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A PERFORMANCE AGREEMENT TO ALIGN THE OPERATION OF A LOADING DOCK AND A FLEET*

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ABSTRACT

This article examines a company whose distribution operation is carried out by a loading Dock and a Fleet of trucks. For a number of reasons, each department optimizes its operation locally, with no concern for the operational alignment of the overall system. To resolve this problem, a contract is proposed that will provide an incentive for improved operations, particularly at the loading Dock. The contract specifies a payment from the Fleet to the loading Dock calculated on the basis of a reduction in Fleet size made possible by improvements in the Dock operations. This methodology is applied to a mass consumption product distributing company in Santiago, Chile. Significant savings opportunities result, thanks to operational alignment.

Keywords: Performance Agreement, Alignment, Fleet, Incentive, Transfer
JEL Classification: C61

RESUMEN

En este artículo se considera una empresa cuya distribución se realiza mediante una unidad de Despacho de camiones y una Flota de transporte. Debido a diversas causas, cada una de ellas está optimizando localmente su operación, sin preocuparse por el alineamiento operacional del sistema global. Para solucionar este problema se plantea un convenio de transferencias monetarias que incentiven mejoras operacionales, particularmente en la unidad de Despacho. El monto de dicha transferencia se calcula a partir de la rentabilidad de las mejoras que produzcan una disminución del tamaño de la flota. Esta

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metodología es aplicada en una empresa distribuidora de productos de consumo masivo de Santiago, derivándose importantes oportunidades de ahorro gracias al alineamiento operacional.

The operation of a company which distribution system consists of two autonomous units, namely *Dock* and *Fleet* is analyzed herein. Even if part of the same company, such autonomy may arise from an interest in making the units' management independent from each other in order to identify possible inefficiencies, or to allow the Fleet to service other clients. In addition, in some circumstances tax legislation favors outsourced transport services, so strong incentives exist to create a satellite enterprise for that purpose. Nevertheless, even if the Dock and the Fleet belong to different owners, these businesses may form a strategic alliance whereby both ventures benefit from the success of the other.

Being autonomous, often these units determine the size of their operating capacity so as to optimize local results. According to the conceptual framework proposed by Donoso (1998), this situation is very likely to generate a loss of alignment with respect to the company's overall objectives.

In contrast to this, a centralized strategy would determine the optimal configuration for the company's operation, and then instruct each unit to size itself to match optimal requirements. This can be achieved through modeling the distribution system, which is subsequently optimized using quantitative methods. For examples of the use of this technique for transport Fleet sizing see Dejax and Crainic (1987), Beaujon and Turquinst (1991) and Du & Hall (1997).

One decentralized course of action, which has been described by Mostafa *et al*. (1984), consists of implementing *transfer prices* whereby a company's internal units are economically rewarded for services provided. The underlying philosophy of this technique is to simulate market conditions, where prices assign value to the more effective and efficient agents. In the words of one of the founders of economic liberalism Adam Smith (1776), "[Every individual] pursues his ... own gain ... By protecting his own interest, he frequently promotes that of the society more effectively than when he is really trying to do it".

Ronen and McKinney (1970) point out that monetary transfer agreements between a company's different units must meet three conditions: *Accuracy* in evaluation, *consistency* with overall objectives and *autonomy* of each unit in determining its manner of operating. The accuracy condition requires that the value of the transfer should be a function of objective operating variables accurately measured. Consistency is attained by analyzing the overall system, and then defining transfer agreements that encourage units to find the desired configuration rather than imposing changes in a centralized way. Autonomy is guaranteed if no operating standards are set *a priori*, so that units are granted freedom of action for these purposes. In summary, a transfer agreement is a formal performance agreement that according to Donoso (1998) can be an important part of organizations' structuring process which enables them to achieve their strategic objectives.

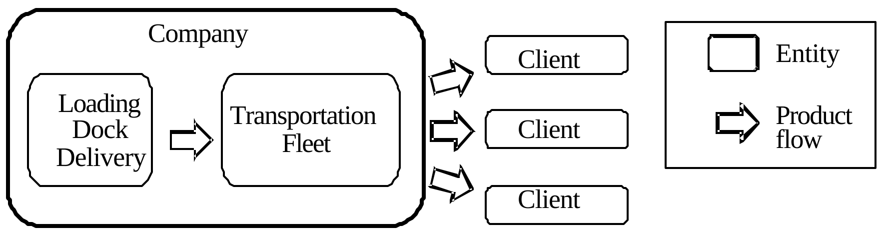
The purpose of this work is to design a monetary transfer agreement between the Dock and Fleet units, following the integrated conceptual model of the physical distribution system. Section I describes the physical distribution system operation and structure, as well as the advantages a transfer agreement affords in achieving operational alignment. Section II identifies the main operating variables and derives their relationship, permitting us to estimate how their improvement may result in savings from a reduction on the Fleet. Section III shows this design methodology as applied to a mass product distributing company in Santiago, Chile. Section IV presents an agenda to define a performance agreement between the Dock and Fleet units, whereby the latter encourages the former's improved operation. Finally, Section V deals with the complexity of the scheme presented as well as with the benefits of implementing it to facilitate the company's operational alignment.

I. DISTRIBUTION SYSTEM ANALYSIS

The distribution system analyzed herein is made up of the following entities, whose mutual relationship is shown in Figure 1.

- Loading Dock: Responsible for product handling, including pallet set up, loading and unloading, dispatching and truck control.
- Transportation Fleet: Exclusively dedicated to the distribution of company goods.
- Clients: Points of sale that distribute the product to end item consumers in the city. Their sales volumes are assumed to vary sharply from day to day, and thus they are the main source of system variability.

FIGURE 1
DISTRIBUTION CHAIN ENTITIES RELATIONSHIP



The company is expected to be capable of reacting to its clients' demand variability in order to comply with a committed delivery schedule. Such a commitment may be due to a quality service policy aimed at differentiating the company from its competition. In addition, delivery times may be defined on the basis of the nature of the consumer good, and could be cancelled if the product is delivered within specified times. For instance, if a bakery does not meet today's demand for bread, this will not accumulate for tomorrow, but will be lost.

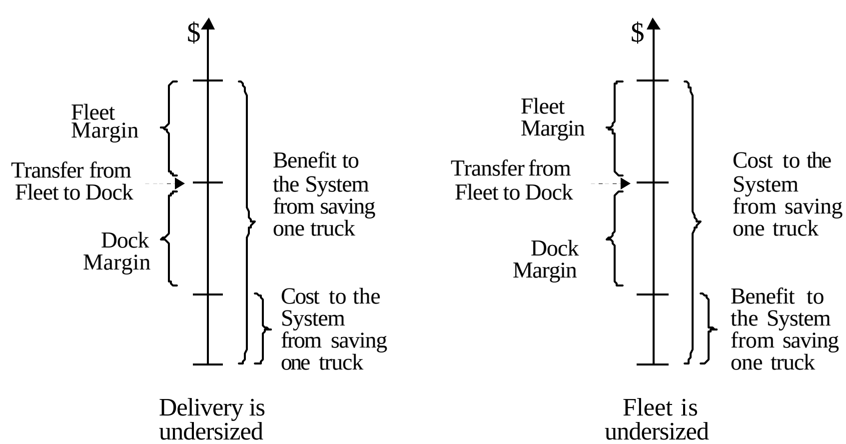
Accepting the fact that constraints exist in delivering products on time, there are two primary situations which threaten operational alignment from the efficiency viewpoint: That the Dock is undersized and the Fleet is suffering or, conversely, that the Fleet is undersized and affecting the loading Dock.

An undersized Dock will result in slower than adequate service and long waiting times for trucks loading and unloading, particularly as queues begin to form. Waiting reduces the Fleet's productivity, forcing it to operate a larger number of trucks at increased fixed costs. On the other hand, if the Fleet is undersized, the Dock would then have to maintain an economically inconvenient service capacity in order to stretch the trucking resources as fast as possible. Most Docking systems require minimum loading and unloading times, and beyond a certain point up, improving these times may prove extremely costly.

From a theoretical point of view, it can be determined whether any one of the system's units is undersized, because it is possible to evaluate the costs and benefits of increasing capacity in each of the departments. For example, in the case of the Fleet market prices exist for different types of trucks, so the precise cost of one additional truck is easily determined. However, Dock-related costs may be very complex. This unit often performs a number of activities besides loading, such as managing storage of raw materials, intermediate goods and end products. The loading process itself is also complex, involving various activities, people and resources that are difficult to measure accurately. While Activity-Based Costing (ABC) systems such as the ones described by Miller (1996) have made significant progress, it is never possible to capture the entire operational complexity in a given accounting system.

Adopting transfer agreements allows one to avoid part of this technical difficulty because it only defines a *ceiling* and/or a *floor* for the operational betterment-related benefits based on the trucks' market cost. Figure 2 shows the two possible operating misalignments mentioned above. The goal is to find a configuration where the benefits for the Fleet from saving one truck and the cost to the Dock for increasing service thus permitting them to do so are the same, implying that the Fleet size is optimal (assuming the cost function is unimodal). If these costs aren't equal, then there is the opportunity of removing one truck if the Dock is undersized, or of increasing the number of trucks if the Fleet is undersized.

FIGURE 2
CAPACITY MISALIGNMENT ALTERNATIVES



In the first case a ceiling is calculated for a transfer from the Fleet to the Dock because the latter is providing better service which permits elimination of one truck. Based on this fact the parties involved should negotiate the exact transfer value which -according to Watson & Baumler (1975)- must include other elements such as a Dock costs estimate, their willingness to pay, the relative urgency of the betterments, etc. Dock management assesses locally whether the difference between the expected transfer and the cost of the savings will make the service improvement profitable. This type of management may do a much more accurate evaluation than one done centrally, as the Dock has the necessary know-how and information, which may not be present at the organization's upper levels. In other words, the Dock margin shown in the figure must be consistent with the incentive given for it to implement the appropriate improvements. In the case where the Fleet is undersized, transfers are handled in an analogous manner, only in this case it is the Dock that transfers resources to the Fleet in order to increase the number of trucks. Once the general framework transfer agreement has been defined, it is necessary to accurately determine the effect of the service provided by the Dock on the size of the Fleet. This calculation is made in the next section assuming an undersized Delivery, although as mentioned above, the converse situation can be handled analogously.

II. RELATIONSHIP BETWEEN OPERATING VARIABLES

Our analysis centers on deriving the mathematical relationship between the duration of the service provided by the Dock and the size of the transport Fleet. This relationship's makes trade-offs explicit, permit us to estimate returns and negotiate amounts transferred due to improvements at the Dock. This analysis might later be complemented by simulation tools, that allow for including exceptional situations such as accidents and likelihood distributions for different operating variables.

In the analysis below a pledged 24-hour delivery deadline is assumed, so Fleet size must be defined for peak daily demand. Therefore, the analysis of the Dock operations and possible betterments thereof are done in terms of peak demand days.

A. Effect of Dock Cycle Length on Number of Hours at Plant

FIGURE 3
PLANT DIAGRAM

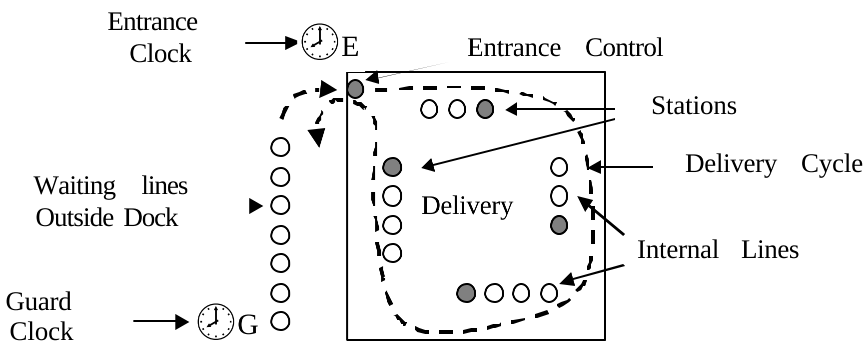


Figure 3 shows a Dock model where trucks are subject to two types of waiting, namely *outside*, that is, waiting in line to get into dock, and *inside*, due to the service at each Dock station as well as inside queues.

The following operating variables are defined:

- *Number of Hours at Plant*: The total time the truck stays at the plant to complete one loading cycle. This is calculated through expression (1).

$$\textit{Number of Hours at Plant} = \textit{Dock Cycle Length} + \textit{Outside Waiting Time} \qquad (1)$$

- *Dock Cycle Length*: Average time a truck takes between the entrance station and the exit station.
- *Peak Cycle Change*: The Percentage change of peak-hour *Dock Cycle Length* with respect to the daily average *Dock Cycle Length*. If this index is smaller than 1, then during peak hours the service rate is increased.
- *Outside Waiting Time*: Average time that a truck waits in line before passing through the Entrance Station.
- *Number of Trucks at Dock*: Total number of trucks in the Dock during peak hours. This number is assumed to be large enough to ensure there is no idle capacity at certain stations, while not causing internal congestion.

- *Number of Trips*: Total number of truck-loads dispatched by the Dock during the day.

The variable *Outside Waiting Time* is the average value of the waiting time in the outside queue over all the trucks. Assuming the number of truck arrivals increases during peak hours, such waiting becomes proportionally more important. Therefore:

$$\begin{aligned}&\text{(average) } \textit{Outside Waiting Time} \times \text{(total) } \textit{Number of trucks} = \\ &\quad \text{(peak) } \textit{Outside Waiting Time} \times \text{(peak) } \textit{Number of Trips} \; + \\ &\quad \text{(off-peak) } \textit{Outside Waiting Time} \times \text{(off-peak) } \textit{Number of Trips}\end{aligned} \qquad (2)$$

Since during off-peak hours the size of the outside queue is negligible, the (off-peak) *Outside Waiting Time* is assumed to = 0, so expression (3) is derived:

$$\begin{aligned}&\textit{(average)Outside Waiting Time} = \\ &\textit{(peak)Outside Waiting Time} \times \frac{\textit{(peak) Number of trips}}{\textit{(total) Number of trips}}\end{aligned} \qquad (3)$$

The (peak) *Outside Waiting Time* depends on the following parameters:

- t_a : Average time between the *arrival* of two consecutive trucks to the queue outside the Dock during peak hours. This figure is inversely proportional to the volume of demand for the Dock service during peak hours; the larger the demand, the greater the flow of truck arrivals and therefore the shorter the time between two consecutive arrivals. The exact value of t_a can be measured by a ⌚G chronometer installed at the plant's guarded entrance.
- s_a^2:Variance of time between the *arrival* of two consecutive trucks to the queue outside the Dock during peak hours. This figure depends on the regularity of truck arrivals to the Dock. The exact value of s_a^2 can also be measured by the ⌚G chronometer.
- t_s : Average time between *service* or departure from the Dock of two consecutive trucks during peak hours. This figure is inversely proportional to the Dock's service capacity, during peak hours: The greater the capacity, the larger the truck departure flow and therefore the shorter the period between two consecutive departures. The exact value of t_s can be measured with the ⌚E chronometer.

The average value of this variable is obtained via Little's Law (1961):

$$t_S = \frac{Delivery\ Cycle\ Length \text{ x } Peak\ Cycle\ Change}{Number\ of\ Trucks\ at\ Dock} = \frac{(peak)\ Delivery\ Cycle\ Length}{Number\ of\ Trucks\ at\ Dock} \quad (4)$$

- s_s^2 :Variance of the period between departure from the Dock of two consecutive trucks during peak hours. This figure depends on the Dock's service regularity: Any unforeseen event in the operation will result in an exit flow discontinuity and thus in a larger variance. The exact value of s_s^2 can be measured with the ⌚E chronometer.

The (peak) *Outside Waiting Time* in the queue outside the Doc is estimated using Kingman's formula (1970):

$$(peak)\ Outside Waiting\ Time = \frac{s_a^2 + s_s^2}{3 \times (t_a - t_s)} \quad (5)$$

Substituting for *Outside Waiting Time* in the expression results in:

$$(Peak)\ Outside\ Waiting\ Time = \frac{s_a^2 + s_s^2}{3 \times \left(t_a - \frac{(peak)\ Delivery\ Cycle\ Length}{N^\circ\ of\ Trucks\ at\ Dock} \right)} \times \frac{(peak)\ N^\circ\ of\ Trips}{(total)\ N^\circ\ of\ Trips} \quad (6)$$

This formula indicates that the length of the outside waiting line will depend on a set of parameters besides the *Dock Cycle Length*: It increases when t_s, s_a^2 or s_s^2 increase, and it decreases if t_a increases. This is of vital importance, because a transferred contract that considers *Outside Waiting Time* without considering the other parameters might lead to incentive allocation errors. For example, assume the Dock was penalized for increasing both its *Dock Cycle Length* and the *Outside Waiting Time.* The case might be that the Dock was actually making improvements in order to reduce the *Dock Cycle Length*, but that s_a^2 was increasing considerably for reasons outside of the Dock performance. This could lead to a fine charged to the Dock despite its improvement, resulting in incentive system failure.

Combining the above formulas, an expression showing the *Number of Hours at Plant* as a function of *Dock Cycle Length* can be derived, that is:

$$Number\ of\ Hours\ at\ Plant = Number\ of\ Hours\ at\ Plant\ (Dock\ Cycle\ Length) =$$

$$Dock\ Cycle\ Length\ + \frac{s_a^2 + s_s^2}{3\times\left(t_a - \dfrac{Dock\ Cycle\ Length \times Peak\ Cycle\ Change}{N^o\ of\ Trucks\ at\ Dock}\right)} \times \frac{(peak)\ N^\circ\ of\ Trips}{(total)\ N^\circ\ of\ Trips} \quad (7)$$

B. Effect of the Number of hours at the plant on the number of trucks in the Transport Fleet

This analysis considers the following management variables:

- *Number of Trucks*: Size of transport truck Fleet engaged in product distribution
- *Number of Units Sold*: Product units to be delivered.
- *Return Index*: Percentage of sales that are returned, that is, this index measures the number of product units that are transported twice.
- *Number of Units per Truck*: Capacity of each truck in terms of product units.
- *Reloading Factor* = *Number of Trips Per Day*: Number of times a truck makes a full distribution circuit in one day.

We know that the number of trucks to book is equal to the daily demand to be transported, divided into the daily transport capacity per truck, that is:

$$Number\ of\ Trucks = \frac{N^o\ of\ Units\ Sold \times (1 + Return\ Index)}{N^\circ\ of\ Units\ per\ Truck\ \text{x}\ Reloading\ Factor} \quad (8)$$

In turn, the *Reloading Factor* depends on the following management variables:

- *Number of Working Hours*: Hours worked by a truck in one day.
  Number of Hours on Route: The time a truck takes to complete a distribution round trip.

- *Number of Hours at Plant*: The time a truck stays at the plant after a trip, defined in the previous section as follows

$$\begin{aligned} &NumberHours\,at\,Plant = Dock\,Cycle\,Length + OutsideWaiting\,Time \\ &OutsideWaiting\,Time = (peak)Dock\,Cycle\,Length \times \frac{(peak)Number of\ trips}{(total)Number of\ Trips} \end{aligned} \tag{9}$$

The *Reloading factor* is given by:

$$Reloading\ Factor = N^{\circ} of\ Round\ Trips\ per\ day = \frac{N^{\circ} of\ Working\,Hours}{N^{\circ} of\ Hours\,in\,Route + N^{\circ} of\ Hours\,at\,Plant} \tag{10}$$

By replacing in the first equation an expression is obtained for *Number of Trucks* as a function of the *Number of Hours at Plant,* that is:

$$\begin{aligned} &Number\ of\ trucks = Number\ of\ trucks\ (Number\ of\ hours\ at\ plant) \\ &= \frac{N^{\circ}\ Units\ Sold \times (1 + Return\ Index)}{N^{o} of\ Units\ per\ Truck \times \left(\dfrac{N^{o}\,Working\ Hours}{N^{o}\,Hours\ in\ Route + N^{o}\,Hours\ at\ Plant} \right)} \end{aligned} \tag{11}$$

C. Profits From Saving One Truck

The following operating function is defined:

- *System Cost* (*Number of trucks*): Annual cost of physical distribution system as a function of the number of trucks in the transport Fleet.
- To calculate how the *System Cost* (*Number of trucks*) varies as a result of saving one truck, cost items are reviewed for the distribution system, determining how each of them is modified. The labor item is reduced by the number of drivers per truck plus company costs from social security and welfare agreements. Also helpers per truck are saved, these also represent a cost because of wages, social security and welfare agreements. Input costs such as fuel, tires, lubricants, etc. do not vary because total kilometers ridden by the reduced Fleet are the same since the number of clients serviced remains unchanged.

The removal of one truck has the direct result of saving its associated costs from preventive maintenance and repair. However, it might be argued that the use of the remaining trucks will be heavier and consequently their wear and tear, spare parts, overhaul, etc. will also increase. Because these effects cancel out, no change in the cost structure is considered due to this item.

Savings exist from other operating expenses such as insurance, license plates, incidental expenses and safety elements and communications. Also included as cost savings from one fewer truck is the leasing yearly installment, which approaches the sum of the alternative financial cost plus annual depreciation. There are no savings from administrative costs because the reduction in the number of trucks is marginal and therefore do not affect indirect costs. In summary, the change in the function *System Cost* (*Number of trucks*) from removing one truck is as follows:

$$\frac{\partial\, System\ Cost\,(N^\circ\ of\ Trucks)}{\partial\, N^o\ of\ Trucks} \tag{12}$$

It must be noted that the partial derivatives notation used herein is only for illustrative purposes, not literal. Functions analyzed can not be derived in a closed form as they are discontinuous and recursive, that is, the *System Cost* depends on the *Number of Trucks*, but the *Number of Trucks* also depends on the *System Cost*.

D. Dock Improvements Profitability

Profitability of improvements at the Dock is obtained considering the result in Section 2.A that shows the *Number of Hours at Plant* (*Dock Cycle Length*), and the result in Section 2.B that shows *Number of Trucks* (*Number of Hours at Plant*). Therefore:

Number of Trucks (*Number of Hours at Plant* (*Dock Cycle Length*)) =
Number of Trucks (*Dock Cycle Length*). (13)

In the previous section the benefit from one truck saved is calculated, so the overall system benefit from improving the *Dock Cycle Length* can be figured:

$$\frac{\partial\ System\ \ Cost\ \ (N^\circ\ of\ Trucks)}{\partial\ Dock\ \ Cycle\ \ Length} =$$

$$\frac{\partial\ System\ \ Cost\ (\ N^o\ \ of\ \ Trucks)}{\partial\ N^o\ \ of\ \ Trucks} \times \frac{\partial\ N^o\ \ of\ \ Trucks\ \ (Dock\ \ Cycle\ \ Length)}{\partial\ Dock\ \ Cycle\ \ Length} \quad (14)$$

In summary, the analysis shown in the previous sections defines an estimation of the expected benefit for the physical distribution system due to improving Delivery's waiting times. Because of the complexity of the partial derivative, it is more practical to define the equations on a Microsoft Excel worksheet and then enter various possible values, as in the following section's example.

III. APPLICATION TO A MASS CONSUMPTION PRODUCT DISTRIBUTING COMPANY

This section shows the methodology applied to a mass consumption product distributing company operating in Santiago, Chile. It refers to a time study made at the company during a peak month. A substantial portion of the information has been altered to protect confidentiality. Only the information that was used to validate the formulas is shown faithfully, whereas the rest of the data are included herein only to illustrate how the technique operates. Figure 4 shows a diagram of the trucks' route and the function of the stations they pass through.

Figure 5 shows average waiting time and service time at the principal stations, as measured during two peak-demand days.

A pattern for truck arrivals to the Dock is considered, as shown in Illustration 6, where the peak hours are defined to be from 13:00 to 15:00.

FIGURE 4
THE DOCK ROUTE

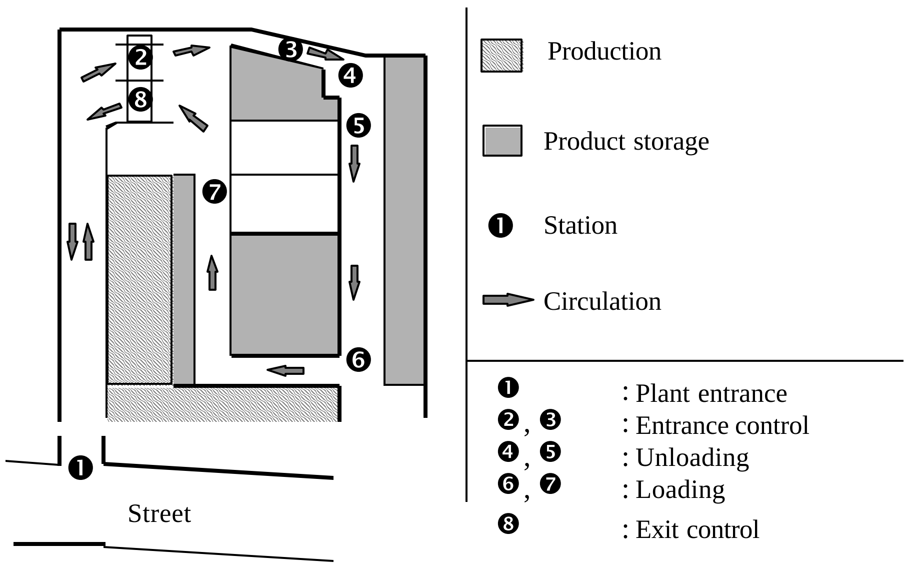


FIGURE 5
AVERAGE WAITING TIME AND SERVICE AT EACH STATION

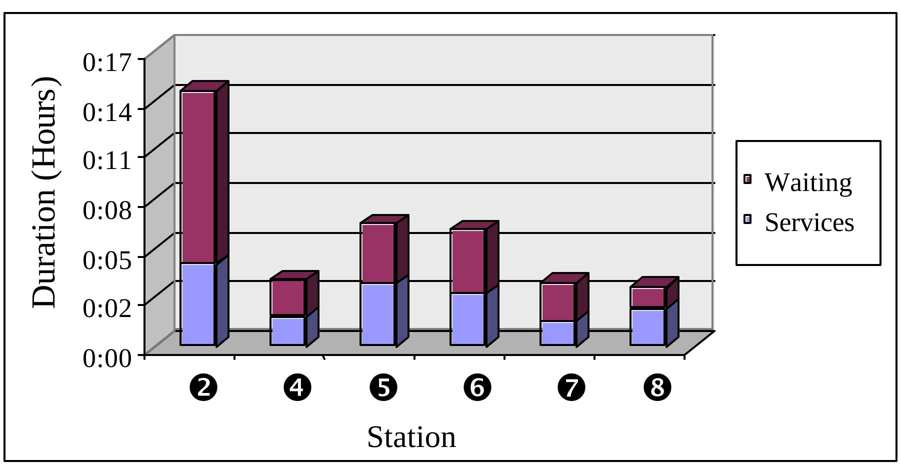
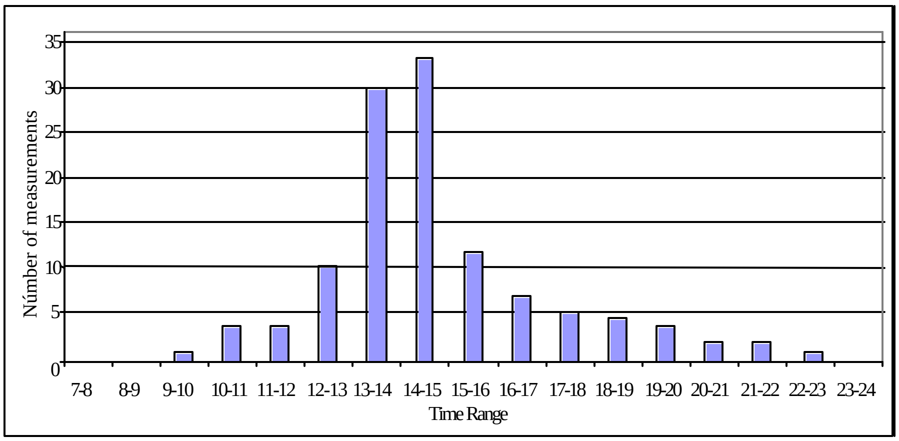


FIGURE 6
NUMBER OF TRUCKS ARRIVING BY HOUR



Two peak-demand days were considered as the basis for this analysis. The parameter estimates from these day are as follows:

- *Dock Cycle Length* = 46 (minutes/truck) obtained from the time study mentioned above.
- *Peak Cycle Change* = 0.86 obtained from the study; this shows a shorter cycle length during peak hours as compared to the average cycle. This occurs due to the fact that the Dock utilizes more people and equipment during this period. Thus the value of the (peak) *Dock Cycle Length* is calculated = 40 (minutes/truck).
- *Number of Trucks at Dock* = 31.5 it is used as an adjustment variable in our analysis. According to several people interviewed this is a reasonable figure, validating our calculations.
- $\frac{(peak)\, N^\circ\, of\ Trips}{(total)\ N^\circ\, of\ Trips} = \frac{63}{127}$, obtained from the time study, which does not include all of the trucks, but rather considers a sample of 127 trips during two peak days.
- t_a = 1.35 (minutes/truck). The data provided by the Dock indicate

that 193 and 165 trucks were served during the 7:00AM to 11:00PM shift of the two peak days considered, respectively. Since half of the trucks are serviced during the two-hour peak period, $t_a = 2 \times 2$ / ((193 + 165) $\times$ 0.5) = 1/44 (hours/ truck) = 1.35 (minutes/truck).

- s_a = 2.6 minutes, a figure obtained from the plant's entrance records.
- t_s = ((peak) *Dock Cycle Length*/ *Number of Trucks at Dock*) = 40/ 31.5 = 1.27 (minutes/truck).
- s_s =0.81 minutes. The (peak) *Number of Trucks at the Dock* is assumed to be constant and equal to 31.5, therefore the standard deviation of the ((peak) *Dock Cycle Length/ Number of trucks at Dock*) is equal to the standard deviation of the (peak) *Dock Cycle Length*/ 31.5. From the time study carried out for the two peak follows that the variance of *Dock Cycle Length* is 650 minutes squared, and therefore s_s = 25.5/31.5 = 0.81 minutes.

With these data the following average waiting time outside the plant is derived for the base case:

$$(peak)\,Outside\ Waiting\ Time = \frac{6{,}7 + 0{,}66}{3\times\left(1{,}35 - \dfrac{40}{31{,}5}\right)} = 30{,}6$$

It must be noted that in the time study of the two peak days considered, the average waiting time before entering the plant at 13:00-14:00 and 14:00-15:00 were 40 and 20 minutes respectively. With these data the following average outside waiting time is obtained for the base case:

$$Outside\ Waiting\ Time = 30{,}6 \times \frac{63}{127} = 15{,}2$$

In the peak-day time study, average waiting time before entering the plant were 20 and 14 minutes respectively, indicating that the formula for estimation is satisfactorily accurate.

Starting from the base case a sensitivity analysis can be performed with *Number of Hours at Plant* as an effect of a reduction in the *Dock Cycle Length* variable:

FIGURE 7
RELATIONSHIP BETWEEN NUMBER OF HOURS
AT PLANT AND DOCK CYCLE LENGTH

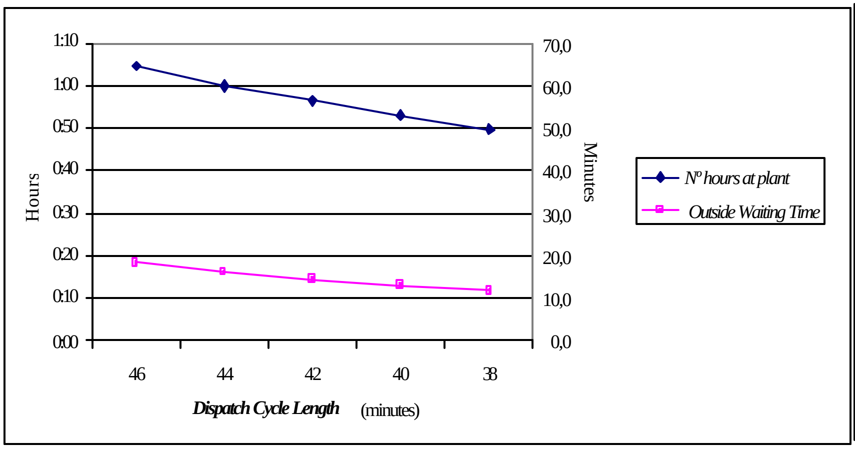
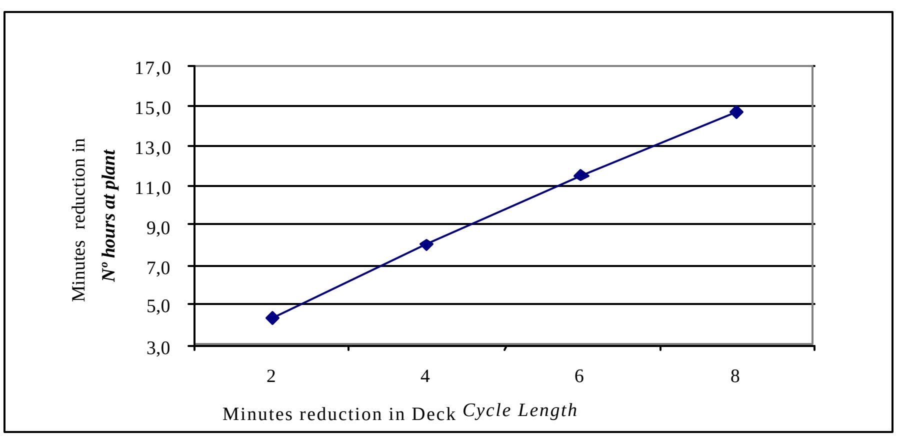


Figure 8 shows the reduction in minutes at the plant due to the reduction in *Dock Cycle Length*, considering a base case of 46 minutes.

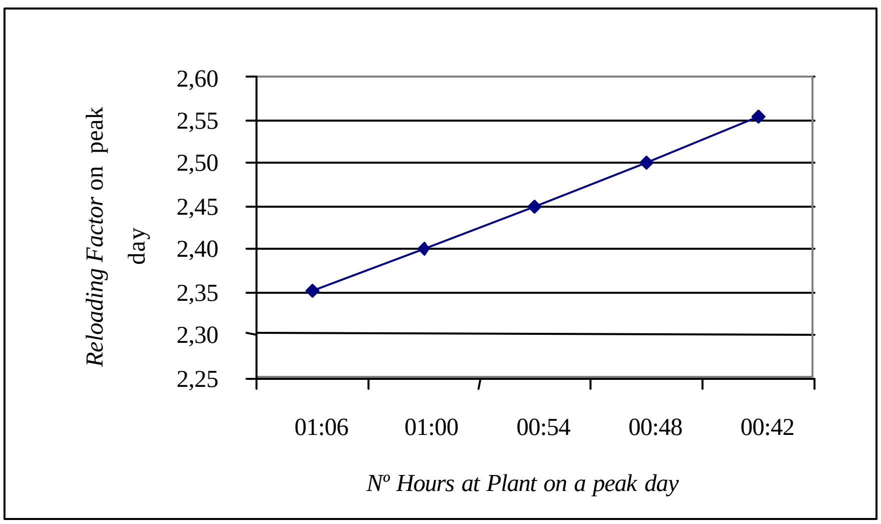
FIGURE 8
MINUTES SAVED AT PLANT BECAUSE OF REDUCTION
IN MINUTES AT DELIVERY



Approximate peak-day data are considered for the case base: The Transport Fleet has a *Number of trucks* equals to 118, the Company delivers a *Number of Units Sold* of 24,500 in one peak day, the *Return Index* is 1.5% and the average *Number of Units per Truck* is 90. The actual *Number of Working Hours* is 12, the *Number of Hours on Route* is 4 and the *Number of Hours at Plant* is 1:06 hours. This data yields a *Reloading Factor* of roughly 2.35.

With the base case as the starting point a sensitivity analysis is made which is shown in Figure 9, that relates the increase in the *Reloading Factor* to the reduction in the *Number of Hours at Plant.*

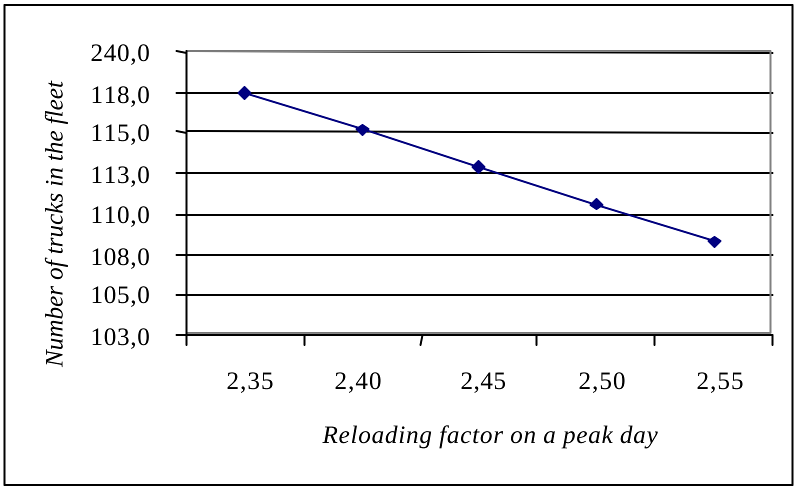
FIGURE 9
INCREASE IN RELOADING FACTOR ON PEAK DAY



With an increase in the *Reloading Factor* on peak day, the number of trucks needed can be reduced, as shown in Figure 10.

In summary, this relationship indicates that the *Number of Trucks* decreases virtually lineally with respect to the *Number of Hours at Plant* at a rate of 0.37 trucks/year per minute of total waiting time at the plant. This relationship is interpreted as following from the fact that a reduction in the time spent at the plant will permit more loads to be carried on average per truck per day, resulting in a reduction in the Fleet size required by the system.

FIGURE 10
REDUCTION IN NUMBER OF TRUCKS OF THE TRANSPORT FLEET



To determine the economic benefit of saving one truck, the different cost items were reviewed and the way each item would be modified was determined. The Labor item includes 1.1 drivers per truck plus company costs due to social security and welfare agreements. Also two helpers per truck are considered, who are also paid salaries, social security and welfare. As mentioned above, the costs of inputs such as fuel, tires, lubricants and the like do not vary because the aggregate number of kilometers remains the same with one truck less.

Summarized savings for the physical distribution system due to the removal of one truck is shown on Table 1.

TABLE 1
SAVINGS ITEMS DUE TO REMOVAL OF 1 TRUCK

Item	In thousands of US$ per year
Operating Costs	
Labor costs	26
Fuel and inputs	
Maintenance and Services	
Other operating costs	2.8
Financial costs	2.2
Deterioration and devaluation	5.7
Administrative expenses	
TOTAL	36.7

The analysis suggests that the physical distribution system's expected profit from the Dock time improvement is as shown in Table 2:

TABLE 2
SAVING DUE TO THE DOCK IMPROVEMENTS

Reduction in the Dock Cycle Length	Trucks Saved	System Cost Savings (thousand US$ a year)	Saving as a percentage of Flee
2 minutes	3.2	115.7	2.7
4 minutes	4.9	184.2	4.1
6 minutes	6.3	229.4	5.3
8 minutes	9.6	270.6	8.1

It is important to note that the values obtained are very sensitive with respect to the base case considered. That is, when designing transfer agreements this methodology must be used in conjunction with accurate measurements. It must also be kept in mind that this analysis is a marginal one, and therefore cannot be extrapolated indefinitely, because other system constraints may hinder savings.

IV. AGENDA TO DEFINE A PERFORMANCE AGREEMENT BETWEEN THE DOCK UNIT AND THE TRANSPORT FLEET

The necessary steps to define a Performance Agreement between the Dock and Fleet, the purpose of which is to reduce service time at the Dock, are shown below.

a) Define the days considered peak according to number of units demanded. We hereby propose to identify the ten heaviest days of the year and consider them peak.
b) Define the peak hours within the peak days. We suggest between 13:00 hours and 15:00 hours, which is normally when the first reloading is done.
c) Find the base case parameters, as have been estimated herein. For this it is necessary to have control points such as the plant entrance so the time a truck remains at the Dock can be accurately measured, along with the variance of time between departures, number of trucks in Delivery, and the like. The required variables are: *Dock Cycle Length*,

Change in Peak Cycle, *Number of Trucks at Delivery* (peak), *Number of Trips* (total), *Number of Trips*, t_a, s_a, t_s = ((peak) *Dock Cycle Length*/ *Number of Trucks at Delivery*), s_s, *Number of Trucks*, *Number of Units Sold*, *Return Index*, *Number of Units per Truck*, *Number of Working Hours* and *Number of Hours on Route*.

d) With this data the methodology explained in Sections A and B can be repeated. The goal of this analysis is to obtain an accurate measure for savings from a reduction in time at the Dock.

e) The profit from removing one truck is estimated to be 36,700 (US$/year). When using approximate data for a base case the result was that a reduction from 46 to 44 minutes in the *Dock Cycle Length* results in savings of 3.2 (trucks/year), or 115,700 (US$/year). A reduction from 46 to 42 minutes in the *Dock Cycle Length* results in savings of 184,200 (US$/year), and so on. Such savings should be partly transferred from the transport Fleet to the Dock in some negotiated proportion.

f) Safeguard mechanisms must be defined for both parties. For example, average service times on off-peak days must not exceed that of peak days; if service to any particular truck is exceptionally high, the reason for it must be explained and the truck removed from the sample, etc.

g) Upon this agreement the Dock shall be “free” to implement operational improvements. Such freedom will allow The Dock to evaluate the operations from their cost/benefit standpoint. They can then choose to reduce the *Dock Cycle Length* if the benefits obtained through the transfer agreement prove that such improvements are profitable.

V. CONCLUSIONS

The goal of formulating the relationship between the various operating variables is to make the trade-off between them explicit. From the time study indicated by Figure 5 it can be seen that roughly 2/3 of the time that trucks are at the plant is spent waiting to be serviced at some of the Dock stations. Assuming that a number of operating improvement opportunities exist, the methodology displayed herein permits one to define the terms and values associated with a Performance Agreement designed to give incentive for service time reductions at the Dock. In the case of the mass consumption product distributing company analyzed herein, a savings opportunity of 115,700 (US$/year) was estimated, that accounts for nearly 3% of the Fleet, from a reduction of only 2 minutes in service time at the Dock during peak hours.

While the original goal was to determine how many trucks could be saved by improving the Dock process it also proved possible to estimate the regularity of this process, as well a the regularity of truck arrivals. Although the arrival process is not part of this study since it relies on commercial client allocation policies, it is clear that improvements in this area could also result in increased efficiency.

Finally, it is worth noting that the Performance Agreement described above may appear difficult to implement, because the Dock and the Fleet distribution processes are strongly *coupled*. That is, it is technically difficult to isolate the effect of each of these processes on the system's productivity, because of their close interaction. Despite this difficulty, the benefits from correcting misalignment are considerable, and therefore agreements such as the one described herein may become important management tools in the near future.

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