 10} \left( 1 + \frac{\delta K}{\delta Q} \right) \]
where:
- \( K = K_{car} + K_{truck} \)
- \( K_{car} = F_c \left( 4.174 \cdot 10^{-0.115} + 10^{-0.03} F_{ac} \cdot (V - F_{ac}) y \right) \)
- \( F_{ac} = \frac{5.882 \cdot 10^{2.122} + 10^{-0.43} F_{atr} \cdot (V - F_{atr}) y}{V_c} \)
- \( L_{eq} = 10 \log(Q) + 10 \log(K) - 10 \log(r) + 1.14 \)

### Maintenance

\[ C_M = 800,950N^{0.384}L^{0.603} \]
\[ MC_M = 800,950N^{0.184}L^{0.401}t/T \]

### Equations

Based on these functions and for each OD pair in the network, the Full Marginal Costs are defined as:

\[ ORMC_{r,s} = \sum_{i=1}^{k} FMC^i = \sum_{i=1}^{k} d(MC_{op}^i + MC_{cong}^i + MC_{acc}^i + MC_{inf}^i + MC_{air}^i + MC_{noise}^i) \]  
(4)

Where,
- \( ORMC_{r,s} \) = One Route Marginal Costs for travel between \( r \) and \( s \)
- \( FMC \) = Full Marginal Cost ($/mile)
- \( MC_{op} \) = Marginal vehicle operating cost ($/trip)
- \( MC_{cong} \) = Marginal Congestion cost ($/trip), split into private and externality costs
$MC_{acc}$ = Marginal Accident cost ($/trip),
$MC_{inf}$ = Marginal Infrastructure cost ($/trip)
$MC_{air}$ = Marginal Air pollution cost ($/trip)
$MC_{noise}$ = Marginal Noise Cost ($/trip)

$r, s$ = Origin-Destination pair

$k$ = Number of links between origin destination pairs, on the shortest route.

$d$ = Trip distance (miles)

5. DATA

The Port of New York and New Jersey is the largest port complex on the East Coast of the US. It is located at the hub of the most concentrated and affluent consumer market in the world, with immediate access to the most extensive interstate highway network in the region. Map 1 shows its most immediate markets.

Since this traffic travels mainly on the Northern New Jersey highway network, for this study, this network was coded and calibrated. Figure 2 depicts this network.

Figure 2: Northern NJ Highway Network
Two key points should be observed about this network. First, I-95, I-80, and I-278 are the most heavily traveled corridors in the metropolitan region (see dashed line in Map 1). Second, the key market (destination) for port (origin) related truck traffic is the Camden-Philadelphia market. The distance, along I-95 and I-80 between these O-D locations is about 80 miles long. I will use this distance in the subsequent calculations of FMC from the additional expected truck traffic.

**Map 1: The Port of NY/NJ to Camden/Philadelphia Market**

Data for the cost of highway resurfacing was obtained from 61 resurfacing projects in New Jersey, between: 2005-2006. The data consisted of average number of lanes, length in miles and total project costs. A simple resurfacing cost function, based on the number of lanes and length was developed and estimated.

Accident dataset consists of a detailed accident summary for the years 1991-1995 in New Jersey. For each highway functional type, the number of accidents in a given year by was reported. Note that these functions are based on unit accident cost for each accident type. The statistical results of accident occurrence rate estimation. The assumed unit accident costs can be found in Ozbay et al. (2001).

Finally, the Noise Depreciation Sensitivity Index (NDSI) as given in Nelson (1982) is defined as the ratio of the percentage reduction in housing value resulting
from a unit change in the noise level. Nelson (1982) suggests the value of 0.40% for NDSI.

6. COMPUTATIONS OF FMC FOR THE ADDITIONAL TRUCK TRAFFIC

Given the network presented above and current trip volumes, it was possible to FMC by categories for an average private car trip of 10 miles. The results are shown in Table 5.

**Table 5: FMC by categories for average trip distance of 10 miles (VOT=$7.2)**

<table>
<thead>
<tr>
<th>Private Costs ($)</th>
<th>Investment Costs ($)</th>
<th>Non-internalized Externality (social) Costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>Congestion</td>
<td>Infrastructure</td>
</tr>
<tr>
<td>1.389</td>
<td>3.786</td>
<td>0.062</td>
</tr>
</tbody>
</table>

* Accident externality= Marginal Accident Cost - Average Accident Cost = 1.009 - (1.009/1.52)=0.345

The results in Table 6, show average FMC values for all trip types, for all OD pairs, over all links at all times of day, assuming value of time of $7.2/hour. Yet, trucks carrying containers tend to travel at peak periods, over longer distances. Hence, in order to correctly compute FMC for additional port-related truck movements, we need to make further adjustments. First, as observed above truck average trip length is 80 miles. Second, from traffic flow perspectives, Private Car Equivalent (PCE) is 3-4 cars per 1 truck, a ratio that will be used in the ensuing calculations. Third, we need to consider peak travel times/costs.

**Table 6: Key Results (per annum)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Δ container volume (2006-2005)</td>
<td>307,488</td>
</tr>
<tr>
<td>1 Modal Split</td>
<td>75% truck (2006)</td>
</tr>
<tr>
<td>2 Δ truck trips</td>
<td>230,250</td>
</tr>
<tr>
<td>3 PCE</td>
<td>3-4 cars/truck</td>
</tr>
<tr>
<td>4 Δ car trips</td>
<td>690,750-921,000</td>
</tr>
<tr>
<td>5 Avg. FMC per 10 miles trip</td>
<td>$7.2</td>
</tr>
<tr>
<td>6 Truck trip length</td>
<td>80 miles</td>
</tr>
<tr>
<td>7 No. of car trips within 80 miles (80/10)</td>
<td>8 trips</td>
</tr>
<tr>
<td>8 Avg. FMC 80 miles (5)x (7)</td>
<td>$56.8</td>
</tr>
<tr>
<td>9 Total avg. annual FMC (4)x(8)</td>
<td>$39,234,600 - $52,312,800</td>
</tr>
<tr>
<td>10 Peak FMC (VOT=$7.2/hour)</td>
<td>$120/trip</td>
</tr>
<tr>
<td>11 Peak FMC (VOT=$32.3/hour)</td>
<td>$220/trip</td>
</tr>
<tr>
<td>12 Total Peak FMC (VOT=$7.2/hour)</td>
<td>$663,120,000 - $884,160,000</td>
</tr>
<tr>
<td>(4)x(7)x(10)</td>
<td></td>
</tr>
<tr>
<td>13 Total Peak FMC (VOT=$32.3/hour)</td>
<td>$1,215,720,000 - $1,620,960,000</td>
</tr>
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</table>
Figures 3 and 4 below show the distribution of FMC for truck trips by distance, by peak and off-peak assuming VOT of $7.6/hour and 32.3/hour, respectively. In particular the figures show that at 80 miles at peak time for VOT = $7.6/hour, FMC = $130; for VOT = $32.3/hour, FMC = $240.

Figure 3: ORM C FMC by Trip Distance and Peak and Off-Peak Hours (VOT=$7.6)

Based on these results, next I have calculated FMC from additional truck traffic as follows. The number of containers transported from Newark Port, New Jersey in 2005 was 4,785,000 containers and in 2006 5,092,000 containers. If we assume a 75% modal split for containers traveling from and to the Port, the annual total truck volume in 2005 and 2006 are 3,588,750 and 3,819,000, respectively. That translates into an additional 230,250 trucks between 2005 and 2006, which corresponds to a 6.4% increase. If we assume PCE of 3 or 4 passenger cars, then the total number of additional cars (between 2005 and 2006) traveling in the NJ Turnpike corridor is 690,750 to 921,000.

Given the 80 miles trips distance using average FMC of $7.1 per 10-mile trip implies, $56.8/trip (= $7.1 x 8) for the 80 miles trip. Multiplying the total additional
number of vehicles (921,000) by $56.8/trip, we get total FMC of $52,312,800 per year.

If we assume $120/trip for 80-mile trip for traveling at peak period assuming VOT = $7.2/hour total FMC is $884,160,000 per year. Assuming $220/trip for 80-mile trip (VOT = $32.3/hour) total FMC is $1,620,960,000. Table 6 presents these calculations.

Figure 4: ORMC FMC by Trip Distance and Peak and Off-Peak Hours (VOT=$32.3)

7. DISCUSSION OF RESULTS

The calculations presented in Table 8 shows that for PCE = 3, 4 cars, and for VOT of $7.2/hour, Full Marginal Costs are estimated to be between $663,120,000 and $884,160,000 per annum. For a higher VOT ($32.2/hour) the comparable results are between $1,215,720,000 and $1,620,960,000 per annum. What are the implications of these results for the expected increase in truck movement?

These results are quite conservative:

a) Using a micro-simulation traffic model FMC is much higher

b) Due to the non-linear nature of FMC, loading the network incrementally (not by 6.4%) would have yielded higher estimates

First, it should be observed that these are quite conservative results. The FMC results shown in Table 10 were produced using a simple assignment model. Further analysis using a micro-simulation traffic (PARAMICS) model, has produced much higher results (Ozbay et al, 2007). Second, since the flow-travel time functions depicted in Figures 3 and 4 are exponential functions loading the network incrementally (not by 6.4% as was done here) would have yielded more than
proportional travel time results. Third, more recent data show that trucks now comprise about 80% of freight movement in the NY-NJ metropolitan area. Forth, all parameters used in the above calculations are conservative values. For example, according to local air quality officials, in the Port of Los Angeles, ports’ activities produce 12% of all particulates in the LA basin, and 9% of the Nox, which are way above what the parameters used here imply.

In general, what this analysis shows that port expansion, which aims at increasing the number of containers that enter the port, will also generate substantial truck traffic volumes. And this flow, in turn, will generate significant private and non-internalized externality (social) costs. Thus, in assessing future port capital investments these costs need to be incorporated into their cost-benefit analysis scheme.

8. SOME POSSIBLE SOLUTIONS

This paper’s main focus is the estimation of societal costs from additional truck traffic, resulting from port infrastructure expansion aimed at meeting growing maritime trade. Yet, it might be asked, could the expected additional truck traffic be “managed” to reduce, the above estimated, societal costs? The answer is, of course, “yes”, but at the expense of reduced trade and economic activity. Thus, what we might want to pursue are policies, which will curtail these costs while enabling trade growth unabated. Below I briefly outline three such policies: use of barges, demand management and efficient pricing.

A. Barges: As pointed out above, the main destination of truck traffic generated from the PNYNJ is the Philadelphia-Camden market. Using a seaway route (see blue line in Map 1) it is possible to transport 180 20TEU containers per barge, thereby, eliminating a similar number of trucks from the highway network. Table 7 compares barge, rail and trucks movements in this market.

<table>
<thead>
<tr>
<th>Barge</th>
<th>Rail</th>
<th>Truck</th>
</tr>
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<tbody>
<tr>
<td>Miles (one way)</td>
<td>234 (Nautical)</td>
<td>100</td>
</tr>
<tr>
<td>Travel Time (one way) hours</td>
<td>29</td>
<td>10</td>
</tr>
<tr>
<td>Number of Containers per Movement</td>
<td>180</td>
<td>50</td>
</tr>
</tbody>
</table>

For shipper, however, the use of a truck is more cost efficient than barge. Thus, current over-the-road price to truck shippers is about $380.00 round trip or $2.00 per mile. Per mile barge costs are much higher, due to travel time differences, additional loading and unloading movements and, most importantly, the externality costs estimated above, which shippers to not pay. Policies aiming at increasing barge operation can thus be used to reduce truck traffic.

B. Demand Management: economic incentives might be useful in inducing trucks out of peak travel times and into evening and weekend shifts. Thus, extra charges for each truckload using the port during the normal eight-hour day shift, and no fees for the off-peak times might be quite effective in this regard. Elements
of this approach have been implemented at the PNYNJ and were successful in shifting significant gate traffic to the off-peak hours. Mostly independent owner-drivers trucks, making short-haul drayage runs to distribution centers in nearby Riverside County have embraced the program, finding that they can make more trips per shift and encounter less traffic congestion by taking advantage of the off-peak hours. Other means such as dedicated truck lanes and the use of information technologies to better schedule gate queues have also been suggested. Of major importance are subsidies aiming at encouraging truck owners to replace aging highly polluting diesel engines with modern ones.

C. Efficient Pricing or Tolling: It is debatable whether efficient road pricing will indeed reduce the number of peak-hour truck trips. Key arguments are:

(a) Truck movements by time of day reflect demand levels and spatial patterns by shippers and customers. Yet, only an insignificant proportion (about 10%) of toll increase will be passed on to consumers, who therefore are unlikely to change their demand.

(b) Change in hauling prices is divided among many customers with insignificant effect on each.

(c) Tolls are regarded as fixed costs, which would not change behavior, as contracts are distance-based.

(d) Since the trucking industry is highly competitive, increase in fixed costs may be absorbed by falling profit margins but not by increasing prices, which in turn are needed to effectuate demand.

9. CONCLUSIONS

This paper attempted to estimate the total marginal private and social costs from additional port-related truck movements. The calculations show that additional truck traffic, resulting from expanded trade activities at the Port of NY and New Jersey, translates into substantial annual costs. These costs range from $663 million to $884 million assuming a low VOT ($7.6/H) to $1.215 billion to $1.620 billion for higher VOT ($32.3/H). In part, these costs are due to the fact that the NY-NJ metropolitan area is a highly congested and densely populated region with a rather very limited freight rail transport.

Two main policy conclusions can be drawn from this analysis. The first relates to the Cost-Benefit evaluation of additional port investments, which aim at accommodating growing international trade activities. Thus, benefits from these investments should be weighed against societal costs, from the expected increase in truck traffic, as shown in this paper.

The second conclusion relates to the use of alternative freight modes, mainly rail and barge. The need for a new rail freight tunnel linking NJ with Manhattan has long been recognized, though to date, there is no consensus regarding if and when it will be built. On the other hand, there are some initial plans to introduce barge service between PNYNJ and the Camden-Philadelphia market as indicated by the blue arrow in Map 1. While from the shippers’ viewpoint, such as service is regarded inferior mainly because of travel time when considering barges’ capacity, it can substantially reduce the private and social costs associated with
truck traffic. Presently, additional work is carried out to ascertain the economic viability of barge activities.

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NYMTC, 2005, the New York Metropolitan Transportation Council, Regional Freight Plan, (www.NYMTC.org)
