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The truth, the myths and the possible in freight road pricing in congested urban areas

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Abstract

This paper discusses a number of myths related to the trucking industry, its economics, and the industry response to pricing and what the author considers a fundamental truth and a possible course of action. The paper analyzes the empirical and econometric evidence about the behavioural impacts of freight road pricing, complements it with game theoretic analyses, and concludes that moving trucks to the off-hours require comprehensive policies targeting key components of the supply chain (i.e., receivers and carriers). The paper discusses the role of agent interactions and their role in determining freight mode choice, and the carrier industry response to time of day pricing. The paper shows that shipper-carrier interactions are part of a cooperative game in which both agents interact to find the overall optimal.

The paper also shows the decision about delivery times is jointly made between carriers and receivers, as part of the “Battle of the Sexes” game. This suggests that moving truck traffic to the off-hours requires a change in the behaviour of receivers, so that they accept off-hour deliveries. This could be accomplished by a combination of financial incentives to receivers in conjunction with freight road pricing. Due to the fact that transporting during the off-hours is more efficient than during regular hours, it is likely that, should a sufficient number of receivers be willing to accept off-hour deliveries, the carriers will follow suit. The paper suggests a toll surcharge to finance the incentives to receivers.

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1. Introduction

The need for road pricing arises because the drivers only consider their own (private) costs when deciding on the amount of driving they make, as they do not take into account the amount of externalities produced. As a result, since their private costs are only a small fraction of the total costs to society, car users drive in excess of what is economically optimal. In the case of automobile transportation, there is ample theoretical support and empirical evidence that, indeed, show that road pricing is an effective transportation demand management technique, that not only increases economic welfare but generates a significant amount of revenue that could support transportation...
investment (Sullivan, 2003; Sullivan and Harake, 1998). In the case of freight transportation, however, the picture is not so clear. This is because urban freight transportation exhibits a number of rather unique features that reduce the effectiveness of road pricing, as is discussed in the paper. Obviously, understanding how these factors hinder or foster freight road pricing is a crucial first step towards the definition of urban freight policies. Achieving this goal requires discussing a number of misconceptions that affect the way in which professionals think about urban freight. These misconceptions represent the “myths” discussed in the paper, which are then contrasted with the “truth” and the “possible.”

This paper is based on two different research projects that provide complementary views of the behavioural impacts of pricing on the commercial trucking sector in the New York City (NYC) metropolitan area. The first project focused on the quantification of the behavioural impacts produced by the Port Authority of New York and New Jersey’s time of day pricing initiative (Holguín-Veras and Ozbay et al., 2005). The second project focused on the definition of comprehensive policies, i.e., targeting the entire supply chain, to induce a shift of urban commercial truck traffic to the off-hours (Holguín-Veras, 2006). Taken together, these projects provide the most comprehensive examination of the observed impacts of pricing on commercial traffic and the first stated preference analyses of policies that go beyond road pricing. To a great extent, this paper relies on previous publications (Holguín-Veras and Cetin et al., 2006; Holguín-Veras and Pérez et al., 2006; Holguín-Veras and Polimeni, et al., 2005; Holguín-Veras and Silas et al., 2006a; Holguín-Veras and Silas et al., 2006b; Holguín-Veras and Silas et al., 2006c; Holguín-Veras and Wang et al., 2006) to attempt to put together the most comprehensive treatment of the subject that the limited empirical evidence permits.

The paper starts with a conceptual description of the fundamental interactions between the different agents involved in urban freight. The second section provides a brief summary of key findings of the research projects on which this paper is based. This is followed by a section in which myths and truths of freight road pricing are discussed. The conclusions at the end of the paper highlight the key findings.

2. The Fundamental Interactions

Freight demand is the result of complex interactions among numerous agents, including: producers, shippers, freight forwarders, carriers (both private and common), receivers, regulatory agencies, to name a few. This should not come as a surprise because it is well known that transportation demand is derived from the interactions among economic sectors geographically dispersed. In the case of freight demand the derived nature of transportation demand is obvious because of the different agents involved, as opposed to the passenger demand case in which the existence of a sole decision maker, i.e., the passenger, tend to obscure things. As a way to simplify this complex picture, one could re-define and re-group the freight agents so that the focus is placed on the functions most important for modelling purposes: shippers, carriers, and receivers. In the context of this paper, the “shipper” refers to the economic agent(s) associated with the production and the shipping of goods. The “carrier” represents the companies (e.g., transportation companies, Third Party Logistics providers) that are physically in charge of transporting the goods. The final group, i.e., “receivers,” represents the consignees of the cargoes. Again, this group of companies or individuals may end as well as intermediate users.

In this context, it is obvious that the interactions between shippers, carriers, and receivers, must affect truck traffic patterns, though not much is known about how to effectively consider these interactions in the context of planning models. This is surprising because these interactions are at the very heart of two of the most important decision processes in freight transportation planning: freight mode choice and freight road pricing. A solid understanding of the former is required to define policies aimed at reducing the dependence on trucking; and, in the same way, a thorough understanding of the latter is needed for the definition of efficient policies to move truck deliveries to the off-hours, when doing so makes sense.

Regarding the freight mode choice process, there is ample econometric evidence that indicates that the interactions between shippers and carriers determine mode choice. This seems to be the result of the interactions between shippers and carriers by which shippers, after experimenting with various shipment sizes and receiving input (e.g., prices, level of service, damage rates) from the carriers, finally settle down on a given shipment size, as discussed elsewhere (Holguín-Veras, 2002). This literature makes a convincing argument that freight and vehicle choices are best considered as part of a discrete-continuous choice problem in which the shipment size is the continuous variable and mode (or vehicle in the case considered in Holguín-Veras, 2002) is the discrete variable.
The evidence suggests that the shipment size choice, in essence, determines mode/vehicle choice, as correctly stated by Samuelson (1977): "...the relevant transportation choice which a shipper makes is not simply a choice between modes, but a joint choice of mode and shipment size. In most cases, the shipment size is practically mode determining...." (Samuelson, 1977).

In this context, shipper-carrier interactions could be interpreted as a cooperative game. The reason why can be appreciated by constructing the corresponding payoff matrix (see Table 1) that shows the anticipated payoffs to each player for cooperating, or not, with the other agent. The resulting four quadrants, corresponding to the different combinations, are labelled by superscripted numbers I, II, III and IV. The payoffs are indicated as a duplet with two signs, where a positive sign indicates a net benefit and a negative sign a net loss. The first sign in the duplet represents the payoff to the agent in the left of the matrix, while the second sign in the duplet represents the payoff to the agent on the top of the matrix.

As shown in Table 1, the three quadrants (i.e., II, III and IV) involving some degree of non-cooperation between shippers and carriers have negative payoffs for both agents, because:

- under typical market conditions, the non-cooperative carrier of quadrants II and IV would be sooner or later be replaced because its customers are not likely to be satisfied with its non-cooperative behaviour; and,
- the non-cooperative shipper of quadrants III and IV, by not choosing a shipment size convenient to its carrier, is likely to experience higher costs or lower quality of service.

If both agents choose to cooperate with the other, as shown in quadrant I, both of them are likely to be better off. This is because an adequate shipment size is likely to bring about lower transportation costs and better level of service because it would enable the carrier to take advantage of its strengths. In this context, since cooperation is the only logical alternative this is a cooperative game. This result has also been confirmed by economic experiments (Holguin-Veras and Preziosi et al., 2007).

<table>
<thead>
<tr>
<th>Shipper</th>
<th>Carrier</th>
<th>Cooperative</th>
<th>Non-cooperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative</td>
<td>(+, +)</td>
<td>(-, -)</td>
<td>(-, +)</td>
</tr>
<tr>
<td>Non-cooperative</td>
<td>(-, +)</td>
<td>(-, -)</td>
<td>(-, -)</td>
</tr>
</tbody>
</table>

The other case, which is the main focus of this paper, pertains to time of travel and delivery time decisions in urban areas. In this case, receivers, by imposing delivery time constraints and by virtue of being the carriers’ end customers, have a significant amount of power to influence the time of day at which trucks travel. It is obvious that without receivers willing to accept deliveries during the off-hours, the carriers cannot switch out of the peak hours. There shall be no doubt that carriers, with everything else being equal, would prefer off-hours to congested day hours. According to the estimates produced, if deliveries were made during the off-hours, the carrier costs would be 28% cheaper than in the regular hours (Holguín-Veras, 2006). Similarly, following the implementation of PierPass and toll surcharges for container moves during the day hours, surveys have confirmed that truck productivity has increased (Mongelluzzo, 2006).

A second factor, is the nature of the relationships linking shippers, carriers, and receivers. Two important cases ought to be discussed: integrated, and independent operations. Integrated operations refer to the case in which the agents in question are part of the same company, which leads to a decision making environment with a central decision maker that decides on behalf of the entire operation. Independent operations consider the case in which the agents are independent companies trying to maximize their profits. In this case, these agents engage in strategic interactions of the kind studied in Game Theory. These interactions give rise to numerous possibilities, as shown in Figure 1.

In the case of private carriers, i.e., those that only provide transportation service to a parent or related company, there is a significant degree of cooperation between the shipping and the receiving operations, in which what really
matters is the overall performance of the operation (as opposed to the financial performance of one of the parts). This is because of:

- the internalization of the benefits, which enable cross-subsidization between the carrier and the receiver operations; and
- the companies’ ability to switch all or none of the carrier-receiver operations to the off-hours, which enables them to extract the maximum benefits of off-hour deliveries, should they decide to do so.

As a result, since the decision is made on the basis of the overall performance, game theoretic analyses do not apply because there is only one decision maker that decides what is best for the entire operation. Because of this, it should not come as a surprise that the bulk of the companies that have implemented off-hour delivery operations (e.g., 7/11, Walmarta and Linens N Things) have private carrier operations.

The case of common carriers is completely different because there are two players (carrier and receiver) each trying to maximize profits. The payoff matrix for this case provides interesting insight into the nature of the dynamics between carriers and receivers. Table 2 shows the payoff matrix for the basic decisions associated with travelling and accepting deliveries during the regular or the off-hours. As shown in Table 2, the payoff matrix is very different to the one discussed before because there is no clear win-win situation. Obviously, if carriers and receivers do not agree in the delivery time (quadrants II and III) both of them would experience potentially significant economic losses. This is because the carriers would not complete the job and get paid, and the receivers would not get the cargoes they ordered. As a result, no rational set of players would select quadrants II or III. In the case of quadrant I, the receiver benefits because it receives the goods during normal hours when no additional staff are needed, though the carrier has to deal with the low productivity associated with travelling in congestion. The case outlined in quadrant IV represents the situation in which the carrier benefits from the higher productivity of travelling during the off-hours, while the receiver faces the additional costs of accepting deliveries during the off-hours (e.g., staff, security).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Receiver</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regular hours</td>
<td>Off-peak hours</td>
</tr>
<tr>
<td>Carrier</td>
<td>(-,+) (I)</td>
<td>(-,-) (II)</td>
</tr>
<tr>
<td>Regular hours</td>
<td>(-,-) (III)</td>
<td>(+,-) (IV)</td>
</tr>
<tr>
<td>Off-peak hours</td>
<td>(-,-) (III)</td>
<td>(+,-) (IV)</td>
</tr>
</tbody>
</table>

Figure 1 Nature of interactions

Table 2 Payoff matrix for integrated (common carriers) operations

The case of common carriers is completely different because there are two players (carrier and receiver) each trying to maximize profits. The payoff matrix for this case provides interesting insight into the nature of the dynamics between carriers and receivers. Table 2 shows the payoff matrix for the basic decisions associated with travelling and accepting deliveries during the regular or the off-hours. As shown in Table 2, the payoff matrix is very different to the one discussed before because there is no clear win-win situation. Obviously, if carriers and receivers do not agree in the delivery time (quadrants II and III) both of them would experience potentially significant economic losses. This is because the carriers would not complete the job and get paid, and the receivers would not get the cargoes they ordered. As a result, no rational set of players would select quadrants II or III. In the case of quadrant I, the receiver benefits because it receives the goods during normal hours when no additional staff are needed, though the carrier has to deal with the low productivity associated with travelling in congestion. The case outlined in quadrant IV represents the situation in which the carrier benefits from the higher productivity of travelling during the off-hours, while the receiver faces the additional costs of accepting deliveries during the off-hours (e.g., staff, security).
This means that the equilibrium solutions will be either in quadrants I or IV, where both players agree with the delivery time. However, which quadrant is selected, depends on which player has most market clout because there is no way to cross-subsidize. Since, as a rule, the receiver is the dominant agent, because it is the client, it follows that in most of the cases the solution is in quadrant I. This is obviously the case in most urban areas where the bulk of deliveries take place during the regular hours. In New York City, for instance, only 4.09% of deliveries are received during the off-hours (Holguín-Veras and Silas et al., 2006a). However, this is not to say that carriers do not have any power. As shall be seen later in the paper, some carriers do have some level of control to impose price increases and other measures that make receivers share the burden of road pricing.

Since from the societal point of view the most beneficial combination is the one in quadrant IV, because of the more balanced use of existing capacity (Yannis and Golias et al., 2006), it follows that the only way to move the equilibrium solution to the socially optimal outcome is to provide the receivers with financial incentives to convince them to accept deliveries during the off-hours. These compensation schemes are absolutely crucial to the success of policies aimed at moving trucks to the off-hours. Although admittedly simplified, these payoff matrices capture the essence of the dynamics between the agents involved in this decision. The reason why other factors, e.g., price signals, were not included in the discussion is clarified later in the paper.

In the following sections, the paper proceeds to discuss a number of myths, i.e., misconceptions, about freight road pricing and the carrier industry. As the truth, the author decided to focus on what he considers the key finding from the research conducted. The possible describes a proposal that is consistent with the key findings from the research conducted.

3. The Myths, the Truth and the Possible

This section discusses a number of rather popular ideas that, implicitly or explicitly, pervade transportation policy. Each of these ideas is examined under the light of the data and findings from the projects described in the previous section.

3.1. Myth #1: “All trucks are created equal”

This idea is implicit in transportation policy because of the lack of explicit recognition that different truck types have different impacts in terms of the externalities they produce. Since a fundamental objective of transportation policy is to foster the use of sustainable and socially beneficial technologies, not taking into account the differences among vehicle types is a major policy flaw. It is frequently argued that the larger truck combinations produce more externalities than smaller trucks. As a result, restrictions are frequently placed on the use of large trucks overlooking the fact that large trucks are more efficient than the small trucks. For that reason, restrictions on the use of large trucks end up increasing the traffic of smaller trucks that produce more externalities than the ones that would have been produced by large trucks in the first place. This is illustrated with two important externalities: pavement deterioration and road space consumption.

Pavement deterioration is measured by the Load Equivalency Factors (LEF), that quantify the total damage produced by a given design vehicle, which is measured in Equivalent Standard Axle Loads (ESALs). In this context, the LEF is the total number of ESALs produced by a given axle weight configuration. Table 3 shows estimates of LEF for different types of vehicles, together with estimates of the average payloads, and the resulting LEF/unit ton. As shown, although the five axle semi-trailer does produce more pavement deterioration than two or three axles single trucks, it is the most efficient type of truck because it is the one with the lowest value of LEF/unit cargo transported. As the reader could verify, transporting 150 ton could be accomplished by either using 6 semi-trailers or 14 three-axle trucks. However, while the semi-trailers produce 11.4 ESALs, the three-axle trucks produce 26.6 ESALs, i.e., more than twice the semi-trailers’ amount.

Table 4 shows similar computations for road space with respect to payloads. The road space was estimated assuming that it is equal to the summation of the vehicle length and a suitable value of spacing (assumed to be equal to 7m). As in the previous case, it is found that semi-trailers are the most efficient type of trucks. The author’s conjecture is that if similar calculations are done for environmental impacts or other forms of externalities, similar results would be found.
Table 3 Load Equivalency factors by vehicle type

<table>
<thead>
<tr>
<th>Vehicle Class</th>
<th>Description</th>
<th>Load Equivalency Factor (LEF)</th>
<th>Average Payload (metric tons)</th>
<th>LEF / Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial vehicles</td>
<td>2 Axle SU truck</td>
<td>1.4</td>
<td>3.23</td>
<td>0.4333755</td>
</tr>
<tr>
<td>5</td>
<td>3 Axle SU truck</td>
<td>1.9</td>
<td>11.38</td>
<td>0.1669329</td>
</tr>
<tr>
<td>6</td>
<td>4 Axle SU truck</td>
<td>5.4</td>
<td>15.64</td>
<td>0.3452685</td>
</tr>
<tr>
<td>7</td>
<td>4 Axle – 1 Trailer truck</td>
<td>2.8</td>
<td>18.04</td>
<td>0.1552106</td>
</tr>
<tr>
<td>8</td>
<td>5 Axle – 1 Trailer truck</td>
<td>2.4</td>
<td>19.92</td>
<td>0.1205012</td>
</tr>
<tr>
<td>9</td>
<td>6 Axle – 1 Trailer truck</td>
<td>5.5</td>
<td>22.88</td>
<td>0.2403703</td>
</tr>
<tr>
<td>10</td>
<td>5 Axle - Multi-Trailer truck</td>
<td>2.3</td>
<td>19.30</td>
<td>0.1191906</td>
</tr>
<tr>
<td>11</td>
<td>6 Axle - Multi-Trailer truck</td>
<td>5.5</td>
<td>19.53</td>
<td>0.2815721</td>
</tr>
<tr>
<td>12</td>
<td>7 Axle - Multi-Trailer truck</td>
<td>6.4</td>
<td>23.42</td>
<td>0.2732893</td>
</tr>
</tbody>
</table>

Table 4 Road space vs. payload

<table>
<thead>
<tr>
<th>FHWA Vehicle Class</th>
<th>Description</th>
<th>Road space used (m)</th>
<th>Average Payload (metric tons)</th>
<th>Length / Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial vehicles</td>
<td>2 Axle SU truck</td>
<td>14.6</td>
<td>3.23</td>
<td>4.5194878</td>
</tr>
<tr>
<td>5</td>
<td>3 Axle SU truck</td>
<td>16.1</td>
<td>11.38</td>
<td>1.4147627</td>
</tr>
<tr>
<td>6</td>
<td>5 Axle – 1 Trailer truck</td>
<td>23.7</td>
<td>19.92</td>
<td>1.1899491</td>
</tr>
<tr>
<td>9</td>
<td>6 Axle - Multi-Trailer truck</td>
<td>26.9</td>
<td>19.53</td>
<td>1.3771438</td>
</tr>
</tbody>
</table>

This stands in sharp contrast with current toll practices in the United States where toll policy either disregards the differences between truck types, or penalizes large truck combinations. This issue studied in a previous paper (J. Holguin-Veras and Cetin et al., 2006). The analyses highlighted that tolls for commercial vehicles, particularly large trucks (semi-trailers and long combination vehicles), seem to be disproportionately higher than the tolls for passenger vehicles with respect to their absolute values and their contributions to road space consumption and pavement damage (Holguin-Veras and Cetin et al., 2006).

3.2. Myth #2: “All carriers are created equal”

To the untrained eye, the carrier industry seems rather homogeneous, which could not be farther from the truth. This perception is a major problem because understanding the differences between the different segments of the carrier industry is a necessary condition to understand how to constructively engage it in policy making. The inherent heterogeneity of the trucking industry means that its different segments exhibit different behavioural responses to transportation policies. The analysis of the time of travel flexibility collected by the PANYNJ project indicates that for-hire carriers, are more constrained by their customers’ schedules and, as a result, have much less flexibility than private carriers. The average flexibility window reported by carriers with some flexibility (i.e., 26.6% of private, and 25.1% of common carriers), show that while private carriers could arrive about 79 minutes later, and about 55 minutes earlier; for-hire carriers could arrive only about 26 minutes later, and about 24 minutes earlier (Holguin-Veras and Wang et al., 2006). This implies that for-hire carriers are less sensitive to tolls because they have less flexibility to change the time of delivery. This should not come as a surprise because, as discussed before, private carriers enjoy more of a cooperative relationship with their receivers than common carriers.

The data shows statistically significant differences in the company characteristics between the carriers that
changed behaviour and those that did not. Carriers that changed behaviour are more likely to:

- focus on full truckload (FTL) services;
- employ relatively fewer interstate truck drivers; and
- venture in the areas outside New Jersey and New York making long haul trips.

The data shows that 28.0% of carriers that changed behaviour transported shipments that originated in areas other than New Jersey and New York, compared to those that did not change (9.9%), and that 30.4% of carriers that changed behaviour transported cargoes to areas outside the Mid-Atlantic region, while only 16.2% of those that did not change did so. This suggests that the segment of the carrier industry that showed the highest sensitivity to pricing is the group of companies that use the PANYNJ facilities to make FTL through trips. Conceptually, this makes sense because it is easier for carriers making long-haul trips to change routes and still meet the customers’ requirements. This stands in sharp contrast with the case of urban deliveries, in which even small changes in route or delivery times are likely to inconvenience some or all customers. The length of the trip chain is also another complicating factor. While long haul carriers typically deliver to one or two customers in one trip, urban delivery carriers deliver on average to 5.6 customers per tour (Holguín-Veras and Patil, 2005). This means that implementing changes in delivery patterns is significantly more difficult for urban delivery carriers than for long haul carriers.

3.3. Myth #3: “All commodities are created equal”

As a corollary of myth #2, one could be tempted to believe that the type of cargo transported is not relevant to transportation planning. Again, this could not be farther from the truth because the commodity type is a proxy for the industry segment in which the carrier operates. As a result, it should not come as a surprise that the vast majority of the behavioural research conducted on freight decision making has found out that the commodity type is a key variable. An obvious reason of why this is the case is that different commodities have different operational requirements that may require the use of specialized equipment, e.g., liquid cargoes.

A less obvious reason has to do with the nature of business relations. Many freight carriers develop business relations with specific customers, which lead them to get to know other customers in the same line of business; which may lead the company to focus, eventually, on a particular market segment for purely historical reasons. A third important reason is that the consideration of the commodity type implicitly captures the effect of the opportunity cost of the cargo. In this context, it is likely that a company transporting jewellery will exhibit an entirely different response to pricing than a company that specializes in cotton waste.

3.4. Myth #4: “Truckers love to drive in congestion”

This assumption is implicitly made whenever transportation planners and policy makers fail to realize that truckers travel during the congested hours of the day simply because their customers demand it, and not simply because they want to do so. Of course, truckers do not like to drive in congestion. This is obvious given the fact that their travel time values could be several times larger than the travel time value for passengers.

At this point, it is important to discuss the empirical evidence collected by the PANYNJ Evaluation Study (J. Holguín-Veras and Ozbay et al., 2005). The surveys conducted asked current regular users that did not change behaviour the reasons why they did not react to time of day pricing (Holguín-Veras and Wang et al., 2006). The largest group of reasons is that they do not have a choice (75.3% of truck trips) because they cannot change schedule due to the customers’ requirements (68.9%), or they must use the quickest route (6.4%). (These results are consistent with the fact that the same survey found that only 26.6% of private carriers and 25.1 of common carriers had some flexibility of time of travel.)

In general, for-hire carriers and private carriers reported the same main reasons for not changing their behaviour: they either do not have flexibility (due to their schedule or route constraints) or, to a lesser extent, their costs are paid by someone else. On the other hand, they exhibit some differences. For-hire carriers seem more likely to be constrained by their schedules; while private carriers tend to be less willing to change their routes. 72.3% of for-hire carriers cited cannot change schedule due to customer requirements while approximately 61% of private carriers reported the same reason. It was also found that a larger proportion of for-hire carriers (21.2%) did not worry about
toll increases since they transferred costs to their customers, compared to 16.3% for private carriers. (The reader shall take notice of the relatively small percentage of carriers that could pass the extra costs to their clients.)

3.5. Myth #5: “Truckers cannot react to pricing”

Trucking industry representatives argue that carriers cannot react to road pricing because they have to travel when the customers demand it. The truth of the matter, on the basis of the evidence discussed in the paper, is that carriers could indeed react to pricing, though the nature of this reaction may not be what one would expect. The PANYNJ data indicate that 20.2% of truck trips changed behaviour (this includes changing shipping charges) after the time of day pricing initiative. This includes current regular users that changed behaviour in different ways though still continuing to use the PANYNJ facilities (15.5% of carriers and 17.7% of truck trips); and some former regular users who cited tolls as the key reason to stop using the facilities (2.5% of carriers and 2.5% of truck trips).

The most striking feature of the carriers’ behavioural responses to pricing is their multidimensional nature, which included fifteen different individual behavioural changes. To facilitate the analysis, the individual behavioural changes reported by the carriers were re-grouped in three different strategy groups. Changes in facility usage includes all behavioural changes that imply changes in the amount of use of the facility. Productivity increases considers all behavioural changes that bring about increases in efficiency and productivity. Cost transfers includes behavioural changes by which cost is transferred to the end customer. Figure 2 shows the breakdown of responses (Holguín-Veras and Wang et al., 2006) in the form of a triangle in which the vertices represent pure strategies, i.e., without the use of strategies from another group. Two-dimensional combinations of strategy groups are represented as the mid points of the sides of the triangle; while the combination involving all three strategy groups is the centre of the triangle.

![Figure 2 Major combinations of strategy groups](image-url)
As shown in Figure 2, the single most important combination is to only implement Productivity increases (42.79%) which is shown as the lower left vertex of the triangle, followed by Cost transfer plus Changes in facility usage (27.60%), and Productivity increases plus Cost transfer plus Changes in facility usage (19.32%) that taken together represent 90% of all trips (Holguín-Veras and Wang et al., 2006). It is interesting to note that no carrier implemented changes in facility usage as the sole strategy, which is what most transportation professionals would expect. In all cases, Changes in facility usage are implemented in combination with other strategies.

Figure 2 suggests the existence of three different situations delimited by dashed lines. The first one represents the cases in which the carriers implement strategies that enable them to absorb the impacts of pricing, while insulating the receiver (with 42.79% of trips). At the other end of the spectrum, one finds the group of carriers that implement strategies that primarily impact the receivers (with 32.66% of trips). Somewhere between these groups, there are carriers that implement strategies that affect both the receivers and the carriers (the remaining 24.55%). This suggests that the response is determined by the balance of power between receivers and carriers. In this context, if the balance of power favours carriers, it is likely that policies that transfer most of the impacts to receivers be implemented. At the other end of the spectrum, if receivers dominate the relationship, the carriers have no choice but to focus on strategies, such as Productivity increases, that while insulating the receivers, enable them to mitigate the impacts of time of day pricing.

3.6. Myth #6: “Road pricing is the solution to get rid of those damned trucks”

The analyses of the data clearly suggests that road pricing is not THE solution to freight demand management in urban areas, though it is part of the solution. This is because of the nature of carrier-receiver interactions, the significant role played by receivers in setting delivery times, and ultimately trucks’ time of travel. In this context, receivers would react to road pricing and consider off-hour deliveries if, and only if, the price signal reaching them is larger than the incremental costs of moving operations to the off-hour. However, two factors work against this from happening. The first factor is that, because of the extremely competitive nature of the urban delivery industry, most urban carriers have a hard time transferring toll costs to their customers. The second factor, and most important factor, is that even when the carriers could pass the costs, only a diluted price signal—of no consequence when compared to the marginal costs of accepting off-hour deliveries (e.g., overtime costs, security, electricity), reaches the receivers.

To illustrate the point, it is important to discuss the findings from the PANYNJ project. The data indicate that carriers were only able to transfer costs to their customers in 9.0% of the cases (Holguín-Veras and Wang et al., 2006). The average increase in shipping charges (all carriers) was 15.5%, which is generally lower than the toll increases. This reflects the workings of an extremely competitive market with marginal cost pricing, where cordon tolls vanish from the marginal costs because they are fixed costs.

The dilution of the price signal occurs because most urban carriers tend to allocate the toll surcharges among all the customers in a given tour, on average 5.6 customers/tour (Holguín-Veras and Patil, 2005). As a result, the price signal reaching the receivers is on average about one sixth of the toll surcharge. This reflects the workings of an extremely competitive market with marginal cost pricing, where cordon tolls vanish from the marginal costs because they are fixed costs.

3.7. The truth: “Comprehensive policies targeting receivers and carriers are needed”

It shall be clear by now that freight road pricing as a demand management tool is not likely to be as effective as most transportation planners expect, and that expanding the scope of the supporting policies is absolutely necessary. This section discusses examples of alternative policies aimed at increasing the amount of off-hour deliveries. The analyses are based on the econometric modelling conducted using the stated preference (SP) data collected as part of the off-hour delivery project. Table 5 shows the model estimated for the scenario in which a tax deduction is offered
to receivers willing to accept off-hour deliveries. As shown, there is a direct relationship between the tax deduction and the likelihood of receivers agreeing to off-hour deliveries, as evidenced by the positive sign of the tax deduction. Furthermore, receivers of wood/lumber, alcohol, paper, medical supplies, food, printed material, and metal, are particularly sensitive to this policy. As a result, the net effects for these industry segments, the summation of the generic plus the industry specific coefficients, are significantly larger than for the rest of the industry.

Table 5 Best binary logit model for receiver’s tax deduction scenario

<table>
<thead>
<tr>
<th>Variable</th>
<th>Name</th>
<th>Coefficient</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility of off-peak deliveries:</td>
<td>C1CHOICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A tax deduction in any employee assigned to OPD</td>
<td>TDEDUCT</td>
<td>8.392E-05</td>
<td>1.410</td>
</tr>
<tr>
<td>Reasons for not receiving OPD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No access to building/freight entrance after hours</td>
<td>REASON1</td>
<td>-1.234</td>
<td>-1.571</td>
</tr>
<tr>
<td>Interferes with normal business</td>
<td>REASON2</td>
<td>-0.591</td>
<td>-1.208</td>
</tr>
<tr>
<td>Additional costs to the business if accepting more OPD</td>
<td>COST</td>
<td>-0.888</td>
<td>-3.232</td>
</tr>
<tr>
<td>Policy interaction terms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax deduction for Wood/lumber</td>
<td>TDCOM8</td>
<td>6.968E-04</td>
<td>2.219</td>
</tr>
<tr>
<td>Tax deduction for Alcohol</td>
<td>TDCOM4</td>
<td>4.356E-04</td>
<td>2.209</td>
</tr>
<tr>
<td>Tax deduction for Paper</td>
<td>TDCOM9</td>
<td>2.627E-04</td>
<td>2.988</td>
</tr>
<tr>
<td>Tax deduction for Medical supplies</td>
<td>TDCOM22</td>
<td>2.598E-04</td>
<td>3.188</td>
</tr>
<tr>
<td>Tax deduction for Food</td>
<td>TDCOM2</td>
<td>1.875E-04</td>
<td>3.973</td>
</tr>
<tr>
<td>Tax deduction for Printed Material</td>
<td>TDCOM21</td>
<td>1.652E-04</td>
<td>1.802</td>
</tr>
<tr>
<td>Tax deduction for Metal</td>
<td>TDCOM13</td>
<td>1.415E-04</td>
<td>1.410</td>
</tr>
<tr>
<td>Other interaction terms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of employees in a branch facility</td>
<td>BRANEMP</td>
<td>9.867E-03</td>
<td>1.612</td>
</tr>
<tr>
<td>Utility of no off-peak deliveries:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative specific constant</td>
<td>CONSTANT</td>
<td>1.599</td>
<td>4.151</td>
</tr>
</tbody>
</table>

R² 0.172
Adjusted R² 0.140

The discrete choice models estimated with the stated preference data collected from the carriers provided solid econometric evidence of the role played by receivers, and the ineffectiveness of freight road pricing. The carriers were asked if they would do off-hour deliveries if a given percentage of their customers request it, and if they could save on tolls by travelling during the off-hours. The models showed that the percent of customers requesting off-hour deliveries is a strong explanatory variable that impacts all carriers, which is obvious given the fact that the receivers are the customers. In contrast, toll savings only play a role in specific segments of the carrier industry, with a negligible impact on receiver behaviour. The model shows that only the carriers transporting petroleum/coal, wood/lumber, food, and textiles/clothing were found to be mildly sensitive to tolls. These are either non-perishable, low valued cargoes, or cargoes destined to receivers (restaurants) that tend to be open during the off-hours. In other words, while a request from the receivers has the potential to impact the entire carrier industry; toll savings only play a role in four different market segments.

These results indicate that policies that focus on providing financial incentives to receivers in exchange for their commitment to implement off-hour deliveries are more likely to succeed than policies solely based on freight road pricing. Given that receivers play the dominant role, their move to the off-hours is likely to pull the carriers, which the carriers would happily do if sufficient numbers of receivers request the service. There shall be no doubt that, in equality of conditions, most carriers would prefer to work in the night hours because the operating costs are 28% lower than in the congested day hours (Holguín-Veras, 2006).
3.8. The possible: Freight road pricing combined with incentives to receivers

Providing financial incentives to receivers willing to accept off-hour deliveries leads to the practical question of how to fund these incentives. The idea proposed in this paper entails using toll revenues to fund tax deductions to the receivers willing to accept off-hour deliveries. For illustration purposes, consider the effect of a toll surcharge of $5 to trucks travelling in the regular hours. Assuming 8.2 million trucks/year, which is the truck traffic at the PANYNJ facilities, the corresponding toll revenues would reach $40 million dollars (allowing for some demand contraction). On the other hand, a $10,000 tax deduction to restaurants accepting off-hour deliveries would lead to 20% of the restaurants switching from the regular to the off-hours (Holguín-Veras and Pérez et al., 2006). Although a 20% market share does not sound that impressive, the reader should keep in mind that according to the Census Bureau there are approximately 6,500 restaurants and drinking places in Manhattan; each of them receiving between 6 to 8 deliveries per day. Assuming that each truck is able to serve two restaurants in the same stop, this translates into a total truck traffic reduction in the day hours of 1.3 million trucks/year in the New York City network at a total cost to taxpayers of $13 million/year (Holguín-Veras and Pérez et al., 2006). More significantly, this would translate into a shift of truck traffic to the off-hours several times larger than the shift that occurred after the 2001 toll increases, and at a much lower political cost.

The remainder of the toll revenues could be used, very effectively, to provide financial incentives to large traffic generators (e.g., Grand Central Terminal, colleges and government offices), some of them receiving hundreds of deliveries per day, to accept off-hour deliveries. This is made easier by the fact that the vast majority of large traffic generators have central delivery stations that could receive off-hour deliveries and deliver them to the end customers during normal hours. The marginal costs of the off-hour delivery operation would be minimal.

In one sweep, providing incentives to receivers in exchange for their commitment to off-hour deliveries would, reduce congestion and environmental pollution, and equally important, increase the economic competitiveness of the urban area. The broad nature of these impacts, together with its policy appeal, is likely to facilitate full scale deployment.

4. Conclusions

The paper has attempted to put together, on the basis of the research conducted as part of two different research projects, a comprehensive picture of the potential role and inherent limitations of freight road pricing as a demand management tool in congested urban areas. The analyses, complemented with game theoretic discussions of the interactions between carriers and receivers, conclude that moving trucks to the off-hours require comprehensive policies targeting receivers and carriers.

The paper shows that a request from receivers asking carriers to do off-hour deliveries is likely to impact the entire carrier industry; while freight road pricing only impacts, and rather mildly, specific segments (i.e., carriers transporting petroleum/coal, wood/lumber, food and textiles/clothing) and that the magnitude of the price signal reaching receivers is of no consequence when compared to the cost of moving operations to the off-hours. This suggests that the most efficient way to induce a shift of truck traffic towards the off-hours is to provide financial incentives to the receivers. In all likelihood, once sufficient numbers of receivers are willing to accept off-hour deliveries, the carriers will follow suit.

The paper highlights and rebukes a number of myths related to freight road pricing in urban areas. Separating myth from truth and identifying the possible is a necessary condition to achieve the sound policy objective of moving towards a more balanced use of the existing transportation systems capacity.

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