Intermodal Chassis Supply in the US- A Bayesian Game Model

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Abstract

A container requires a chassis for every over the road move. In North America, unlike Europe, approximately 30% of chassis have been owned by ocean carriers, who are divesting their chassis. Older chassis bring higher risk for damage or disruption on a trip, though they cost much less than new chassis. Who will provide chassis to facilitate container moves by truck for the growing amount of intermodal traffic flowing through the US? The issue is important for successful port operation, and may require at least operational improvements, and governance decisions by ports or terminal operators. We examine strategic possibilities for a trucker and shipper supplying chassis, using a Bayesian game. We find equilibrium and estimate typical values of decision parameters to make predictions about the signals shippers will send and corresponding truckers’ strategy. Making truckers supply chassis may not be practical in North America, so additional specific policies and practices are needed. Inducing truckers to supply chassis under present economic conditions may require capital subsidies or higher freight costs, as well as improved operations.

Keywords: game theory, intermodal transportation, port logistics, container chassis, Bayesian games.

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1. Introduction

A shipping container chassis is a complementary product; we need one with every move by truck from the port, over the road or to the rail so demand for chassis is dependent. The provider of the chassis gets to charge for it, either by embedding the charge in the rate quoted for the move, deducting it from the freight bill, or explicitly as a rental fee. There are also expenses; the chassis must be inspected for roadability, a US federal requirement, twice in each turn; and the chassis will likely require occasional maintenance and repair, though not on each trip. There is a finite probability the chassis will fail during the trip and another must be provided, resulting in a deduction from revenue. Finally, there is the capital cost of the chassis, an opportunity cost which must be deducted. The party that does not provide the chassis must pay for it or reduce payment by an amount equal to the rate for a move charged by the provider. It does not matter whether the provider charge is actually paid, or simply reflected in her need to charge the ultimate customer; it reduces her contribution margin.
Chassis availability poses serious operations issues for marine and inland ports (Mongelluzzo, 2014). Without a chassis, cargo will not move; delays in getting one will be reflected in the reliability and performance of deliveries, affecting supply chains that use the port. Some ports operate their own pools to assure they have them; others rely, at least in part, on third party pools (Bonney and Mongelluzzo, 2014). Truckers need to pick up the chassis promptly without delay; finding a suitable unit with the expectation that it is operational. They also want an easy return. Maintenance should be conducted according to good practice standards. At certain ports, such as the Ports of Los Angeles/Long Beach, disputes between maintenance unions and port operators regarding who did the maintenance also introduce delays (DT.Gruelle, 2014). Such issues require governance activity, rules and obligations, as well as simple operational improvements. The atomic transaction, matching a chassis, trucker, and shipper for a single move, is worth understanding in detail. Game theory gives us an economically rational view of their strategic decision process. Policies or practice changes should be assessed in this light.

The primary players in this interaction are the potential providers. In the US, relatively few truckers own chassis, since their businesses usually try to reduce capital cost to the minimum. A trucker may lease or buy chassis. But she most often rent it at a daily rate from someone (a pool operator, yard, beneficial cargo owner, leasing company, shipper, or another private party). In the US, chassis interchanges are usually governed by the Uniform Intermodal Interchange and Facilities Access Agreement (UIIA) (Intermodal Interchange Executive Committee, 2013), developed and maintained by the Intermodal Association of North America (IANA) that spells out responsibilities of motor carriers and equipment providers. There may be no restriction on use of the chassis for the time rented; they may carry several containers in separate loads. However, the chassis must be returned to a specified location, and may vary, sometimes during the actual move, and result in lost time, a significant issue in contracting. Recent reports by truckers (IANA, 2013) indicate some providers are striking out or amending their contract terms without prior consultation, indicating that there is some contention. There is also great risk that a chassis can be idle due to its location, thus requiring substantial repositioning cost without a backhaul and liability associated with ownership. Truckers and ocean carriers prefer that ownership lie elsewhere. Since transportation deregulation in the US, there is close to perfect competition for the transportation product and few ways to distinguish the service. Thus the chassis must be obtained as cheaply as possible with little extra risk.

Opportunities for free riding occur, by failing to provide full inspection or maintenance. Truckers can today pick up chassis owned by others at a yard; they may need to check 3 to 4 before a road-able unit is found (Transportation Research Board, 2012). And there is moral hazard; when they return the chassis later there is a possibility that they will try to return a slightly compromised unit without repair and hope it is not noticed, leaving someone else to cover the damage. Until recently, chassis were not marked or identified, and roadability checks were documented only on paper reports (Federal Register, 2008). In 2011, the US Federal Motor Carrier Safety Administration (FMCSA) found that 17% of chassis inspected had roadability issues (Berg, 2011). The introduction of electronic chassis registration by FMCSA (Federal Motor Carrier Safety Administration, 2013), and the filing of electronic maintenance and inspection reports may result in less free riding but the press of providing guaranteed service times
to customers may still beg shortcuts, and it is not clear how policing would be effected if incorrect reports were submitted. If there were major damage from a chassis malfunction, reporting might allow responsible parties to be identified, but threat of a lawsuit is not necessarily a major deterrent. The FMCSA proposed a rule (Penn Intermodal Leasing, 2013) which would require reports to be filed only when the equipment was found not suitable for the road. This would reduce paperwork for truckers, but would prevent assessment of repair frequencies, and improvements in roadability.

The European model, in which truckers own the chassis (See, for example, Odyssey Logistics & Technology, 2012, and Rodrigue et al., 2010), is feasible there because trips are mostly shorter, resulting in quicker turns and more rides per day. Europe has chassis inspection rules similar to those coming into effect in the US. In the US, as in Europe, many drivers are owner operators, working at a piecework rate, and are under-capitalized (Arruñada et al., 2004). US firms with over $1 million in revenue average about 25% owner operators; in Europe the percentage is closer to 70% (Arruñada et al., 2004).

Bankruptcies are common in both areas (Cassidy, 2014; James, 2009). A diversity of chassis is required in the US, since the standard domestically is 53 feet, while for international containers it is 20 feet or 40 feet, each requiring different chassis; though there are newer chassis available which will fit universally. A typical new chassis costs $15,000, and the average age of the chassis fleet in the US is about 18 years (Rodrique et al., 2010). Only 2% of intermodal chassis are later than 2002 (DNJ, 2014). Many older chassis are outfitted with recapped tires rather than radials, and it is common for radials to be stolen from idle chassis in unprotected situations, so it is often not cost effective to upgrade the tires. IANA reports that theft of LED lights is a frequent cause of noncompliance on inspections (IANA Operations and Maintenance and Repair Committee, 2013). A used chassis from an ocean carrier fleet might cost as little as $3000 (see, e.g. Truck Paper, 2014), but would be subject to substantially higher maintenance expense and higher risk of failure en route.

Other possible providers are shippers, ocean carriers, pools, leasing companies, or terminal operators. Rodrigue et al. (2010, 2012) discusses chassis availability and its impact on port performance with alternatives in different areas described. It's an important US problem, as Bonney (2011) and Bonney and Mongelluzzo (2014) indicate. Two US chassis pools are CCM, a consortium owned by 18 ocean carriers, (see Chicago and Ohio Valley Consolidated Chassis Pool (2013) for their Chicago area locations) and TRAC Intermodal (TRAC Intermodal, 2013). The home improvement chain Lowe's has begun operating its own chassis fleet (American Shipper, 2013b). The American Trucking Association has successfully petitioned the US Surface Transportation Board (American Shipper, 2013a) to operate its own pool as a non-profit on behalf of truckers. The pool is known as the North American Chassis Pool Cooperative (NACPC) and has begun operation with about 3000 chassis in the Memphis TN area (Berg, 2013). Truckers and shippers alike are concerned about how to make chassis available.

Providing a chassis for a trip is a strategic dyadic interaction between the trucker and shipper. Non-cooperative game theory is therefore ideal for examining it. In contrast, cooperative games deal with outcomes, not negotiations. “In the cooperative approach we look directly at the space of outcomes, not the nitty-gritty of how one gets there” (Aumann, 1997). Since chassis provision is part of a more comprehensive contract, studying the single interaction is appropriate. It involves asymmetric information; trucker does not know if shipper has resources to supply a chassis in case she does not.
We can expect players to use their beliefs about the power of the opponent in shaping their strategy; thus an extensive Bayesian game is useful.

Bayesian games were introduced by Harsanyi (1977), extending strategic game equilibrium theory to cases of asymmetric information. Fudenberg and Tirole (1992) discuss them at length in two chapters of their text; they are applied, for instance, to Cournot competition in which one firm has private information about its cost (Fudenberg and Tirole, 1986); wars of attrition in marketing (Bishop et al., 1978); auctions (Chatterjee and Samuelson, 1983); and games of mechanism design, involving a principal and agents who have private information. Some Bayesian game modeling of individual transactions, such as terrorists selecting targets, has been done (for instance, Azaiez, 2009). Applications of Bayesian games to port economics or port operations are few. In their review Pallis et al. (2011) mention only two game theory applications, and these are not Bayesian. Also, the port literature has focused on decisions at the level of the major port actors, not specific transaction analysis. Recently, Wang and Pallis (2014) used mechanism design, a related asymmetric information game, to model moral hazard in port concession agreements. Sauri and Robusté (2012) use a principal-agent model with asymmetric information to analyze incentives in terminal concession contracting. Zheng and Negenborn (2014) use principal-agent theory and dynamic games to analyze optimal tariffs, capacities and efficiencies under centralized or decentralized port management practices. All of these model high level strategy between port authorities and terminal operators, rather than individual transactions.

Section 2 discusses the staged decision process for Trucker and Shipper and presents the Bayesian game. Section 3 provides some basic data for the North American market, and use the model to make predictions. Section 4 investigates sensitivity to some of the model parameters based on the earlier North American market estimates. Section 5 concludes with a summary of findings and suggestions for further investigation.

2. Bayesian Game Model

Consider two players, designated Trucker (T) and Shipper (S). Ocean carriers and terminal operators can qualify as shippers, as well as other consignors or consignees of the containers. Leasing companies are an intermediary, representing the shipper in short term leases. In making a deal for carriage, the trucker begins a two-stage process by assessing whether the shipper has access to chassis of her own, or not. There are two types of shipper; endowed (E) or weak (W). The Shipper has private information about their type; their ability to provide a chassis to move the cargo if 'push comes to shove'. The Trucker does not know the Shipper's type, but has a prior belief, expressed as a probability distribution on the two-point state space; Pr(W) = p, and Pr(E) = 1 - p.

Trucker can provide a chassis or not, strategies C or N. Trucker's strategy may depend on Shipper's type. An endowed shipper has a ready source of chassis, perhaps owned or easily accessed. To calculate payoffs to each player i in {T, S} under each strategy profile, let Z represent contribution margin or profit to i when they provide the chassis. Let W be the per trip rental price, the revenue to the player for use of the chassis for the trip, taken as given in our model. (It may be an opportunity cost, or a reduction to the overall drayage fee, for supplying). It is public knowledge; in the negotiation for a ride each party
must reveal their rental price. While a type W shipper might not disclose the information, the market for carriage is very competitive, with each side close to the market price for a complementary item, so that trucker can easily surmise a value near what shipper would charge her for use of a chassis.

The contribution margin \( Z_i \) from a trip is obtained from \( W_i \), reduced by the operating expenses and capital expenses related to supplying the chassis. Define the operating value ratio \( \phi_i = (1 - \rho_i - \mu_i - \gamma_i) \) the fraction of the use price left after costs of the trip are deducted, where \( \rho_i \) = risk of failure on a run requiring provision of a replacement chassis, modeled as a probability of failure; \( \mu_i \) = average cost of inspection on each trip as a percentage of trip revenue; \( \gamma_i \) = average cost of maintenance and repair as a percentage of per trip revenue. These parameters in practice are not always well known and different owners report widely varying values. Average maintenance cost per trip could in fact exceed the trip rent (\( \gamma_i > 1 \)), especially for older chassis; we must therefore not rule out the possibility that contribution to the owner is negative. But since the freight fee will not be gained without a chassis, the negative earnings might be justified in a broader complementarity sense. \( W_i \phi_i \) is the operating margin, the contribution without considering cost of capital.

\( K_i \) is the capital cost of the chassis, and \( r \) is the assumed interest rate per trip on capital. Clearly \( r \) varies with financial strength of the provider; we assume \( r \) the same for all. It is easy to extend our result by sensitivity analysis on rate variation; it is of some interest because in the US the truckers often have high borrowing costs, while large shippers may have much lower capital rates.

The contribution margin of the trip is then \( Z_i = W_i \phi_i - rK_i \). We assume the provider makes a positive charge to use the chassis, which may be identified, or bundled with the rate; \( W_S, W_T \geq 0 \). And we assume capital cost is positive; \( rK_S, rK_T > 0 \). Situations could arise when the effective interest rate for chassis purchase is negative; it may have prevailed recently, when potential tax credits could be offset against minimal borrowing costs. However, negative interest rates are very uncommon, and analysis of negative capital cost is left to another paper.

Operating margin per trip could be negative, if the sum of inspection, maintenance, and risk costs exceed the fee charged. In a complementary product situation, this is not impossible, though clearly any firm would wish to be sure they could charge enough to at least cover them. In economic terms, charging less would be charging below marginal cost and would not be sustainable in the long run. But we assume operating margin \( W_i \phi_i > 0 \) for both S and T.

The extensive Bayesian game structure is portrayed in Figure 1. Circles represent decision nodes; the letter inside identifies who makes the decision. Players’ payoffs are in the appropriate terminal box. Decisions for Trucker are in the set \( \{C, N\} \) where C means provide a chassis, and N signifies do not provide one. Information sets, where the same decision must be made at each node, are formed by connection with dashed lines.

A set of payoffs appears in this figure. The difference between weak and endowed Shipper payoffs occurs only when both parties have chassis. In that case, when S is weak, T's chassis is used, and when S is endowed, S's chassis is used. Otherwise, when player i provide a chassis they obtains operating profit
while their opponent receives \(-W_i\). The Shipper knows their type, but trucker begins only with a belief \(p\). Shipper moves first by sending a message or signal, an answer to “Can you provide a chassis?”, with possible values Yes or No. Either signal may be sent. A Shipper of type \(W\) could use a mixed strategy, sending Yes with probability \(\sigma(\text{Yes} \mid W)\), and No with probability \(\sigma(\text{No} \mid W) = 1 - \sigma(\text{Yes} \mid W)\). Likewise, a shipper of type \(E\) could send Yes with probability \(\sigma(\text{Yes} \mid E)\), and No with probability \(\sigma(\text{No} \mid E) = 1 - \sigma(\text{Yes} \mid E)\).

Once Trucker gets the signal, she has the opportunity to alter the belief. Rationally she will use Bayes’ theorem on conditional probabilities; Truckers are not necessarily Bayesians, but they do learn from experience, and the model may be sufficiently close to reality.
After revision, Trucker has the belief $s = \Pr(W \mid \text{Yes})$ when the message is Yes, and $t = \Pr(W \mid \text{No})$ when the message is No. Her Bayesian ex-post probabilities are computed using her prior probabilities $p$, $1-p$ and conditional probabilities of each type of Shipper.

$$s = \Pr(W \mid \text{Yes}) = \frac{p \sigma(\text{Yes} \mid W)}{[p \sigma(\text{Yes} \mid W) + (1 - p) \sigma(\text{Yes} \mid E)]} \quad (1)$$

$$t = \Pr(W \mid \text{No}) = \frac{p \sigma(\text{No} \mid W)}{[p \sigma(\text{No} \mid W) + (1 - p) \sigma(\text{No} \mid E)]} \quad (2)$$

Trucker has separate information sets depending on the message received, the dotted lines connecting Trucker nodes. Trucker must use the same strategy at both nodes, since she cannot tell how the information was received. Trucker may play a pure strategy, C or N; or a mixed strategy, depending on the relative payoffs of the two options. If Trucker has a dominant pure strategy at an information set, she will clearly use it; otherwise, a mixed strategy will be employed. It might or might not be based on her ex-post belief of likelihood that shipper is of an appropriate type.

A Bayesian signaling game has a perfect Bayesian equilibrium if three conditions hold.

1. Shipper's strategy (message), pure or mixed, maximizes her payoff.
2. Trucker's strategy (pure or mixed) maximizes her payoff subject to her belief about the Shipper's type.
3. Trucker's strategy uses the ex-post probabilities $s$; $t$ computed using Bayes' theorem based on Shipper's message strategy, for every on-the-path message shipper sends, that is, a message which Shipper actually has a nonzero probability of sending.

There may be multiple perfect Bayesian equilibria; some may rely on threats which are not credible.

In the game in Figure 1 it is immediate that Shipper will never send the No message; it is off-the-path, since her payoffs for the Yes message dominate. In symbols this is expressed by $\sigma(\text{No} \mid W) = \sigma(\text{No} \mid E) = 0$. Since payoffs are common knowledge, Trucker (as game theorist) knows she will never observe a No message. If Trucker were to observe the No message from Shipper, she has a dominant strategy C, to provide a chassis, but her equilibrium strategy upon receiving the No message could be anything; it will never be executed.

When the message Yes is received, Trucker prefers C when

$$sZ_t + (1 - s)(-rK_T - W_S) \geq -WS. \text{ So } s[Z_t + rK_T + W_S] \geq rK_T + W_S - WS \geq (rK_T) / (Z_t + rK_T + W_S). \quad (3)$$

A mixed strategy will be played at the probability given by (3). Trucker's Bayesian updated probability of Shipper being weak conditional on the message Yes being sent uses Equation (1)

$$\Pr(W \mid \text{Yes}) = \frac{p \sigma(\text{Yes} \mid W)}{[p \sigma(\text{Yes} \mid W) + (1 - p) \sigma(\text{Yes} \mid E)]} = (p * 1 + (1 - p) * 1) = p;$$

there is no updating, a pooling equilibrium, in which all types send the same message. If Trucker's ex-ante belief $p$ is used in her mixed strategy for $s$, the outcome is a perfect Bayesian equilibrium, by
condition 3. We can test whether the computed value $s$ using (3) is greater than $p$, when C will be chosen; if smaller, N will be chosen; or exactly $s = p$, when Trucker will randomly use $p$ choose C or N.

3. Game Analysis for US Chassis Supply

Estimates were made of parameters for US Trucker and Shipper chassis cost (for example in Truck Paper, 2014), rental fees, nominal interest rates and risk, maintenance and inspection (Swan, 2002). Figures are comparable in Europe (see for instance, T4U, 2014). US figures were gathered in various conversations with truckers and pool operators. Firms are often reluctant to reveal repair and maintenance costs and certainly risk of trip failure. Data collected for our averages were anonymous and based on interviews and conversations, at IANA and other intermodal industry meetings. A wide range of values is reported publicly for these; the interviews may be more current and accurate. More data will become available when the electronic repair reports history is online from FMCSA.

We assume the game is symmetric; figures identical for both players because of competition. An estimate of average holding period of a chassis is 3 days, in which on average 2 trips are made. There are about 120 trips per year for the chassis on average, though this varies with distance of run and congestion issues at ports. Typical inspection time is 1/2 hour, occurring twice in a trip (inspections are mandated at start and end), the expected inspection duration given by FMCSA (2013). A typical trucker wage is $15.00 per hour (Haveman and Monaco, 2009). The capital investment in a chassis $K_i$ is somewhere between $15000 for a new chassis and $3000 for a used one (See for instance Rodrigue et al., 2010 and TruckPaper, 2014). Capital interest rate $r = 6%$.

Typical maintenance costs per year are reported between $200 and $2000 (Swan, 2002); assume an approximate value of $600, a beta-distribution most-likely figure. These are hard to substantiate, since no maintainer is revealing them. Based on a typical chassis rate of $15 per day quoted by local pools, $W_i = $22.50 per trip. Assume that there is a 1% chance of breakdown on a trip; $\rho_i = .01$. Actual rates are probably lower. At the trucker wage above, $\mu_i$ is 0.67. At 120 trips per year $\gamma_i = 0.20$, which would mean repairs on a per trip basis are $4.50. Thus $\phi_i = 1 - .01 - .67 - .20 = 0.12$; the chassis provider keeps about one-eighth of the amount charged for the chassis rent as operating profit. Then $W_i \phi_i = $2.70 operating margin on each trip.

Capital cost per trip $rK_i = $7.50 for a new chassis and $1.50 for a used one. By symmetry, both parties pay the same interest rate. With these estimates, the contribution margin is $Z_i = $2.70-$1.50 = $1.20 with a used chassis, and actually negative, $Z_i = -$4.80 for a new chassis.

Compute the decision probability $s$ for Trucker’s strategy when the message from Shipper is Yes.

\[ s = (1.50) / (1.20 + 1.50 + 22.50) = 0.0596 \text{ using an old chassis} \]

\[ s = (7.50) / (-4.80 + 7.50 + 22.50) = 0.2976 \text{ using a new chassis} \]

The perfect Bayesian Equilibrium portrayed in Table 1 is attained when Trucker uses her prior belief $p$ about the fraction of weak shippers to make her decision.
Table 1 Trucker strategies and prior beliefs in perfect Bayesian equilibrium

<table>
<thead>
<tr>
<th>Pr(W)</th>
<th>Old Chassis</th>
<th>New Chassis</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Value of p</td>
<td>T strategy</td>
</tr>
<tr>
<td>p &gt; 0.06</td>
<td>C</td>
<td>p &gt; 0.30</td>
</tr>
<tr>
<td>p &lt; 0.06</td>
<td>N</td>
<td>p &lt; 0.30</td>
</tr>
<tr>
<td>p = 0.06</td>
<td>[.06]C ⊕ [.94]N</td>
<td>p = 0.30</td>
</tr>
</tbody>
</table>

If Trucker who receives the message Yes is using a new chassis, she should provide it when she believes there is more than a 30% or so chance that Shipper is of weak type; or less than 70% probability that shipper is endowed. And if she has an old chassis, she should provide it when she believes there is more than a 6% chance that Shipper is weak; i.e. even a high percentage of shippers are endowed. Trucker must be convinced there are enough weak Shippers to warrant offering a chassis. It seems that a trucker will be much more motivated to acquire an old chassis, much like used ones ocean shippers have. If she pays for a new one, she must believe there are many weak Shippers.

The Trucker with a new chassis loses money on each trip, not a positive motivation to acquire a new chassis; Trucker might easily choose to operate with an old one. We confounded estimates of maintenance and risk for new and older chassis (see Fender and Pierce, 2012) for evidence on equipment maintenance costs over time), in our estimate of $\phi$. Better data for repairs, risk of trip failure, and reduced inspection costs could change the old vs. new parameters and tip the balance. In particular, DVIR inspections required under the new FMCSA regulations have a standard work time estimate of 30 minutes. This means a trucker loses an hour of wage for the two turns in a load, two-thirds of the rental charged, in our example; about $14-$20 for a typical US independent owner operator (Haveman and Monaco, 2009). Maintenance costs and risk of an aborted trip are much higher for older chassis as well, further handicapping those using them. It is possible that even a Trucker who provides an old chassis will be losing money on each trip.

An additional issue is whether the Shipper and Trucker are truly symmetric, or require separate estimates. In the US, it is quite likely truckers' capital costs are higher than the 6% we adopted. A typical chassis can be leased by an independent for $375 per month ($4500 per year) or a period of 4 years. This represents an implied interest rate of 9.24% if the chassis were purchased at $15,000. (Hartman, 2013). Admittedly, the lease cost includes imputed depreciation; however the trucker is responsible for maintenance during use of the chassis. Ports might consider options to lower capital costs for truckers.

A final small point: we implicitly assumed that the operating profit $Z_j > -W_j$ when j is different from i. We discuss this below. Time cost for obtaining a roadable chassis at a yard, ramp, or pool site, another drain on the chassis profitability, has also not been factored in. This time would affect both partners equally, and not change the equilibrium. However, it is certainly a concern for Trucker. It might also force violation of the assumptions on $W_i$ or $W\phi$.

4. Sensitivity Analysis
How low does $Z_T$ go before Trucker will not provide a chassis under any circumstances? In Equation 3, if $r_K > 0$ is small enough and $W_T \phi_T$ large enough $s$ will approach 0, and will always be less than $p$. Trucker should always play C. If interest rates go up so that $r_K$ is large, or if $W_T \phi_T$ becomes very small or negative, Trucker will be more motivated to play N if her belief is below the threshold. $r_K > W_T \phi_T + W_S$ means N certainly will be played on hearing message Yes. Trucker would be motivated not to provide chassis when capital cost of ownership is larger than the net of rent of a chassis from another party and loss from operating herself. $W_T \phi_T$ might be negative, when risk, maintenance, and inspection cost are large. Clearly $W_T \phi_T < 0$ is a bad situation for Trucker; no operating margin means marginal cost exceeds short term marginal revenue; Trucker would leave the market when capital was exhausted. With chassis as loss leader; eventually trucker ranks would be depleted.

A second factor is the size of $\phi_T$. It is small when risk, inspection, and maintenance costs cover a large part of $W_T$. It is possible that they could exceed it, and $W_T \phi_T < 0$. In this case $Z_T$ is even more negative. If $Z_T < -W_S$, even if a Yes signal is received, Trucker would choose N. There would be no reason to supply a chassis; the simplest thing to do would be to force shipper to supply one, requiring all shippers to be endowed. Some issues of operational nature could clearly be influenced by practice at the port and through port monitoring:

1. Inspections are costly in terms of trucker time. Steps could be taken to decrease the cost.
2. Maintenance, which according to the UIIA is a Trucker's responsibility, will not decrease. A case in point: LED lighting, approximately 5 times the cost of standard lighting, must produce great improvements in risk to be justifiable. Radial tires similarly need to reduce the risk of a load failure greatly to be worth the cost, and offset the risk of theft which disables the trailer.
3. The risk may well be below 1 in 100 loads aborted (about once per year), but even reduction a hundredfold would not affect the current cost picture more than 1%.

IANA has established a Task Force on Roadability (National Operations and Maintenance and Repair Committee, 2013) to study these multiple operational issues. Its purpose is to decrease risk of failure, lost time in preparing to use equipment, maintenance cost, and uptime for drivers, recommending best practices in usage, repair, and exchange of chassis and other equipment. The task force is headed by a senior executive of an equipment leasing firm, which shows that there is great concern.

To convince a trucker to bear the cost, shippers could pay a larger rental, or take actions such as reducing time truckers wait to obtain or return chassis. Another strategy is to arrange to keep the cost of investment low for truckers, for instance by pooling capital for low cost loans, though such rules could violate US constraint of trade provisions unless the capital was accessible to all. Ports could facilitate this much as the Clean Trucks Programs (Clott and Hartman, 2013) subsidized costs of emissions upgrades to trucks.
Too many endowed shippers and too low rental rates tip the balance toward reluctance on the part of truckers to provide chassis, creating risk of a shortage, reducing service levels and profits for shippers. It is possible that shipper-operated pools contribute to the perception that shippers have chassis.

One must consider bounded rationality; truckers and shippers might do something different from the equilibrium. If shippers send the No signal, it would encourage truckers to supply chassis. However, endowed shippers would supply anyway if it were profitable, making truckers more skeptical of weakness claims. If charges were different, trucker would have to offer a price enough below \( W_S \) to induce shippers not to supply, reducing trucker’s profit. We do not investigate this asymmetry here. Truckers might not use their ex-ante belief, but some other belief about the shipper. Since a trucker plays repeatedly with different shippers, there is likelihood that over time a successful trucker will adjust beliefs toward \( p \); convergence to equilibrium is often observed in repeated experiments with game situations.

5. Conclusions

In this paper we have modeled the transaction of providing a container chassis for hauls as a Bayesian game; shippers signal whether they can provide a chassis, not necessarily their actual type, and trucker responds by providing or not. But analysis with typical US parameters and a symmetry assumption show that in equilibrium, shippers will always say they have a chassis available, whether or not it is true. Trucker then bases their decision to offer on prior belief. Essentially, Trucker evaluates whether they believe there are enough truly weak shippers to make it worthwhile to offer a chassis. If their chassis is new, they must believe there are more than 30% weak shippers; if their chassis is old, more than 6%. These cut points depend on risk that the chassis will prevent delivery, inspection costs, maintenance costs, ownership costs, and what the shipper would charge, versus what they would charge.

Contribution to Scholarly Knowledge

This model of the shipper-trucker micro transaction in a port economics setting is new. It is a pure Bayesian game, not a principal-agent scenario, unlike most other game modeling in ports; most address higher level interactions rather than examining what individuals do. Modeling dynamics of the transaction illuminates for those concerned the rational economic pressures present in the trucker-shipper situation; this will influence governance policies toward chassis and focus operational revisions to chassis procurement. It is worthwhile to note that potential parallels exist with container or simalift acquisition, and even to special use trailers such as chemical or agricultural products; our conclusions are related to any item complementary to an intermodal move.

Implications for Managerial Practice

The larger profit motive truckers have, the more likely they will provide a chassis. Shippers, such as ocean carriers, who need the cargo moved, cannot afford to be bereft of ways to get chassis; it is cheap talk to declare weakness. The evidence that 18 ocean carriers have formed the CCM pools, cited above,
indicates they want to be sure they have chassis available. This makes them endowed players. Rational truckers fail to supply not just because of unfavorable economics, but also their prior belief that most shippers are not weak. They therefore seem to 'play the odds' they will not get to supply the chassis anyway in most cases. And they may be right.

Perhaps a better strategy for shippers is to allow truckers to charge more for transport with their chassis, or provide very cheap credit for chassis capital cost. As with the Clean Truck Programs at the Port of Los Angeles/Long Beach, capital may be needed as microfinance to assist truckers. This could take the form of a subsidy, or a buy-down of interest rates to acquire chassis. Here ports and shippers might cooperate to create such a strategy. Subsidies in the Clean Truck Program proved very successful in getting trucks upgraded to 2007+ emissions standards. Economic study of microfinance methodologies and their impact would be useful research. A chassis is not costly, but truckers have scarce capital and the variety of chassis in use makes it unlikely that a trucker would buy chassis without a guarantee of business. However, US truckers have demonstrated they value their independent status and dislike rules that prevent it. Intermodal chassis policies need to be measured carefully against truckers' motives, including rational economic ones.

On the operational side, any actions which increase availability of chassis, decrease delays and restrictions in getting and returning them, and improve maintenance would tend to increase trucker participation. These uncompensated costs for truckers additionally bias their choice. Eliminating them should take priority at ports and chassis pool locations, and throughout intermodal operations. Chassis providers could also reduce cost of inspection and maintenance by providing chassis unlikely to fail in service.

Impending trucker and chassis shortages are being realized now at some ports (O'Reilly, 2011), and are much discussed in the US currently. Understanding rational motivations and signaling behavior is important for port operators and for policy makers, as the chassis is a crucial part of container movement. Ports must facilitate their container traffic, and some action will be needed to assure supply of both trucks and chassis. Better policies and mechanisms will arise from this understanding.

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References


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