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Penalty and reward contracts between a manufacturer and its logistics service provider

Emel Aktas¹ · Fusun Ulengin²

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Abstract Contracts are used to coordinate disparate but interdependent members of the supply chain. Conflicting objectives of these members and lack of coordination among the members lead to inefficiencies in matching supply with demand. This study reviews different types of contracts and proposes a methodology to be used by companies for analyzing coordinating contracts with their business partners. Efficiency of the contract is determined by comparing the performance of independent companies under the contract to the supply chain performance under the central decision maker assumption. We propose a penalty and reward contract between a manufacturer and its logistics service provider that distributes the manufacturer's products on its retail network. The proposed contract analysis methodology is empirically tested with transportation data of a consumer durable goods company (CDG) and its logistics service provider (LSP). The results of this case study suggest a penalty and reward contract between the CDG and its LSP that improves not only the individual firm's objective functions but also the supply chain costs. Compared to the existing situation, the coordination efficiency of the penalty and reward contract is 96.1 %, proving that optimizing contract parameters improves coordination and leads to higher efficiencies.

Keywords Logistics contract · Case study · Newsvendor problem · Consumer durable goods sector · Third-party logistics service provider

1 Introduction

Supply chain contracts are widely used to coordinate disparate but interdependent members of the supply chain. Contract clauses are legally binding for the supply chain parties, and within the scope of a supply chain relationship, parties define expected actions from each other and measures in case these expectations are not met. In this study, we analyze two companies operating in a supply chain using such contracts. The two companies are a consumer durable goods manufacturer (CDG) and its logistics service provider (LSP). We find the contract parameters that improve the efficiency of coordination and provide the decision maker, in particular the CDG, with alternative parameter combinations to achieve the same level of efficiency. We empirically test our proposed contract with the CDG's data on deliveries distributed by the LSP on the CDG's retail network.

In its broadest definition, coordination is managing dependencies between activities [1]. Supply chain coordination, on the other hand, is the parties' optimal arrangement of factors related to the supply chain to minimize total supply chain costs or to maximize total supply chain profits, considering the parties' own objectives [2]. In line with the established literature on supply chain coordination with contracts, we define a coordinating contract as a contract that Pareto dominates a non-coordinating contract, where each firm is no worse off and at least one firm is strictly better off with this contract [3]. This means, even if the contract is not optimizing the supply chain performance

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(for example, minimize supply chain cost or maximize supply chain profit), it would still be considered coordinating as long as the parties using the contract are better off with the contract than without the contract.

A coordination mechanism should improve the overall system performance and distribute the benefits of coordination in a manner that entices both decision makers' cooperation [4]. Bilateral contracts signed between supply chain members define the expectations of each party within the scope of the supply chain relationship, as well as the measures to be taken in case one or more of these expectations are not met. The lack of coordination is generally due to different information levels and/or different incentives of the parties, and it may lead to reductions in supply chain performance by means of incorrect forecasts, low capacity utilization, low stock turnover, high holding and related storage costs, delays in product launch, low-order fulfillment rates, insufficient customer service, or low customer satisfaction [5].

Our research aims to coordinate production and distribution by analyzing alternative contract parameters for a newsvendor model-based *penalty and reward contract*. This contract is empirically tested and observed to improve the performance (i.e., cost and profit) of supply chain members. In this respect, we focus on applicable contracts between a manufacturer and its logistics service provider and provide a concise review of the recent advancements in the field in Sect. 2, present our methodology in Sect. 3, test and discuss the proposed penalty–reward contracts with empirical data in Sect. 4, and discuss the findings and conclude the paper in Sect. 5.

2 Literature review

Logistics play a key role in the distribution of goods from raw material suppliers to original equipment manufacturers to end-consumers. Logistics outsourcing is an effective way to achieve a competitive advantage, improve customer services, and reduce logistics costs [6]. Firms that choose to outsource their logistics activities can reduce their fixed costs and increase their flexibility. For subcontracting manufacturing or outsourcing logistics, contracts are widely implemented across various stages of the supply chain [3]. A large amount of research focuses on contracting as primary source of coordination between supply chain members [7]. Selviaridis and Norrman [8] explore key challenges of adopting, analyzing, and managing performance-based contracts for advanced logistics services from the viewpoint of logistics service providers and highlight the limited empirical work in this area. They recognize the challenges associated with contract analysis

as the definition of performance metrics and highlight the resource investment as an issue for contract management.

Kaya [9] analyzes supply chain contracts for decentralized supply chain models and identifies which contracts between two parties are the best to use in different cases. The contracts modeled are between an original equipment manufacturer (OEM) and its contract manufacturer for the production of one of the OEM's products. Taking into account the effort exerted by the OEM or its supplier to affect the demand for the products together with the pricing decisions, the author considers centralized and decentralized models of the supply chain. Especially for the decentralized setting, he analyzes and compares several different contracts with each other and concludes that the coordinating contract depends on the party exerting the effort.

Liu and Wang [10] model the logistics service supply chain considering logistics service integrators and logistics service providers and investigate the influence of risk attitudes of chain members on quality control in the logistics service supply chain. Rather than optimizing the contract parameters, these authors analyze the LSP's compliance and non-compliance with the contract that governs the relationship between the LSP and the logistics service integrator using game theory. They conclude that risk attitude combinations affect the coordination efficiency; in particular, the logistics service integrator prefers a risk-seeking LSP when it aims to achieve high supply chain coordination efficiency [10].

Within the supply chain contract literature, *option contracts* are preferred when there is a high uncertainty of demand. In option contracts, the buyer prepays a certain amount of money (reservation premium) to the seller so that the seller commits to reserving a certain level of capacity for the buyer. In the event that the buyer does not exercise the option to ship the goods, the reservation premium is lost. If the buyer exercises the option, then it pays the agreed contractual unit price [11–15]. On the other hand, *revenue-sharing contracts* are preferred when the cost of procurement is high. In revenue-sharing contracts, the seller offers the buyer a low price at the beginning of the contract period. The buyer, in response, shares its revenue with the seller at the end of the period [16–19]. Revenue-sharing contracts coordinate the supply chain by allocating the supply chain's profit between the seller and the buyer [20]. He and Liu [21] model the logistics service supply chains using a joint option contract and a revenue-sharing contract between a logistics service integrator, an LSP, and a logistics service subcontractor among which the logistics capacity should be coordinated. The contracts aimed at stimulating the logistics service subcontractor to improve its service level and providing a cost and revenue

sharing between the logistics service integrator and the LSP.

On the other hand, in the *penalty and reward contracts*, the buyer either charges a penalty to the seller for undelivered items or gives a reward for on-time shipments. The basic purpose of such contracts is to motivate the seller to reserve sufficient capacity for the buyer. Since, whether the seller reserved sufficient capacity or not will be known only after the buyer has placed its orders, this type of contract can be analyzed using the well-known newsvendor models [3, 22–25]. The three characteristics that define these models are:

1. any resource requirement is governed by random processes
2. the decision as to how much of this resource to have is made before the requirement for the resource is known, and
3. all economic results can be represented by either having too much or too little of the resource. The newsvendor model minimizes the total overage and underage costs of the buyer.

Contracts coordinating the manufacturer and its service provider have not yet drawn much attention in the literature. Notably, Alp et al. [28] modeled the contracts between a manufacturer and its LSP within the framework of a bidding mechanism. However, in our study, the LSP has already been selected, and therefore, contract parameters, which would make the LSP fulfill the manufacturer's delivery orders, have to be determined. Within this scope, the methodology suggested here for analyzing contracts, and particularly contracts between a manufacturer and its service provider, can easily be adjusted for use in other domains.

Summing up, the contracts between supply chain members can help reduce supply chain costs and achieve coordination. It is possible to describe the objective functions of different members of the supply chain using mathematical equations, in particular the buyer's cost function and the seller's profit function. The works in the previous literature used the total supply chain cost under central decision maker assumption as a benchmark to evaluate the coordination efficiency of proposed contracts (e.g. 3, 9). Informed by the works cited, we describe our method to analyzing contracts to coordinate a manufacturer and its logistics service provider in the next section.

3 Methodology

Coordinating contracts between supply chain partners can be analyzed using the distributed decision-making (DDM) paradigm, which is defined as the analysis and coordination of interconnected decisions [26]. It is especially useful when there are multiple decision makers in the system, and these

decision makers have different information statuses and decision-making rights. Self-coordination, two well-known mechanisms of which are competition and cooperation, is not always possible in a distributed decision-making setting, especially when hierarchical relationships exist between the decision makers [26]. Generally, the priority and the precedence characteristics of interconnected decisions that need to be analyzed and coordinated result in a hierarchical structure. This hierarchy can be power based (depending on the authority of decision makers) or time based (depending on precedence of decisions). There are basically three different stages of interdependence: anticipation, instruction, and reaction. The party at the top level of the hierarchy (CDG) is either the more powerful party or it has the decision precedence, whereas the party at the base level (LSP) is rather dependent on the decisions of the top level, which is the CDG. The CDG anticipates the reaction of the LSP before making a decision and then informs the LSP of its decision (instruction, which are the contract parameters). The LSP responds to this instruction by maximizing its objective function (reaction, maximizing its LSP's profit). The LSP does not have a say on the level of parameters but has a right to accept or reject the contract and can decide to increase its capacity dedicated to the CDG if it helps improve its profits. The DDM system between the CDG and the LSP affects the performance of each party as well as the supply chain. The hierarchy of decisions between the CDG and the LSP is given in Fig. 1.

When the capacity availability of the LSP is an issue, penalty and reward contracts can be used to coordinate the parties. We consider the long-term capacity of the logistics service provider as T . The logistics service provider serves not only the CDG but also other clients. To include this aspect of the logistics network, we incorporate t as a random percentage of the LSP's available capacity with a lower limit t_l and an upper limit t_u . When the CDG places its order, the LSP knows the probability density function $f(t)$ of t but does not know the realized value of t . For a continuous function, the probability density function is the probability that the variate has the value x . Since for continuous distributions the probability at a single point is zero, this is expressed in terms of an integral between two

points: $P[a \leq X \leq b] = \int_a^b f(x)dx$. This is a way of incorporating the uncertainty in the supply chain into the relationship between CDG and LSP.

As explained in the literature review, the LSP can be stimulated to increase its delivery capacity dedicated to the CDG by i , before it receives orders from other companies in its supply chain, so its capacity available to the CDG would be $tT + i$. The deliveries of the LSP (x) depend on CDG's delivery orders (o) and the LSP's capacity ($tT + i$)

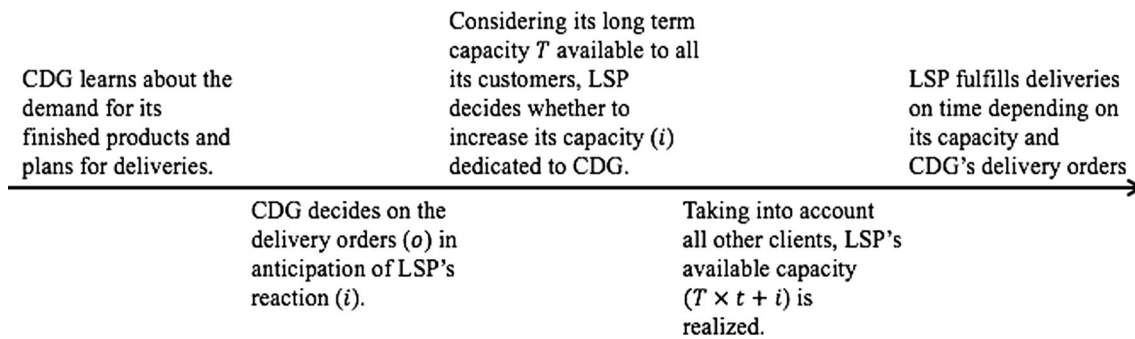


Fig. 1 Hierarchy of decisions between the CDG and the LSP

available to the CDG. Deliveries of the LSP cannot exceed its available capacity or the order placed by the CDG ($x \leq \min(o, tT + i)$). CDG's cost depends on LSP's fulfillment of the delivery orders. If the LSP fulfills fewer deliveries than CDG needs, then CDG faces unmet delivery cost (u); if CDG orders more than required, it incurs a cost of excess orders (d). CDG also incurs the delivery cost (c) depending on the actual number of deliveries (x). Hence, the cost of CDG is $\text{CDG}^{\text{cost}} = u[X - x]^+ + d[x - X]^+ + cx$. Here, X is the demand for the CDG's finished goods (required deliveries) in the classical newsvendor setting [22].

T expected cost of CDG depending on its delivery orders (o) is given in Eq. (1) [23].

$$\begin{aligned}
 E(\text{CDG}^{\text{cost}}(o)) = & u \int_{t_1}^{\min(\frac{o-i}{T}, \frac{X-i}{T})} (X - (tT + i))f(t)dt + u(X - o) \\
 & \int_{\frac{o-i}{T}}^{t_u} f(t)dt 1_{\{X > o\}} + d \\
 & \int_{\frac{X-i}{T}}^{\frac{o-i}{T}} (tT + i - X)f(t)dt + d(o - X) \\
 & \int_{\frac{o-i}{T}}^{t_u} f(t)dt 1_{\{X \leq o\}} \\
 & + c \int_{t_1}^{\frac{o-i}{T}} (tT + i)f(t)dt + co \int_{\frac{o-i}{T}}^{t_u} f(t)dt
 \end{aligned} \quad (1)$$

The term $1_{\{X > o\}}$ in $E(\text{CDG}^{\text{cost}}(o))$ is $1_{\{X > o\}} = \begin{cases} 1 & X > o \\ 0 & X \leq o \end{cases}$ and $1_{\{X \leq o\}}$ is defined similarly. The o^* minimizing CDG's cost would be $o^* = \text{argopt}(E(\text{CDG}^{\text{cost}})$,

which would make $\frac{\partial E(\text{CDG}^{\text{cost}}(o))}{\partial o} = 0$ (Eq. 2). The derivation of $\frac{\partial E(\text{CDG}^{\text{cost}}(o))}{\partial o}$ is given in the "Appendix".

$$o = X + T \left[F^{-1} \left(\frac{n + e}{c + e} \right) - \frac{ut_1 + dt_u + c(t_u - t_1)}{u + d} \right] \quad (2)$$

Determination of the lower bounds and upper bounds of the integrals in Eq. (1) follows from the cost of CDG (CDG^{cost}); CDG incurs unmet delivery cost (u) when the orders are less than required by the demand for its finished products (X); and excess delivery cost (d) when delivery orders are more than required by the demand for its finished products; and the cost of deliveries (c) depending on the realized deliveries. In each case, the CDG's cost depends on the LSP's capacity to meet the orders ($t \geq \frac{o-i}{T}$) or required deliveries ($t \geq \frac{X-i}{T}$).

Since CDG is paying for the service it receives from the LSP, the profit of the LSP can be written in a similar fashion: $\text{LSP}^{\text{profit}} = c \min(tT + i, o) - e[tT + i - o]^+ - ni$, where c is the unit payment made by CDG to LSP, e is the unit cost of unutilized capacity, and n is the unit cost of capacity increase incurred by the LSP. Then the expected profit of LSP is given in Eq. (3).

$$\begin{aligned}
 E(\text{LSP}^{\text{profit}}(i)) = & c \int_{t_1}^{\frac{i-o}{T}} (tT + i)f(t)dt + co \int_{\frac{i-o}{T}}^{t_u} f(t)dt \\
 & - e \int_{\frac{o-i}{T}}^{t_u} (tT + i - o)f(t)dt - ni
 \end{aligned} \quad (3)$$

Since the LSP already has the long-term capacity T , it needs to decide on the capacity increase dedicated to the CDG (i). The i^* maximizing LSP's profit would be $i^* = \text{argopt}(E(\text{LSP}^{\text{profit}}))$, which would make $\frac{\partial E(\text{LSP}^{\text{profit}}(i))}{\partial i} = 0$ (Eq. 4).

$$i = o - T \times F^{-1}\left(\frac{n+e}{c+e}\right) \quad (4)$$

The penalty and reward terms can then be incorporated into the CDG's expected cost and the LSP's expected profit by integrating on the intervals where the LSP would incur a penalty cost for unmet delivery orders and receive a reward where the orders are met. There will be an additional penalty term in CDG's equation that would reduce the cost and an additional reward term that would increase the cost since the reward would be given out to the LSP. The expected cost of CDG is given in Eq. (5) depending on its delivery orders (o) as well as the penalty (p) and the reward (r) terms.

$$\begin{aligned} E(\text{CDG}^{\text{cost}}(o, p, r)) &= u \int_{t_1}^{\min(\frac{o-i}{T}, \frac{X-i}{T})} (X - (iT + i))f(t)dt + u(X - o) \\ &\times \int_{\frac{o-i}{T}}^{t_u} f(t)dt 1_{\{X > o\}} + d \int_{\frac{X-i}{T}}^{\frac{o-i}{T}} (iT + i - X)f(t)dt + d(o - X) \\ &\times \int_{\frac{o-i}{T}}^{t_u} f(t)dt 1_{\{X \leq o\}} + c \int_{t_1}^{\frac{o-i}{T}} (iT + i)f(t)dt \\ &+ co \int_{\frac{o-i}{T}}^{t_u} f(t)dt - p \int_{t_1}^{\frac{o-i}{T}} (o - (iT + i))f(t)dt + r \int_{\frac{o-i}{T}}^{t_u} f(t)dt \end{aligned} \quad (5)$$

Similarly, the penalty term would reduce the LSP's profit and the reward term would increase the LSP's profit. As explained earlier, the LSP does not have a right to decide on the penalty (p) or the reward (r) but can decide on its capacity increase (i) given the penalty and the reward. In Eq. (6) we provide the expected profit of the LSP given the penalty and the reward terms based on the capacity increase i .

$$\begin{aligned} E(\text{LSP}^{\text{profit}}(i)) &= c \int_{t_1}^{\frac{i-o}{T}} (iT + i)f(t)dt + co \int_{\frac{i-o}{T}}^{t_u} f(t)dt \\ &- e \int_{\frac{o-i}{T}}^{t_u} (iT + i - o)f(t)dt \\ &- ni - p \int_{t_1}^{\frac{o-i}{T}} (o - (iT + i))f(t)dt + r \int_{\frac{o-i}{T}}^{t_u} f(t)dt \end{aligned} \quad (6)$$

From the supply chain management perspective, it would be optimal to determine the capacity increase that incurs the minimum expected cost for the entire supply chain; hence, we define the expected cost of the centralized supply chain as the difference between the total cost of the CDG and the total profit of the LSP since the supply chain we analyze for the contract is focused on the transaction between these two companies. The centralized supply chain can be interpreted as a single decision maker who manages both the CDG's operations and the LSP's operations [21]. Then this central decision maker would like to minimize the expected centralized supply chain cost that is given in Eq. (7).

$$\begin{aligned} E(\text{SC}^{\text{cost}}(i)) &= u \int_0^{\frac{X-i}{T}} (X - (iT + i))f(t)dt \\ &+ \min\{d, e\} \int_{\frac{X-i}{T}}^1 ((iT + i) - X)f(t)dt + ni \end{aligned} \quad (7)$$

In the centralized supply chain analysis, there is no need for delivery orders (o) since the central decision maker will organize deliveries according to the external demand X .

Accordingly, we define seven possible scenarios (Table 1) between the CDG and the LSP, to represent the current situation (S1), the delivery orders that lead to the optimum capacity increase under the centralized supply chain (S2), the delivery orders that minimize the CDG's cost (S3), the penalty that leads to the optimum capacity increase under the centralized supply chain (S4), the reward that leads to the optimum capacity increase under the centralized supply chain (S5), the penalty and the reward that lead to the optimum capacity increase under the centralized supply chain (S6), and the optimum capacity increase under the centralized supply chain (S7).

The S1 is the current situation, where the CDG and LSP act independently, and the S7 is the ideal situation where a central decision maker optimizes the capacity increase that would minimize the expected total cost for the entire supply chain, using the total costs incurred by the CDG and the LSP. In S2 and S3, the CDG does not use the penalty or the reward in the contract but tries to stimulate the LSP to increase its capacity by its delivery orders. S2 is analyzed to reflect the optimal capacity increase under the centralized supply chain, whereas S3 is analyzed to reflect the situation that minimizes the CDG's cost. S4–S6 are analyzed around the penalty and reward terms, all stimulating the optimal capacity increase required under the centralized supply chain, by using only the penalty (S4), only the reward (S5), and both the penalty and the reward (S6).

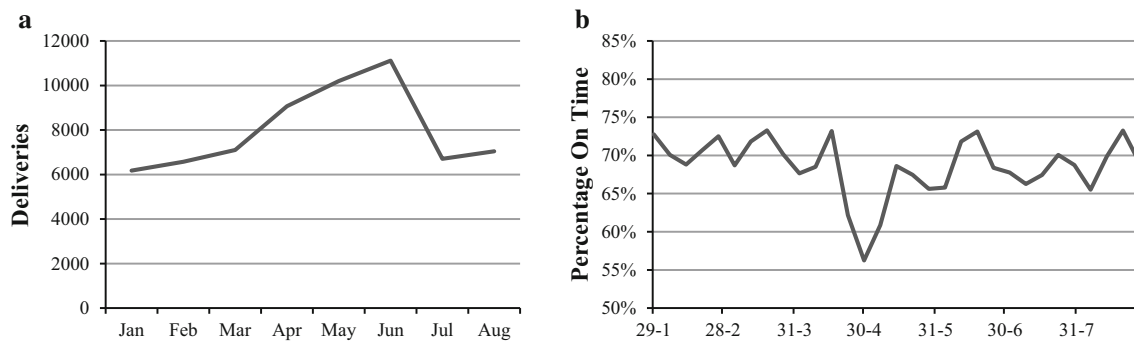


Fig. 3 **a** Monthly deliveries of CDG; **b** LSP's on-time delivery performance

economic activities. This reduction resulted in increased sales until the end of June 2009 when the reduction ceased to be in effect (Fig. 3a, volumes disguised due to confidentiality) and sales dropped back to the level before the government's intervention. In the analysis period (January–August 2009), CDG's LSP has completed 65,000 deliveries (disguised), with an on-time delivery performance presented in Fig. 3b.

Apart from the low on-time delivery performance in April–May originating from the unexpected increase in CDG's demand due to tax reduction introduced by the government to revitalize the economic activity in the country, the LSP does not reserve sufficient capacity for CDG; it is late 30 % of the time, on average, and a capacity increase in the fleet is required. With the exception of 56 % on-time delivery performance of the LSP at the end of April and beginning of May, it is observed that the LSP's on-time delivery performance ranges between 65 and 75 %. This interval is the percentage of LSP's available capacity ($t \in [0.65-0.75]$, uniform-distributed with the mathematical expression given in Table 1) in the current situation. It is clear that a mechanism is needed for the LSP to increase its available capacity for CDG to decrease the costs associated with non-delivery or late delivery. Figure 4 provides the volume of late deliveries for 1–6+ days. CDG explains that most of these delays are based on operational planning deficiencies or not taking into account

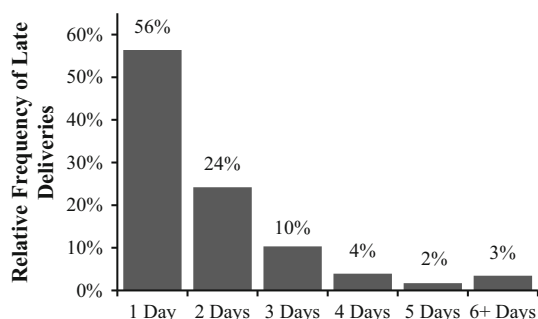


Fig. 4 Late delivery breakdown

local conditions (for example, regular closures of main streets due to local farmers markets).

The LSP's late deliveries result in CDG's not being able to place their products in the market on time and consequently incurring lost sales. For the white goods industry, the value of lost sales is calculated as 11 % of the sales value [27]. This rate is used to estimate the CDG's cost due to late deliveries. In the analysis phase of the contract, aggregated data are used; delivery volumes are represented in terms of vehicles and delivery costs are calculated based on average values because the data on deliveries, delivery costs, and sales are not kept at the same detail. To meet the confidentiality requirements, we had to disguise all of the actual figures. Following from [27], we calculate 11 % of the average sales per vehicle to estimate the cost of unmet deliveries per vehicle for CDG ($u = \text{TRY } 6275$). Based on the proportion of transportation cost in gross sales provided by CDG, we calculate the average transportation cost per vehicle ($c = \text{TRY } 1550$).

There are also costs associated with CDG's ordering more than required due to forecasting errors or marketing decisions. When CDG sends products more than the actual demand, these products may be returned by the dealers on the basis of insufficient space. All returns are transported back to the factory using the LSP's courier network since the returned items would not fill up a truck. Subsequently, using the courier network is more expensive than using the freight transportation. Analyzing the returns data (returned items, item volumes, return costs) and aggregating on the basis of vehicles, the transportation cost of returned items per vehicle is calculated to be TRY 1745. Since CDG initially incurred the transportation cost to send these items to its dealers, the cost of ordering deliveries more than required per vehicle (d) is this return cost: TRY 1745 (the return delivery cost using the courier service). At the time of data collection, 9.7 % of CDG's deliveries were returned by its dealers.

According to the analysis on the transported volumes, CDG's monthly delivery requirement is 130 vehicles on

average ($v = 130$). The LSP's delivery capacity is calculated from the information provided on the company website in August 2009. While T is the LSP's available capacity for all its clients, as can be seen in Fig. 3b, the LSP has on average 70 % of its capacity available to the CDG (i.e., $E[t] = 0.7$). Taking into consideration other customers of the LSP, it is estimated that the LSP reserves 91 vehicles to CDG (available capacity in terms of vehicles, $T \times E[t] = 130 \times .7 = 91$) per month, lower than what CDG requires as is evident from the delivery performance. The LSP needs to increase this capacity to improve its delivery performance, and the cost of this capacity increase is calculated based on actual vehicle costs but disguised to be comparable to CDG's costs. The cost of increasing the capacity by one vehicle (g) is calculated to be TRY 1160. The expert opinion of the Chair of Logistics Association (LODER) in Turkey is used to estimate the cost of unused capacity for the LSP. It is suggested that in the long run, this cost would approximate the opportunity cost of not using the vehicle for transportation. Hence, unused capacity cost for the LSP (e) is assumed to be the same as average transportation cost per vehicle $c = \text{TRY } 1550$. We assume that the CDG and the LSP do not behave opportunistically and they do not exploit information about the other party. We also assume that the price paid by CDG to the LSP is externally determined (i.e., it is not optimized in the model).

The contract between CDG and the LSP was not a coordinating one; that is, CDG ordered deliveries as required, and the LSP would temporarily increase its capacity (outsource deliveries to other available low-cost logistics service providers) to satisfy CDG's delivery requirements if needed. However, this temporary increase was not preferable by the CDG since it resulted in poor delivery quality manifesting as late deliveries, or damages to the products. In fact, as a favorable solution, the LSP's permanent capacity increase decision can be affected by the type of coordinating contract employed by CDG. It is possible for CDG to use delivery order levels (o), penalty (p) or reward (r) schemes, or any combinations of these in the coordinating contract. The results of these different coordinating contract parameters are compared to the ideal case, which is full coordination by minimizing the supply chain cost under central decision maker assumption.

CDG is the party deciding on the coordinating contract parameters and affecting the LSP's decision to build extra capacity. Consequently, the LSP acts upon instructions (delivery orders) from the CDG. The LSP's decision to build extra capacity directly affects CDG's ability to fulfill their orders on time, and CDG is confronted with the costs of not being able to provide the products to the market when they are demanded. The anticipation function describes the LSP's capacity increase decision based on

CDG's delivery orders and the penalty or reward clause included in the contract. Table 2 summarizes the parameters used in the contract, all of which are derived from the CDG's delivery records, collected from the Manugistics software used at the time.

Once we validated the model with the problem owner CDG, we solved it under the seven scenarios as described in the methodology section so that the CDG could choose the most appropriate scenario. To evaluate these scenarios, we calculate an efficiency measure taking into account the coordination under central decision maker assumption and the uncoordinated case.

Efficiency of Scenario j = (Performance under Scenario j —Performance under the uncoordinated case)/(Performance under central decision maker assumption—Performance under the uncoordinated case) where $j \in \{1, \dots, 7\}$.

This calculation results in 100 % efficiency for the case under central decision maker assumption and 0 % efficiency for the uncoordinated case. The efficiency of remaining scenarios is in the $[0, 100 \text{ \%}]$ interval.

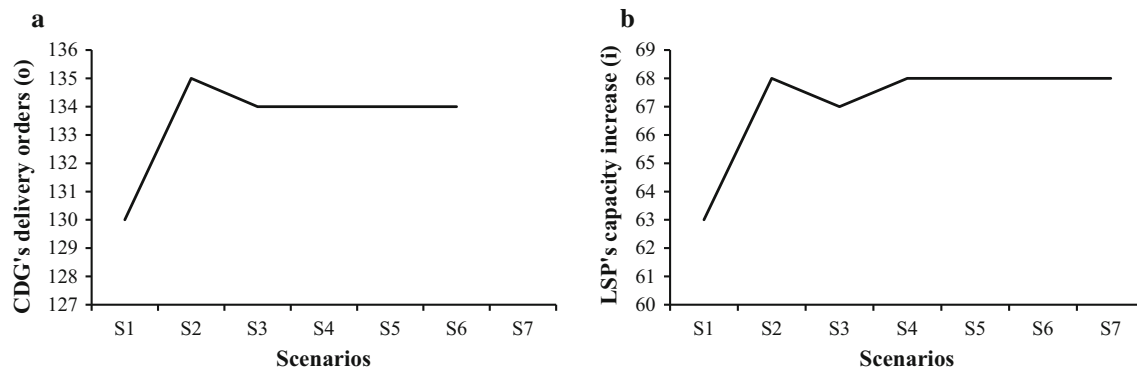
CDG's cost, LSP's profit, and total SC cost are given in Table 3 together with the respective contract efficiencies.

When there is no coordination between the parties, the CDG's cost is TRY 217,498 and the LSP's profit is TRY 123,039, with the total supply chain cost of TRY 94,459. The CDG's cost is lower in any scenario other than S1 (no coordination). The CDG should prefer coordinating the chain either using delivery orders (o), penalty (p), reward (r), or a combination of these rather than leaving the transaction conditions as it is. On the other hand, LSP's profit is the highest with the reward-only contract (S5) and the lowest in the current situation of no coordination (S1). Even with the penalty-only contract (S4), LSP does slightly better (0.05 %) than the no coordination case (S1); hence, any of the coordinating contracts (S2–S6) would be preferable. The efficiencies of S4–S6 are the same (96.1 %) as a consequence of the fact that they coordinate the members with respect to the optimal capacity increase that minimizes the expected cost of the centralized the supply chain.

When the contracts are analyzed in terms of the total supply chain cost, the supply chain cost decreases by 10 % if it were possible to switch from the uncoordinated case (S1) to the full coordination under the central decision maker (S7). The CDG's partial coordination with penalty and reward contracts (S4–S6) leads to lower expected centralized supply chain costs in comparison with coordination with delivery orders (S2–S3) and a 9.6 % reduction in total supply chain cost compared to the uncoordinated case (S4–S6 vs S1). It should be noted that the parameters were disguised to comply with the CDG's confidentiality request and considering the real business environment a small percentage of reduction in

Table 2 Parameters and variables of penalty—reward contract

Symbol	Value	Definition
u	6275	Unit cost of unmet delivery per vehicle; TRY
d	1745	Unit cost of ordering more deliveries than required; TRY
c	1550	Unit cost of delivery; TRY
e	1550	Unit cost of unused capacity; TRY
n	1160	Unit cost of increasing capacity; TRY
v	130	CDG's delivery requirement per month; number of vehicles
T	91	LSP's available capacity per month; number of vehicles
t		A random percentage of LSP's available capacity each month
$F(t)$		Cumulative distribution function of t
$f(t)$		Probability density function of t , $f(x) = \frac{1}{B-A}$ for $A \leq x \leq B$
t_l	0.65	Lower limit of percentage of LSP's capacity t ; $t_l \in [0, 1]$
t_u	0.75	Upper limit of percentage of LSP's capacity t ; $t_u \in [0, 1]$
o		Orders of CDG
x		Actual deliveries
X		Required deliveries
i		Capacity increase of LSP
$E(\text{CDG}^{\text{cost}})$		Expected value of CDG's cost
$E(\text{LSP}^{\text{profit}})$		Expected value of LSP's profit
$E(\text{SC}^{\text{cost}})$		Expected cost of supply chain
p		Penalty to be imposed on the LSP
r		Reward to be given to the LSP

**Fig. 5** **a** Delivery orders (o) and **b** capacity (i) increase under the scenarios

costs is still desirable to the company because of the scale of the costs.

The CDG's delivery orders (o) and LSP's capacity increase (i) are given in Fig. 5a, b, respectively; there is no value for o under S7 since the central decision maker controlling the two parties would not give delivery orders from one party to another but arrange the capacity increase according to the external demand (X).

The capacity increase (i) under the central decision maker assumption that minimizes the total supply chain cost is 68 in Fig. 5b. In the uncoordinated case (S1) the CDG's delivery order is equal to its delivery demand ($o = X$) and is 130 delivery orders per month. The LSP's

capacity increase corresponding to $o = 130$ is at its lowest level ($i = 63$). When the CDG coordinates with the delivery orders that achieve the optimum capacity increase for the supply chain (S2 : $o = 135$), the LSP responds to this level of delivery order with a capacity increase of 68. In other words, CDG should place a delivery order of 135 to force the LSP to increase capacity as much as is required under the central decision maker assumption (S7). In S3, which minimizes the CDG's cost without enforcing penalties, the optimum level of delivery orders is 134, which is responded by the LSP with a capacity increase of 67, lower than the optimal capacity increase under S7. For S4–S6, which achieve the optimum capacity increase

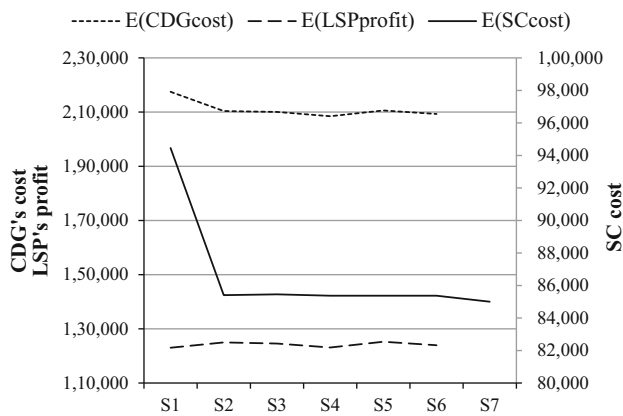


Fig. 6 Performance of CDG, LSP and SC depending on coordinating contract

($i = 68$) with penalty-only (S4), reward-only (S5) and penalty and reward (S6) contracts, respectively; the applicable penalty is TRY 500 and the applicable reward is TRY 3426. For example, the CDG should impose a penalty of TRY 500 on the LSP or offer a reward of TRY 3426 to the LSP for the delivery order $o = 134$ in order to have the LSP increase its capacity by the optimum capacity increase ($i = 68$).

In Fig. 6, the CDG's cost, the LSP's profit and the cost of the centralized SC are plotted with respect to the seven scenarios analyzed for the proposed coordination mechanisms. As was indicated earlier, the lowest cost of SC is obtained under the central decision maker assumption (S7). Consequently, the highest cost of SC is observed in the uncoordinated case (S1). CDG's coordination with delivery orders that minimizes CDG's cost (S3) reduces the cost of SC by 9.53 % in comparison with the uncoordinated case (S1). However, the minimum cost of SC without the penalty-only, reward-only and penalty and reward contracts is when CDG uses the delivery order that achieves the optimum capacity increase for coordination (S2) with a 9.58 % reduction from the uncoordinated case (S1). Similarly, penalty and reward tools decrease the supply chain cost by 9.62 % in comparison with the uncoordinated case (S1).

Again in Fig. 6, CDG's costs are lower in all of the scenarios S2–S6 than S1. The lowest cost of CDG occurs in coordination with penalty that achieves the optimum capacity increase (S4). On the other hand, the LSP's profit is higher in all of the scenarios S2–S6. Thus, CDG can achieve a more efficient supply chain using any of the suggested coordinating contracts.

Figure 7a presents the change in the profit of LSP with respect to the capacity increase in the uncoordinated case (S1). When there is no coordination, CDG opens delivery orders as many as required ($o = 130$) and in response, the LSP's optimum capacity increase becomes 63 vehicles. Under the central decision maker assumption (S7), the total cost of SC is minimized with respect to the capacity increase decision. Optimum capacity increase is 68 and the cost of SC is TRY 85,007 (Fig. 7b). When CDG affects the LSP's capacity increase decision with its delivery orders, the optimum delivery order level that minimizes CDG's cost is 134 vehicles (Fig. 7c). In that case the cost of SC is TRY 85,456 and the efficiency of the contract is 95.2 %.

CDG's delivery orders are analyzed in two perspectives. The first is the S2: coordinating contract with delivery order that achieves the optimum capacity increase ($o = 135$ for $i = 68$) and the second is the S3: coordination with delivery order that minimizes CDG's cost ($o = 133$ and $i = 67$). The level of delivery orders that minimize the CDG's cost (S3) improves the cost by 3.42 % in comparison with the uncoordinated case (S1), whereas the level of delivery orders that provides the optimum capacity increase for the SC (S2) improves the CDG's cost by 3.42 % in comparison with S1 and worsens CDG's cost by 0.16 % in comparison with S3. The LSP's profit increases by 1.27 % in S3 (coordination with delivery order that minimizes CDG's cost) and 1.58 % in S2 (coordinating contract with delivery order that achieves the optimum capacity increase). This level of delivery order ($o = 135$) leading to the optimum capacity increase for the cost of SC decreases the CDG's cost by 3.26 % and increases the LSP's profit by 1.58 %. Consequently, the efficiency of this coordinating contract (S2) becomes 95.7 %. For the

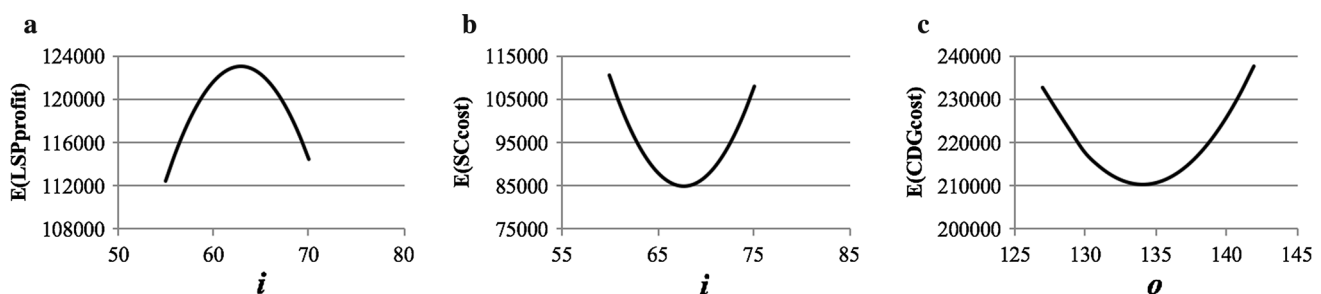


Fig. 7 a Optimum capacity increase of the LSP in uncoordinated case (S1). b Optimum capacity increase for SC under central decision maker (S7). c Optimum delivery order for CDG (S2)

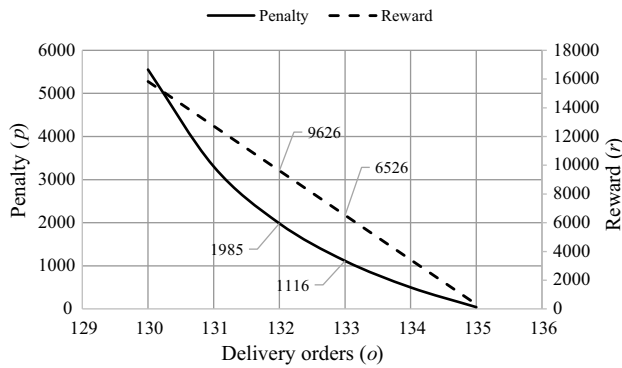


Fig. 8 The relationship between CDG's delivery order, penalty, and reward

coordinating contract with penalty and reward that achieves the optimum capacity increase (S6), penalty (p) and reward (r) that would lead the LSP to the optimum capacity increase decision that minimizes the total SC cost are analyzed together with the delivery orders (o). This way, CDG can choose between various penalty and reward combinations with respect to the delivery orders (Fig. 8).

For example, to have the LSP decide to increase its capacity by 68 vehicles, CDG should give a delivery order of 132 vehicles and pose a penalty of TRY 1985 or a delivery order of 133 vehicles with a penalty of TRY 1116 (see Fig. 8). If the CDG chooses to offer a reward instead of a penalty, then the level of reward that corresponds to the capacity increase decision of 68 vehicles with a delivery order of 132 is TRY 9626. Although this level of reward increases the CDG's cost, it leads to a 2.57 % lower cost (a difference of TRY 5592) than the uncoordinated case (S1). In the coordinating contract with penalty that achieves the optimum capacity increase (S4: $i = 68$) with $o = 134$, the LSP's profit is increased by 0.05 % (a difference of TRY 64) in comparison with the uncoordinated case (S1). Therefore, the LSP would be willing to accept the penalty-only contract if the $o = 134$, since the profit is slightly better (not worse off) than the uncoordinated case.

On the other hand, the LSP would be willing to accept the reward-only coordinating contract with $o = 134$ since it leads to an increase in profit by 1.79 % (a difference of TRY 2201). If the CDG offers a both penalty and reward coordinating contract, the LSP would still be willing to accept this type of contract since its profit will be higher (a difference of TRY 911, 1.79 % higher) than the uncoordinated case (S1), so none of the firms would be worse off with a penalty and reward contract but indeed both of them would be better off.

We also conduct a sensitivity analysis on the parameters of the problem in the current situation (S1) and the penalty and reward contract (S6) to observe how the critical decision variables $E(\text{CDG}^{\text{cost}})$, $E(\text{LSP}^{\text{profit}})$, and $E(\text{SC}^{\text{cost}})$ change depending on the associated unit costs. We decrease and increase one at a time the associated cost of unmet deliveries (u), the cost of excess deliveries (d), the cost of delivery (c), the cost of unused capacity for the LSP (e), and the cost of increasing capacity for the LSP (n) and show the impact (positive and negative) on CDG's cost, LSP's profit, and the SC cost (Fig. 9).

The results in Fig. 9 suggest that the expected cost of the CDG is affected the most by the changes in the LSP's available capacity (T) followed by the changes in the delivery cost (c). On the other hand, the LSP's expected profit is the most sensitive to the delivery charge (c), followed by the cost of increasing capacity (n). We also observe that the total supply chain cost is most sensitive to the cost of increasing capacity and the LSP's available capacity.

To sum up, all coordinating contracts are better (has lower cost) for CDG than no coordination. When the parameters of the problem between CDG and the LSP are analyzed, it is detected that the most critical problem parameter for CDG is the requirement for timely deliveries, followed by clauses addressing the cost of not fulfilling the delivery requests, and delivery costs. On the other hand, delivery costs and capacity-increasing costs are the most critical parameters for the LSP. In terms of total supply

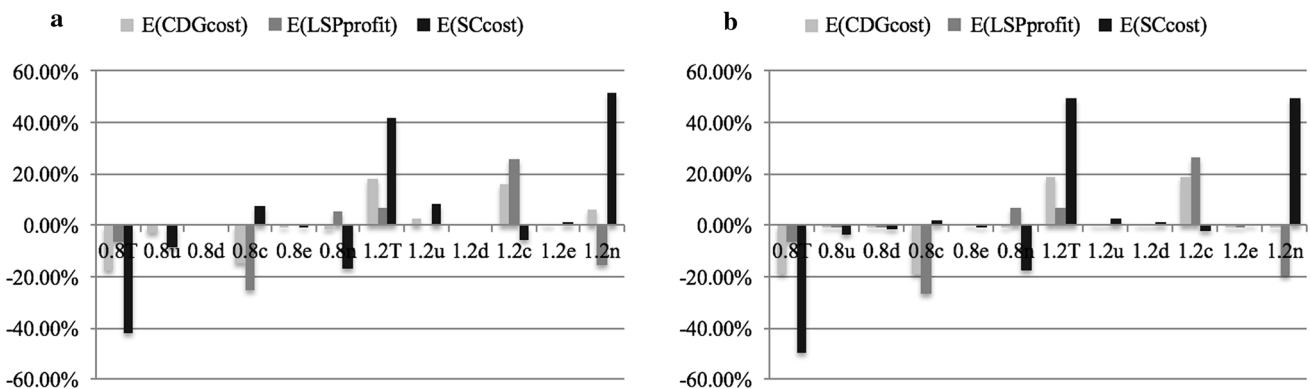


Fig. 9 Sensitivity analysis on the problem parameters for a S1 and b S6

chain cost, the most critical parameters are delivery requirements, capacity increase cost, and delivery cost. One would think that the delivery cost should not be important for the total supply chain cost, since it is the transaction between the CDG and its LSP. However, it is critical in terms of total supply chain costs, since it is an important determinant for the LSP in terms of the level of extra capacity that it determines to build.

5 Discussion and conclusions

The analysis of the current status between CDG and the LSP shows that the transportation contracts coordinating CDG and the LSP could be analyzed as a penalty–reward contract. Since the CDG incurs transportation costs, its objective function is the minimization of related costs. On the other hand, the revenue of the LSP comes from transportation activities; therefore, its objective function is the maximization of profits. Total supply chain costs are calculated by taking the difference between CDG's costs and the LSP's profits. Five coordinating contracts (S2–S6) are analyzed, namely coordinating contract with delivery order (the optimum order quantity for full coordination in the supply chain: S2 and the optimum order quantity for CDG: S3), coordinating contract with only a penalty term (S4), coordinating contract with only a reward term (S5), and coordinating contract with both penalty and reward terms (S6). The performance of all scenarios is compared to the scenario under the central decision maker assumption (S7). Results indicate that CDG always does better if it uses any kind of coordinating contract other than the current situation (S1). However, the LSP's profit is almost the same when CDG offers a penalty-only contract (S4). In all other contracts, the LSP earns a much higher profit. Therefore, using any of the coordinating contracts is recommended.

This study suggests using a penalty–reward contract to improve the contracts between a consumer durable goods company in Turkey and its logistics service provider. It can solve a limited number of problems such as motivating the LSP to reserve or install more capacity for the CDG and hence improving the response rate of the supply chain as well as increasing service levels. One problem this contract is not able to address is related to the behavior of LSP's employees which was highlighted by the CDG during our analysis of the problem. In the eyes of the consumer, employees of the LSP are regarded as the employees of CDG since they are bringing the goods of the CDG. However, irresponsible and reckless behavior of LSP employees were observed by the end-consumers as well as the dealers from time to time and these were raised as complaints in the communication channel of the CDG. This would be a concern very difficult to be addressed in the contract. One remedy can be to invite the LSP's employees

to CDG's headquarters and explain their role in the supply chain, CDG's brand image, and perceptions and expectations of CDG customers from them. In this research we do not test different logistics strategies but actually model the manufacturer's anticipative planning to coordinate the supply chain operations by testing different parameters of penalty–reward contracts.

Although there are numerous studies on the coordination of different aspects of the supply chain, studying coordination separated from other issues may not be helpful in coordinating the whole supply chain. The research on the coordination of the supply chain aspects remains in the early stages. As is also indicated by [2], although the need for coordination is understood, there is a need for studies with a holistic view on coordination, incorporating behavioral aspects as well. Similarly, supply contract models analyzed in this study coordinate the relationship between certain parties of the supply chain at a certain time. However, a holistic model which incorporates all players of the supply chain will provide more realistic results. Building such a model and modeling each player of the chain by using several operational research and decision models will require enormous effort and comprehensive study where confidentiality of information may surface as one of the major problems.

The contribution of this study is that it shows the manufacturer can decide on the contract parameters by anticipating the reaction of its logistics service provider. It is proved in this case study that coordination between a manufacturer and its logistics service provider can be achieved using contracts and that better levels of objective functions can be reached mathematically and empirically. In summary, the proposed methodology and its application were used to solve a real supply chain contract problem and to establish an analytical basis for the manufacturer's contracts with its logistics service providers. The proposed framework can be followed to analyze contracts of the manufacturer with its raw materials or unfinished goods suppliers. However, some limitations of this approach should also be recognized. Depending on the parameter values, market governance could be better than an agreement under a reward–penalty contract. For example, when both companies are worse off under the penalty–reward contract, it would be more appropriate to act independently rather than implementing the contract, which means a penalty–reward contract may not always be efficient. Therefore, a sensitivity analysis should be performed on the parameter values to identify the ranges for which the companies are better off by using this type of contract.

One of the issues to be addressed in logistics contracts, which we did not consider in this work, is the transportation damage. The actions to be taken in the event of transportation damages, as well as the appropriate

Table 3 Performance of CDG, LSP and the supply chain under scenarios S1–S7

Scenarios	o	i	$E(\text{CDG}^{\text{cost}})$	$E(\text{LSP}^{\text{profit}})$	$E(\text{SC}^{\text{cost}})$	Efficiency (%)
S1	130	63	217,498	123,039	94,459	0.0
S2	135	68	210,398	124,989	85,409	95.7
S3	134	67	210,055	124,599	85,456	95.2
S4 $p = 500$	134	68	208,475	123,103	85,372	96.1
S5 $r = 3426$	134	68	210,611	125,240	85,372	96.1
S6 $p = 500; r = 3426$	134	68	209,322	123,950	85,372	96.1
S7	–	68	–	–	85,007	100

communication procedures and responsibilities of the logistics services provider, can be addressed in the contract as separate clauses, or can be mentioned in the appendix of the contract as a protocol or a procedure. It is important to choose a reliable transporter and an appropriate transport vehicle to minimize transportation damage. For the party purchasing logistics services, working with an experienced LSP may be appropriate, since working with a random or untested LSP may lead to damaged products, delays, low quality service, and, accordingly, additional costs and the loss of business. Although profits may not increase as a result of coordination [28], the costs arising from lack of coordination may be eliminated.

The use of logistics services continues to increase all around the world, including Turkey, the subject country of this study. Current and predicted levels of globalization, with the attendant dispersion of production and consumption points all around the world, make it impossible for a firm to have its own logistics operation, as it is neither sustainable nor profitable to do so. Nonetheless, although it is almost obligatory for companies to outsource logistics services, delivery problems (such as losing track/control of the product, late deliveries, transportation damages, not acting as a part of the focal company in interactions with the consumers, etc.) force the focal company to be diligent and selective as to the firm with which it chooses to sign logistics services contracts, and to spend more time on contract parameters. As a response to this, logistics service providers have started to put more effort into building relationships with their partners, emphasizing service quality and trust [29]. This transformation and development is not only inevitable, but also critical for Turkey's integration with the world.

Commonly used contract parameters in third-party logistics include service standards, key performance metrics and timeline requirements [30]. If the members of a supply chain start a strategic partnership with the objective of establishing reciprocal trust and a fair relationship dependent on the processes, then they can handle the problems and their negative consequences in a more efficient way. It would be helpful in building a long-term, mutually beneficial, and strong relationship to spend sufficient effort on the clauses in the analysis phase of the contract, defining the

construction of this strategic partnership. In such relationships, the partners will very rarely and most probably accidentally fail to fulfill their responsibilities and liabilities or violate contract clauses; nonetheless, protection against these rare eventualities is preferable.

Moreover, considering the consequences of globalization, analyzing contracts for those firms operating in international markets by taking into account cross-country differences is another interesting research direction. Here, in addition to the contract parameters found by mathematical models, corrections for differences in culture and bureaucracy will be required.

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Appendix

$$\begin{aligned}
 \frac{\partial E(\text{CDG}^{\text{cost}}(o))}{\partial o} = & -(X - o) * \frac{u}{T * (t_l - t_u)} + \left(t_u + \frac{i - o}{T} \right) \\
 & * \frac{u}{t_l - t_u} + (X - o) * \frac{u}{T * (t_l - t_u)} 1_{\{X > o\}} \\
 & + (X - o) * \frac{d}{T * (t_l - t_u)} - d * \frac{t_u + \frac{i - o}{T}}{t_l - t_u} \\
 & - (X - o) * \frac{d}{T * (t_l - t_u)} 1_{\{X \leq o\}} - c \\
 & * \frac{o}{T * (t_l - t_u)} - c * \frac{t_u + \frac{i - o}{T}}{t_l - t_u} \\
 & + c * \frac{o}{T * (t_l - t_u)}
 \end{aligned}$$

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