Clean trucks in California ports: modelling emissions policy

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Abstract: The Port of Los Angeles (POLA) Clean Trucks Programme is a controversial environmental sustainability initiative adopted to restrict the use of drayage trucks hauling goods to and from port terminal operations. Pending litigation on the constitutionality of the programme, and proposed new legislation that would give the federal government and local authorities a greater role in curbing emissions from harbour trucking, it has important ramifications for the port and shipping sector. We review interactions between maritime ports and the enterprise and institutional interests connected with the current status of the initiative. We use a game theoretical model to anticipate the effects of potential truck conversion policies. Courts, legislators, and interest group advocates can use this knowledge to support proactive policies and create incentives for additional Clean Trucks Programmes.

Keywords: sustainability; harbour trucking; port governance; port economics.


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This paper is a revised and expanded version of a paper entitled ‘Clean trucks in California ports: modelling emissions policy’ presented at Annual IAME Conference 2011, Santiago de Chile, 25th to 28th October 2011.

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1 Introduction

Numerous stakeholders surround the workings of the modern maritime port. The port users comprise the multiple businesses of shippers and carriers connected with the distribution of goods to and from seagoing locations and outlying areas (Jansson and Shneerson, 1982; Verhoeven, 2010). The labour to load and transport goods to various intermodal destinations consists of a mix of highly paid, specialised work and low paid, low skill work; all part of the supply chain. Port authorities and terminal operators operate publicly and privately to respond to market imperatives and the needs of their various constituents. The nearby residents, local, state, and federal authorities, environmental groups, community groups, business associations and ancillary commercial industry interests are all concerned with port policies and costs to address multiple business and socioeconomic ends. The many constituencies have created problems in coordinating long term business planning to larger social and public policy issues such as environmental degradation (Van de Voorde and Winkelmans, 2002; Karatas and Cerit, 2009).

A case in point is the implementation of pollution abatement objectives such as the ‘Clean Truck Program’ (CTP), first proposed at the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) in Southern California, and later in various forms at other North American ports, as a response to particulate emissions from short-haul trucks taking containers to and from the port. The environmental considerations have become part of a much more complex question: whether an individual US maritime port can regulate the use of trucks within the port area to meet federal and state clean air initiatives. Some observers believe the issue will be solved only by a US Supreme Court clarification of the use of the federal pre-emption law, otherwise known as the Commerce Clause (US Constitution Article 1, Section 8). Repercussions of the enactment of the CTP may drive changes at maritime ports around the world (Goodchild and Mohan, 2008).

This paper seeks first to describe the issues and interest groups involved in the implementation of Clean Truck initiatives enacted by POLA and countered in court by trucking and other economic interests. The Los Angeles case is significant because it addresses the right of seaports to regulate harbour trucking for purposes of easing air pollution and traffic congestion. Some other US port cities, such as Long Beach, Oakland, Seattle, New York/New Jersey, and the Virginia area agree with Los Angeles that limited local regulatory authority would be desirable. Secondly, we develop a model based on game theory to study policies setting particulate pollution levels and offering partial compensation for truck conversion. We then show the potential implications for the entities participating in the port trucking activity and the anticipated result of these policies.

In Section 2, we discuss the background of harbour trucking pollution policies and the current lawsuits concerning port authorities’ ability to regulate it, which appear to be headed to the US Supreme Court. We identify the interest groups and their relation to the natural functions of the port, as described by Verhoeven (2010) and others. It is the ports’ ability to restrain competition by specifying conditions for participation that has been called into question. In Section 3, we describe the structure of strategic decision-making between port economic participants. In Section 4, we model the decision to upgrade trucks to meet a particulate pollution standard as a strategic game between drayage firms and owner operators of trucks. We suggest that rational economic behaviour predicts the amount of upgrading the two sides will choose. In Section 5, we discuss policy
prescriptions for the choice of upgrade, and the subsidy structure, to assure support from
the market for truck service. This provides insight into the types of legal or political
decision that will support viable port operation, and in particular cases may provide
bounds for choices port management must make. We conclude indicating some further
research possibilities for individual port decision making in an expanded context, in
which ports must compete or cooperate using pollution control measures.

There are three published research studies that look at the impact of the CTP at the
POLA on terminal operations and federal law. Goodchild and Mohan (2008) looked at
the effects of CTP requirements and policy changes on the terminal operations and
suggested that new technologies would be required to reduce gate processing time.
Among others, Namboothiri and Erera (2008) utilise an integer programming heuristic
that models a port access control system which would reduce truck idle time. England
(2010) examined the scope of the Federal Aviation Administration Authorization Act
(FAAAAA), as it applied to the federal court cases challenging the implementation of the
CTP.

Game theory has its origin in von Neumann and Morgenstern (1953). Many texts in
operations and economics (e.g., Kreps, 1990), books (e.g., Fudenberg and Tirole, 1991;
Binmore, 1991), and multiple research papers (e.g., Curiel, 1997; Zagare, 1984), discuss
strategic game theory applications. There are a few applications in maritime areas (Saeed
and Larsen, 2010; Gkonis and Psaraftis, 2009; Anderson et al., 2008; Song and
Panayides, 2002), but none relating to environmental strategy that we are aware of.

2 Background and current status at POLA

Increases in global trade and structural efficiencies generated through supply chain
management in the last two decades have led to the growth of large mega-ports that have
the capacity to load and unload thousands of shipping containers on any given day. The
economics of the port business centre on maritime traffic, the leasing of terminals, and
collection of wharfage fees when vessels dock at ports (Meersman et al., 2009). Ports are
controlled and regulated by various government and quasi-government agencies as well
as influenced by specialised interest groups. Containers are brought to and from vessels
by short haul diesel drayage trucks connecting ports with nearby container yards,
railheads, warehouses, distribution centres and other largely local points. Continual
innovations in technology have reduced processing times and automated numerous
aspects of containerised shipping at major ports, but have not eliminated the need for a
truck and driver to transfer shipping containers. The number of trucks needed to serve the
port varies with the volume of international trade, the number of terminal gates that can
process goods movement, and the turnaround time of equipment due to infrastructure
constraints (Notteboom, 2006). Despite recent progress in processing the flow of drayage
trucks to be serviced, it is still common to observe a line of idling trucks waiting for
clearance to bring loads to and from container terminals at major maritime ports
(Bensman, 2009; Mongelluzzo, 2010b).

In 2003, the POLA and POLB had become the largest single source of diesel
pollution in the Los Angeles Basin (Zakin, 2003). Research suggests that the Los Angeles
Basin, comprising Orange County and the urban portions of Los Angeles County, is one
of the most air polluted regions within the USA (American Lung Association, 2010). Port
truck operations were identified as a major source of emissions in terms of nitrogen oxides (NOx), sulphur oxides (SOx), and diesel particulate matter (PM) at container terminals, causing increases in asthma and other health hazards for residents living nearby the port facilities (Cooke, 2001).

In 2005, surging growth in import container volume from Asia through the Los Angeles-Long Beach port complex led to long back-ups for vessel discharge, railroad equipment shortages and truck congestion (Kulish, 2005). Approximately 70% of the total Asia to US container traffic arrived on the West Coast in 2005, primarily through the Los Angeles and Long Beach ports (Kulish, 2005). Infrastructure improvements to reduce delays at the ports were deemed inadequate for current and anticipated growth (Kulish, 2005). Port truck traffic clogged an already congested local freeway system, creating legal and political pressure at the state level and in local communities to address problems of traffic congestion and air quality. In 2001, the National Resource Defence Council (NRDC) and nearby community groups sued POLA over construction of a container shipping complex to be operated by China Shipping Company. The 2003 settlement required the Port commit to specific steps to address pollution caused by diesel powered ships and trucks loading and unloading cargo. The Port also pledged to redesign port development projects to avoid further litigation (NRDC, 2011).

2.1 Federal efforts

Cleaning up diesel truck exhaust has been a major initiative of the US Environmental Protection Agency (EPA), established in 1970, and the Clean Air Act of 1972. A national strategy was introduced in 1985 to reduce the risk of toxic air pollutants through the setting of standards for diesel fuel quality, evaporative hydrocarbons and particulate emissions (Kilcarr, 2010). The EPA targeted diesel powered trucks that made up 2% of vehicles in the US but were responsible for up to 60% of all particulates and NOx. Amendments added to the Clean Air Act in 1990 called for a national permit programme, with tighter pollution standards beginning in the model year 1994 on automobiles and trucks. In 1997, emissions standards to reduce NOx and hydrocarbons by 90% from diesel trucks were set to be implemented by 2002, with comprehensive new standards adopted in 2000 to apply in two phases, starting with model year 2007, with a final round of emissions mandates for model year 2010 (Kilcarr, 2010). In 2008, Congress appropriated $200 million for the Diesel Emissions Reduction Act (DERA) Programme under the Energy Policy Act of 2005 to finance retrofits on existing heavy-duty diesel engines in the existing fleet as a means of meeting federal clean air standards.

2.2 State efforts

The California Air Resources Board (CARB) regulates ‘in use’ engines throughout the state of California. In December 2007, it approved a regulation to reduce emissions from drayage trucks at California’s ports and intermodal rail yards. All drayage trucks entering the ports would need to be registered in the CARB Drayage Truck Registry and meet specific air emissions standards (California Air Resources Board, 2010). Phase one would require all pre-1994 drayage truck engines be retired or replaced with 1994 and newer engines by the end of 2009. Trucks with 1994–2003 engines would need to be either replaced or retrofitted to achieve an 85% reduction in diesel PM by the same deadline. The second phase of the regulation required trucks to meet 2007 emissions
standards by the end of 2013. CARB and federal EPA regulations largely coincide, but the state went beyond the federal government by regulating the ongoing use of trucks operating within California (United States Government Accountability Office, 2009).

2.3 The port trucking industry

The US Motor Carrier Act of 1980 enabled short-haul truckers to operate as independent owner-operators, as well as hiring out on an individual basis to trucking companies on a per-contract or per-load basis. This soon resulted in a highly fragmented workforce with over 85% of harbour drayage trucking performed by owner-operators. Transportation costs were reduced as part of the overall movement of goods, but low wages (averaging $10 to $12 per hour), average annual incomes of $28,000 nationwide, and low barriers to entry led to short-haul drayage trucking at ports done largely by recent immigrants operating older trucks near or beyond the retirement age for vehicles. Truckers were typically paid by the load rather than by the hour, creating incentives to wait in long lines for loads rather than arrive by appointment (Bensman, 2009).

2.4 The ports clean air plan and response

To reduce significantly diesel emissions in the Los Angeles Basin from drayage trucks on a per TEU basis by 45% or more by 2012, the POLA and POLB approved a San Pedro Bay Ports Clean Air Action Plan (CAAP) in November 2006 (updated in November 2010) (Higginbotham, 2007; Mongelluzzo, 2010a; Cannon, 2011). POLA has shown reductions in air pollutants every year since 2005 (McCue, 2011). The CTP instituted by the ports in October 2008 set a goal to ban pre-1989 trucks and have a fleet of compliant drayage trucks meeting 2007 emissions standards before the 1 January 2012 target date set by the EPA. At that time, all trucks that did not meet the 2007 Federal Clean Truck Emissions standards would be banned from the port. To help subsidise the cost of newer, cleaner drayage, a fee of $35 per TEU ($70 for a 40 foot container) was instituted in November 2008 for non-2007 compliant trucks with the fee waived for 2007 EPA compliant trucks. In addition, a five-year renewable concession agreement would require trucking companies to sign a concession agreement and adhere to its obligations mandating 100% employee-driver workforce, as well as phasing out independent contractor drivers that made up the bulk of the transport. Trucking companies rather than drivers would purchase and maintain trucks bringing cargo in and out. POLA now has over 1,000 trucking concession agreements (Port of Los Angeles, 2012).

Industry reaction to the plan was negative. Converting independent drivers to direct employees was seen as a violation of the Interstate Commerce Act and the 1984 Shipping Act (Moore, 2009). The timing, during a deep economic downturn, was questioned (Gallagher, 2007). The plan was considered to be more about the ability of the International Brotherhood of Teamsters Union (Teamsters) to organise port truckers, now required to be employed by companies for union membership, and to gain a foothold at the ports (Gallagher, 2007; Higginbotham, 2007; Mongelluzzo, 2008). National and local organisations representing trucking and freight interests, marine terminal and vessel operators, and retail interests argued that the plan would cost over $6 billion in the first year of implementation and result in upwards of $50 billion being passed on to consumers over the life of the plan as well as leading to more, instead of less, congestion.
and pollution in the L.A. Basin (Higginbotham, 2007). They suggested that regulations at the San Pedro Bay ports would drive trade away from the Southern California region to other North American ‘gateways’ in Canada, Mexico, and the US East Coast. Transportation and export/import related trade emanating from POLA and POLB accounted for approximately 1.1 million jobs in California, and 43% of all trade in the USA (Port of Los Angeles, 2009).

### 2.5 Federal, state and local authority

The POLA and POLB further sought to amend the FAAAA of 1986 that reserves to the federal government the right to impose rules that regulate the rates, routes and services of motor carriers engaged in interstate commerce, and allowed companies to classify drivers as non-employees, or ‘independent owner-operators’ who get paid by the load and are responsible for their own trucks and the maintenance to keep them operating. A reformed FAAAA law had been signed by President Clinton in August 1994 in the hope that “freight rates will become more competitive, truck service will become more reliable and employment in the trucking services industry will increase” (Clinton, 1994). The ports argued that local officials and port authorities needed the legal authority to protect their financial interests as a ‘market participant’ in harbour trucking. Many US ports endorsed the amendment and asked that the federal pre-emption be reviewed. In July 2008, the American Trucking Association (ATA) brought suit against the cities and POLB and POLA arguing that the concession agreement portion of the CTP was a violation of the Commerce Clause, which gives the federal government the right to regulate interstate trucking. The ATA argued that requiring owner-operators to become employees of trucking companies would alter long standing trucking regulatory oversight. Los Angeles and Long Beach responded that the concession agreement was allowable under the ports’ authority as landlords, to ensure that trucking companies met environmental, safety and security standards.

In September 2008, US District Court Judge Christina Snyder for the Central District of California ruled against the ATA lawsuit. The ATA appealed; it did not oppose the environmental aspects of the ban, affecting the use and retrofitting or retirement of older trucks, but rather the concessionary part of the CTP, and won an injunction in April 2009 against the POLA ban on owner-operators. The court said the concession agreement was a “blatant attempt to decide who can use whom for drayage services and is a palpable interference with prices and services” (Court Opinion, ATA v. Port of Los Angeles, 2009), and concluded that the ports were attempting to reshape and control the economics of the drayage industry as ‘related to price, route or service’, violating the FAAAA pre-emption authority. In October 2009, the POLB extracted the City of Long Beach from the ATA lawsuit and announced a separate settlement with the ATA that required drivers to register their trucks with the port to meet environmental guidelines with trucks meeting the 2007 emissions standards; but crucially dropped the stipulation that companies must own and maintain new trucking fleets.

In February 2010, the US Court of Appeals for the 9th Circuit rejected the ATA claim that the POLA concession requirements should be declared illegal in their entirety. The Court indicated the Port could enforce provisions of the concession agreements related to motor carrier safety in the port area but could not require that the motor carriers phase in employee drivers by harbour drayage companies. In April 2010, a civil trial of the ATA...
lawsuit challenging the access license component of the POLA CTP was argued before District Court Judge Snyder. POLA argued that they are ‘market participants’ in motor carrier operations and are attempting to protect their financial investments and assets. The ATA said the port did not meet the ‘effective procurement’ test because the port does not procure drayage services. The decision of September 2010 found for POLA, stating that some of the port’s concession requirements fell under an exception to the FAAAA as a ‘market participant’. The ATA immediately appealed the decision to the US Court of Appeals for the 9th Circuit. The outcome will likely be appealed to the US Supreme Court by the loser of the case (Mongelluzzo, 2008).

2.6 Union organising efforts

The efforts to stop the CTP by the ATA and amicus filings by the National Industrial Transportation League (NITL) and the National Retail Federation centred on the requirement that only employee drivers of companies rather than independent contractors would be allowed to haul containers within the port complex. The ATA argued that the port was trying to impose labour controls on the trucking industry in violation of the Motor Carrier Act of 1980, and was an attempt by the City of Los Angeles to aid the Teamsters to organise drivers at the Port. Federal law has prohibited unions from organising independent contractors such as the owner-operators of drayage trucks, but did not prevent attempts by unions to organise direct employees of companies. In 2005, the Teamsters lobbied California to remove the ban on unionising independent drivers, subsequently vetoed by the State Governor. In June 2006, the Teamsters’ national assembly approved a campaign to eliminate the independent owner-operator status of port drivers as part of an effort to regain union membership (Higginbotham, 2007). Environmental groups argued that the higher cost of maintenance and repair of clean trucks could only be borne by financially stable companies rather than owner-operators. The City of Los Angeles, as party to the lawsuit along with the Port, cited reduced pollution from truck emissions and the need for a long-term environmental sustainability plan to address the specific local needs of the Los Angeles Basin (Greenhouse, 2010).

2.7 Paying for the trucks

As of 2010, more than 6,000 clean-diesel and LNG trucks had replaced older trucks at the POLA since the CTP started in 2008. To obtain the money to replace or retrofit the thousands of trucks identified in the Clean Truck Plan, the POLA and POLB sought funds collected from clean truck fees, subsidy programmes operated through the ports, lease programmes through non-profit foundations and state government revenue measures as well as federal funds (Knee, 2009). The POLA has pursued volume discounts with truck makers to reduce the costs of purchasing new trucks and have provided $20,000 for each US EPA compliant truck serving port cargo terminals. In 2009, approximately $127 million was provided in subsidies from the State of California to purchase new trucks for ports state-wide. The motor carrier industry has argued that the majority of the cost of purchasing the new trucks has fallen on companies.
3 Modelling port pollution control

From the discussion above, it is clear that there are many participants in the attempts to deal with pollution in port areas caused by trucks. Stakeholder interests will conflict and a wide variety of pollution abatement schemes have been proposed. In addition, legal challenges have prevented implementation of some plans. Each port authority must maintain its competitive position, and must service the freight load in container traffic it forecasts to receive, while reducing pollution by a target percentage within a particular time frame. However, some decisions could be implemented on a level affecting all ports similarly, or each port could set its own standards and make its own decisions. The latter situation might turn out to be more costly for shipping in general. It is a question of the merits of centralised decision-making versus decision-making by individual ports, or subsets of them. It is definitely a strategic problem for the ports and for the entities with an interest in the outcomes.

Let us examine the potential players in more detail. It is through these players’ activities that pollution standards and capital investment levels are set, and contractual agreements are authorised. Since we are planning to model the effect of a given set of values of these parameters, we take their inputs as givens. By examining the model’s predictions, we understand how the individual PORT positions are affected by changes or proposed changes these entities set forth.

In our model we explicitly consider only ports (PORT), port terminal operators (PTO), large motor carriers (LMC), small motor carriers (SMC), independent operators (OPS), and the Teamsters Union (UNION). These entities have the ability to make financial decisions about specific port operations that affect

1. the competitive position of the port
2. investments in pollution control for trucks
3. use of truck resources in container shipment supply chains.

The Teamsters Union appears in our model only insofar as they affect the cost of freight movement through a higher wage than owner operators, and therefore a higher cost per TEU-mile moved thru a given port. In their roles as lobbyists, influencers, and legal activists they are not explicitly considered. Nor are they considered as organisers of employee operators. Our model will make the following assumption: if an LMC elects 100% participation in an upgrade of trucks to the standard set they will also pay the union wage.

As Figure 1 shows for a single port, the entities are related through a hierarchical set of decisions. The PORT sets the truck pollution goal, the amount of capital support for truck improvement, participant fees for containers or trucking operation, and possibly other rules of play in the contracts. It also selects (or is stuck with) one or more PTO’s. Each PTO selects its motor carriers from among the candidate LMC’s and SMC’s. Carriers of both types may be selected. Note that the SMC’s could include individual owner operators, who might or might not upgrade their truck. The LMC selects OPS either as employee operators (with a higher wage rate), in which case the LMC is responsible for any capital expense to upgrade trucks to meet the port pollution goal; or OPS who are owner-operators; the OPS-OO’s are responsible for the capital expense to upgrade the truck, and receive a lower wage rate. An SMC on the other hand, selects only OPS-OO’s and therefore does not have to pay the capital expense to upgrade the truck; it
is paid by the OPS-OO if she chooses. The SMC pays a lower wage rate to the OPS-OO’s chosen.

**Figure 1** Decision relations between entities at a port

![Diagram](source: Author’s drawing)

Both LMC’s and SMC’s have a choice about the percentage of their operators they will choose with upgraded trucks. If an LMC upgrades its fleet, its percentage $p$ will be 100% (fraction 1). In this case we assume the LMC will choose EO’s or will pay the EO higher wage rate, which translates into a higher truck cost per TEU-mile. If an LMC chooses a mixture of $p$ EO’s and $(1-p)$ OO’s, it will on average pay a blended cost per TEU-mile.

Each EO is assumed to represent an upgraded truck. However, an OO has a choice of whether to upgrade her truck or not with the given capital expense. The EO or OO will receive her wage rate but must cover the capital cost. Considering the aggregate of drivers of type OO, therefore, we assign a percentage $q$ to represent the likelihood that a given OO chooses to upgrade her truck.

In choosing a fleet of EO’s and OO’s, the LMC or SMC must choose enough with upgraded trucks to meet its chosen percentage $p$. Simultaneously, the OO’s are as a type upgrading with probability $q$, and if too few choose to upgrade, there will be a shortage of upgraded trucks. The port will not be able with this pollution goal to obtain enough trucks to meet the demand it forecasts. Hence, its competitive position will be worsened, and it will in the long run lose traffic to other ports that can supply enough trucks, perhaps through lower standards, or a more generous subsidy to the OO’s and MC’s of the capital expense of the upgrades.

4 **A model of drayage firm-owner interaction**

Our model of interaction between drayage firms and owner-operators is a simple simultaneous move two player strategic game between a MC type (D for drayage) and an OPS-OO type (O for owner-operator). A D type D’s strategy is to choose a percentage $p$ of upgrade to its truck fleet to meet the clean standard, paying the upgrade cost CD per year for the period of use of the vehicle. Each O type chooses the probability $q$ with
which it upgrades its truck by paying CK. CD is potentially different from CK because
the amount of the subsidies the port chooses to D and O may differ. Straight line cost
assignment is assumed. Tax advantages may result in different accounting cost for that
purpose, but as an economic cost it should be an equal weight per year. We also do not
consider discounted cash flows, to simplify the argument and eliminate need for
assumptions about discount rate.

A strategy profile for the players (O, D) is therefore the pair of probabilities (p, q).
The expected payoff to D from working with O is given by \( f - (CD)(p - q) \), where \( f \) is the
freight rate per volume unit (which will ordinarily be a TEU), and \( \lambda \) is the volume
units per year moved by O. The expected payoff to O from associating with D is given by
\( w\lambda - (CK)(q - p) \), where \( w \) is the return to the operator per volume unit. We impose the
additional condition that payoffs must be positive for each player to participate. With a
payoff function for each strategy profile, we can determine the Nash equilibria of this
game, and find a Pareto order for them.

To do so, we consider best response (or reaction) functions for D and O, denoted
\( BR(D; q; p) \) for the value of the response of D to O playing with strategy \( q \), as a function
of strategy \( p \), and \( BR(O; p; q) \) for the value of the response of O to D’s play with strategy
\( p \), as a function of O’s strategy \( q \). For D, strategy \( p_1 \) is preferred to \( p_2 \) when \( BR(D; q; p_1) \geq BR(D; q; p_2) \). For O, strategy \( q_1 \) is preferred to \( q_2 \) when \( BR(O; p; q_1) \geq BR(O; p; q_2) \). For D, therefore, \( f - c(p_1 - q) \geq f - c(p_2 - q) \), which yields \( p_1 \leq p_2 \). There are four
possible cases, with outcomes as indicated:

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<tr>
<th>Case</th>
<th>Description</th>
<th>Solution</th>
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<tbody>
<tr>
<td>I</td>
<td>both ( p_1 ) and ( p_2 ) are &gt; ( q )</td>
<td>( p_1 \leq p_2 ) for any ( q )</td>
</tr>
<tr>
<td>II</td>
<td>( p_1 &lt; q ) but ( p_2 &gt; q )</td>
<td>Never</td>
</tr>
<tr>
<td>III</td>
<td>( p_1 &gt; q ) but ( p_2 &lt; q )</td>
<td>Always; for all ( q )</td>
</tr>
<tr>
<td>IV</td>
<td>both ( p_1 ) and ( p_2 &lt; q )</td>
<td>( p_1 \leq p_2 ) for any ( q )</td>
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For O, the symmetric result is \( w\lambda \leq -(c)(q_1 - p) \geq w\lambda - (c)(q_2 - p) \), which yields \( q_1 \leq q_2 \). Again there are four possible cases:

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In addition, the equilibrium chosen must be profitable for both D and O. For this to be
true we have \( f \geq CD \) and \( w\lambda \geq CK \). We put the NE findings
together in Figure 2. Each best response exists only in the northwest or southeast triangle
(respectively). The constraint creates infeasible triangles (grey), in the upper left and
lower right corners, determined by the size of CD and CK respectively. The Pareto order
of each best response is from smaller values to larger ones; a player would rather use the
smallest value of its strategy it can, indicated by the arrow. Hence, the Nash equilibrium
strategy profiles for this game are exactly on the diagonal \( p = q \), and furthermore are
Pareto ordered from (0, 0) best, to (1, 1) worst. We conclude that
Both drayage firms and owner-operators would rather upgrade with the smallest probability.

Each type will choose the percentage the other is choosing. If not, the other will play 0.

The role of the Port, to reduce pollution, is to increase the percentage for each.

Under these conditions, the Port must choose a strategy that keeps the percentage the same for both D and O. Thus, the problem for a Port is to introduce a scheme which will cause the parties to play a high \((p, q)\) strategy jointly. D and O should not be treated differently in terms of rules about percentages upgraded.

And the best thing is to keep CD, CK low (pay higher subsidies), which would make them expect a higher payoff and therefore be more likely to choose Nash equilibrium with a higher \(p\) and \(q\) – more likely to convert trucks. A look at sensitivity shows that if either freight rates or wages are too low relative to the subsidy, the grey infeasible region (upper left or lower right) creeps close to the NE line. Of course the equilibrium must be feasible, but if there is considerable volatility of either \(f\) or \(w\), the player of that type might decide that the risk of it dropping too low means she should not join the game. Thus, the function of the subsidies is to keep the infeasible regions away from the NE decision space. Different subsidies to O and to D do not affect the equilibrium choices, except possibly to rule out certain non-equilibrium strategies. So we have

Subsidies for upgrades must keep the cost of upgrade low enough so that players choose to continue playing in view of their expectations of future freight rates and wages.

Figure 2  Strategy space of drayage and owner types, with regions (see online version for colours)
5 Discussion and conclusions

In this paper we have attempted to give some insight into the conflicts and difficulties experienced in North America so far in putting into place programmes to reduce air pollution by setting standards and subsidising upgrades of the diesel trucks all ports use for harbour trucking. The legal battles themselves show that the many interest groups who have positions can hold up implementation. It is possible that such legal and legislative decisions can prove to be counterproductive, at least to some ports, if they are of sweeping nature. Hence, it is very important to understand the dynamics of clean truck policies and their effect on decision-making.

We chose to model the simple yet strategic interaction in the market between owner-operators of trucks and drayage firms who hire them, using a game in which the strategy for each is the probability of upgrading, and the parameters are freight rates for the drayage operators, wages for the owner-operators, and the cost of upgrading net after subsidies for each party. We conclude that:

1. Percentages of trucks upgraded should be the same for drayage firms and owner-operators, since any other option is not a Nash equilibrium and will not be preferred by economically rational players.

2. Because the equilibria are preferred in the same order (Pareto ordered) for both players, they will prefer the lowest percentage they can obtain. So if a percentage is stipulated they will go no higher.

3. Subsidies for upgrading should be large enough that, considering freight rates for the drayage firms and wages for the owner operators, the percentage both choose is feasible – neither party will lose money on the transaction.

4. Ports must pay attention to expectations of fluctuations in freight rates and in wages, to a lesser extent because they react slower due to contractual commitments. These would cause one or the other party not to generate a profit. This risk factor might induce players to drop from the market game even though it appears currently profitable, because there is not an expectation of continued success. Such concerns would be especially relevant in periods of high volatility, such as when recently the freight traffic dropped drastically at West Coast US ports, and freight rates plummeted. Many truckers felt they could not remain in business if rates went lower, and chose not to upgrade.

Summarising, the choice of subsidies, the going freight rate and wage costs per TEU, as well as choice of the pollution reduction goal and fee structure, affect the amount of truck upgrading, and therefore the ability of the port to meet its demand forecast in TEU. Too low a choice of upgrade percentage will adversely affect the amount of pollution reduced, while too high a percentage may produce a shortage of trucks. Too low a subsidy will reduce the feasible region of operation for firms and owner-operators; if either party feels that there is a chance that the market price for freight or the market wage may fluctuate below feasibility, the players may be reluctant to upgrade due to a perceived risk of operating in the red later on.

The North American ports all see the need for particulate pollution standards and implementation devices. They compete for freight from supply chains of various kinds, either for domestic US delivery, land bridge delivery to Europe, or other routes. Each
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port must be careful to set pollution standards high enough to capture supply chains that have sustainability as a choice criterion, high enough to satisfy regional interest groups, and low enough to assure that there will be trucks to handle the number of units they expect to move. As we indicated above, different regions have made different sorts of efforts to implement a Clean Truck Plan. In addition, the progress of the lawsuits raises the spectre that a federal standard which will apply to all ports will be put in place; or that the individual port’s ability to negotiate subsidies and percentages of trucks upgraded will be compromised legally.

Thus, it is of interest to investigate whether a given policy concerning clean trucks will cause ports to desire to join together in common application of the standards, or will make them more interested in either going it alone or working with a limited set of ports. This they will do if they perceive that they are subsidising other ports (perhaps the larger ones?) by not lowering their standards, or by having to offer large subsidies for clean upgrades. We propose that this scenario be analysed in the future by using cooperative game theory.

References


Port of Los Angeles (2009) ‘Freight industry perspectives and priorities’, Presentation by Christensen, M. to AASHTO Special Committee on Intermodal Transportation and Economic Expansion, 23 October.


