IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 3, Issue 4, Aug-Sept, 2015
ISSN: 2320 – 8791 (Impact Factor: 2.317)
www.ijreat.org

Modeling, Analysis, And Prevention Of Losses In Car Service Contracting

Yossi Avrahamoff, Amir Elalouf

Department of Management, Bar Ilan University, Israel

Abstract

Companies that operate fleets of vehicles are increasingly demanding to purchase car service contracts along with their vehicles. Under these contracts, the vehicle importer covers all vehicle repair and maintenance procedures, and the customer pays a fixed charge per kilometer. The car service contract is currently the best way to manage the expenses of an operational fleet. In a competitive market, contract prices are determined by the market, and importers who wish to remain competitive must adhere to these prices. However, a competitive price might inflict loss on car importers.

This paper presents a model for prevention of losses in car service contracting, based on the premise that several parties that benefit from the sale of the service contract can participate in the costs of the contract. Such cooperation among the various parties can prevent losses, maintain profitability of all parties, and thereby justify the business decision to continue selling car service contracts. The parties that benefit from the sale of vehicles together with car service contracts include the car sales department, the service center (which carries out maintenance and repairs), and the spare parts department. The only department that risks loss is the service contract management department.

The model is based on the delay-time concept, where the process by which a vehicle fails is divided into two stages. The model also incorporates the use of RFIDs to evaluate actual labor hours invested during vehicle service. The proposed model is illustrated through a numerical example.

Keywords: Car services, Vehicles fleet, maintenance, service contract

1. Introduction

In recent years, a growing number of large companies such as DHL, FEDEX, and UPS, as well as medium and small local companies in many developed countries, have been operating commercial vehicle fleets. Currently, the best way for a fleet operator to manage the expenses of an operational fleet is to establish a service contract with the car import company. A service contract is broadly defined as a commercial document representing a business activity. In the context of fleet operations, service contracts between fleet operators (customers) and car importers provide (or pay for) certain repairs and services beyond the vehicles' standard warranty. Under these contracts, the customer is typically charged a fixed price per kilometer driven. Service contracts may include the same terms of coverage as the vehicle's original manufacturer warranty, but they are often different.

Service contracts are becoming more and more popular, with an estimated total value of over several million dollars annually. They provide consumers with the assurance of continuous reliable service, in addition to protection against poor quality and the potential high cost of failure over the long uncertain life of a vehicle. The increasing demand for service contracts has made it necessary for car importers to offer such contracts to commercial companies.

At present, service contracts for car fleets are beneficial for both sides:

Benefits for the customer:
- Transfer of potential loss from the customer to the import company.
- The contract makes it possible to have an annual budget plan for fleet maintenance.
- A fixed cost for every kilometer driven.

Benefits for the importer:

- A new opportunity to sell original spare parts.
- The customer is obligated to use only authorized service centers.
- Direct contact with the customer creates the possibility of selling a new car at the end of the contract period.
- Long-term contracts stimulate economic and business activity, creating new opportunities for increasing revenues.

Despite its benefits, a service contract may involve potential loss for the car importer. Therefore, before establishing service contracts with customers, importers must accurately calculate the costs of operating vehicles. A vehicle's cost of operation consists of three main elements:

Maintenance - The parts that must be replaced according to the manufacturer's instructions.

Wear – The parts that must be replaced due to wear and tear.

Repair – All other parts that may require replacement due to operational failure.

While warranties are provided for all new cars and are included in the basic price of the vehicle, a service contract may be established at any time and always costs extra. The separate and additional cost is the primary distinction between the service contract and the warranty. Under the service contract, customers have no unpredictable expenses. Instead, they pay the amount agreed upon in the service contract. The service contract offered to customers usually begins from the day of purchase and is concurrent with the manufacturer's warranty.

Customers interested in purchasing a vehicle with a car service contract have multiple alternatives for purchasing vehicles from various competing companies and brands, which offer vehicles with identical service contract coverage, providing all services, treatments, and maintenance required for the vehicle in the contract period. This results in a situation in which the competition over vehicle sales or comparisons between competing companies focus on the price of the service contract. Indeed, in this situation there is no difference between high- and low-reliability vehicles, as the companies providing the service contracts are responsible for all maintenance costs. If we assume that, in order to compete, different companies offer their contracts at the same sale price, then these service contracts are likely to result in losses for the companies. The current paper analyzes current data and presents a model that will offer a practical solution for preventing loss in service contracts.

2. Literature review

2.1 Car service contracts

In most cases, importers are responsible for offering car service contracts to customers. These contracts extend the basic coverage received from the manufacturer. Under a service contract, maintenance services are outsourced to a specific company and are performed on a regular basis in accordance with the manufacturer's instructions or in case of failure. The contract period is set in advance and takes into consideration both the service provider and the service recipient. The price of the contract is predefined. The customer’s motivation for purchasing a service contract is clear: such contracts are a step towards reducing risk and preventing uncertainty. In effect, they are a form of insurance. By paying an extra amount, the customer can insure the car against future potential failure and other problems that might occur during the period of the car service contract. Blischke and Murthy (2000) proposed that service contracts can provide an area of flexibility in price negotiations.

Many professionals are now seriously interested in service contracts. By selling contracts, importers can increase their profit. The contract also reduces the occurrence of car failures, as cars sold under such contracts receive regular maintenance from professionals. Service contracts also reduce losses to fleet operators that could be caused by equipment downtime due to unexpected failure of parts.

In practice, the maintenance of vehicles is divided into two main parts:

1. Preventive maintenance - performed according to the manufacturer’s instructions; actions are carried out to reduce the likelihood of failures or to prolong the life of the system (Murthy and Jack 2003).
2. Corrective maintenance - unscheduled actions intended to restore the vehicle to its operational state through corrective actions after the occurrence of failures or detection of fault in the vehicle. This usually involves replacement or repairs of the component responsible for the system's failure.

Chun and Tang (1995) proposed a warranty model for free replacement parts: a fixed-period warranty policy that determines the optimal warranty price for a given warranty period.

Murthy and Yeung (1995) proposed two models for service contracts. They considered these contracts in a demand-supply framework, where the user generates demand for maintenance services, and the service provider acts as the supplier of the services.

1. In the first model, the service provider supplies immediate replacements on demand if the system fails before reaching an age *T*. This could result in higher inventory holding, as the agent must hold spare parts in inventory.

2. In the second model, the service provider is not in a position to provide immediate replacements on demand. The provider compensates the user for the loss of revenue until the failed system is replaced.

Murthy and Ashgarizadeh (1995) developed a game theoretic model for a service contract to characterize the optimal strategies for a single customer and a single agent. Ashgarizadeh and Murthy (2000) extended this work to develop a stochastic model for the service contract to examine the optimal strategies for customers as well as for the agent in a theoretic game setting.

Rinsaka and Sandoh (2006) developed a mathematical model that determines the cost of service when the manufacturer provides an extended warranty. They assumed a unique type of contract stipulating that, after the first failure of a system, the manufacturer would cover replacement of the failed system with a new one. For subsequent failures the contract covered minimal repairs.

Murthy and Kim (2001) developed a model in which the manufacturer sells a repairable product with a non-renewing free-replacement warranty policy with a warranty period. All failures during the warranty period are rectified by the manufacturer through corrective maintenance actions at no cost to the buyer.

Many of the models discussed above are based on several assumptions, such as constant failure rate, replacement with new items only when this is the only option, constant repair costs, and identical customers with a risk-neutral attitude.

Our review of the literature suggests that, although a large amount of research has been conducted on some types of long-term service contracts, only a limited amount of academic research has been carried out to date on the formulation of new policies and modeling costs for service contracts. It also reveals that little or no research has been carried out on developing models that consider the buyer's and the manufacturer's risk preferences and the effect of various servicing strategies on the service contract.

An organization that provides customers with cars together with service contracts relies on several entities within and outside the organization.

The entities involved in the process are:

1. **Car sales department** – Responsible for supplying the car to the customer on schedule. The department's profits are calculated as the price for which the car is sold to the customer minus the cost of the car.
2. **Service contract management department** – This department is responsible for selling the customer a service contract at an agreed-upon price. The department's profits are the total revenues received from the customer minus the maintenance costs paid to the authorized service center servicing the car throughout the contract period.
3. **Authorized service center** – Responsible for receiving the car at the service center and performing maintenance works as defined by the manufacturer (preventive maintenance), as well as repairing the car in case of failure (corrective maintenance). At the end of the service or repair process the service center issues an invoice for the services performed and charges the service contract management department. The invoice includes 2 main components: the cost of the parts assembled in the car and the cost of labor. Cost of labor is determined by the number of hours it takes to assemble each part. Labor hours are defined in standard terms by the car manufacturer; i.e., the time it should take to replace each part is predetermined. The price charged for replacing a part is the predetermined price of a labor hour multiplied by the standard number of hours for replacing the part. The profits of the service center are defined as the difference between the list price for each part and the net price after discount at which the part is sold to the service center.
4. **Spare parts department** – The spare parts department is responsible for supplying the necessary parts to the authorized service center. The service center orders the parts as necessary and according to the types of events it encounters. The parts ordered are divided into two main categories: parts for preventive maintenance and parts for corrective maintenance. Parts are ordered and types of parts are determined at the exclusive discretion of the service center. The profits of the spare parts department are defined as the difference between the net price at which parts are sold to the service center minus the cost of purchasing spare parts for inventory.

All these units are independent, unrelated business units. Each unit has its own goals, and each unit strives to increase its profits. All the units benefit from the process of selling a car with a service contract, but the service contract management department is the only one that risks loss if the service cost is higher than the revenues in the contract. Non-sale of a car will result in a lack of revenues for all units involved in this process.

As noted above, purchasing a car with a service contract enables customers to avoid risk, in that they pay a fixed price per kilometer in exchange for full coverage of the car's maintenance needs. The risk of loss is transferred to the service contract management department. The current paper develops a model that proposes a solution for cases in which a service contract whose price is determined by the market inflicts loss on the service department. Specifically, in cases in which the service contract inflicts loss on the management department, the model proposes that the car sales department and the spare parts department should help subsidize this loss, and that the service center should give a discount on all services and repairs performed at the service center as part of the contract. The discounts given by the service center will be defined as customary discounts for supplying spare parts to preferred customers. The charge for labor hours will be measured by an RFID system that determines actual labor hours. The model is based on the delay-time concept detailed below.

The contributions of this paper are summarized as follows:

1. In the current state of affairs, each department increases its revenues when a new car is sold, but the department that manages the service contracts carries the risk of loss. In the proposed model, the various departments take part in a subsidy process. They enjoy added revenues whenever a new car with a service contract is sold and thus prevent losses, facilitating the sale of new cars with new service contracts.
2. Analysis of the use of RFID technologies with the aim of raising work efficiency of the service center.

2.2 Introduction to the delay-time concept

The delay-time concept proposed by Christer and Wang (1973) has been used extensively in maintenance modeling. The delay-time concept and associated modeling techniques for inspection modeling have been reported in many papers over the last 20 years (see Christer and Waller 1984, Baker and Wang

1991, Wang and Christer 2003, Wang 2008, Wang 2010). The delay time model considers the failure process as a two-stage process. The first stage is from "new" to the initial point of defect. The second stage, from the point of defect to failure, is defined as the "failure" (Golmakani and Moakedi 2012). The time from the initial point of an identifiable defect until failure is called the delay time of the failure. If an inspection is carried out during the delay time of the failure, the defect can be removed or rectified before failure. For any failure, it is assumed that, had the item been inspected at some point prior to failure, the inspection could have revealed the defect that ultimately led to failure (Wang 2012).

Consider, for example, the case of a light truck that does not undergo regular preventive maintenance. During operation of the vehicle, the truck's driver hears a loud noise from the drive shaft and stops the vehicle immediately, to avoid getting stuck in the middle of the road. As the truck does not undergo regular maintenance, and the customer would not normally be expected to check the parts under the vehicle, the defect is not identifiable to the customer, and therefore the delay time in this case is virtually zero (Wang 2008). However, if a qualified mechanic performs a maintenance service, according to the manufacturer's instructions, we assume that the professional mechanic will identify the noise from the bearing. Preventive maintenance actions are carried out to reduce the possibility of failures and extend the life of the parts. The time between the two stages from initial point of defect to the failure, is defined as the delay-time. According to our example, an inspection carried out during the delay-time will identify the problem and prevent the failure of the part.

The delay time as defined in Assumption 4 below provides a window for inspection and repair.

2.3 RFID

Radio-frequency identification (RFID) is a technology that uses communication by radio waves to transfer data between a reader and an electronic tag attached to an object for the purpose of identification and tracking. RFID technology uses an electromagnetic field produced by a proximity reader (RFID reader) for transfer of information received from RFID tags at close ranges. Using energy generated by the field, proximity tags can operate without an external power source and convey memory contents to the reader.

Recent technological developments have significantly decreased the cost of tags, and improved reading distances. RFIDs are used in practical applications such as warehousing, inventory management, logistics, computers, medicine, and more.

By using RFID technology, it is possible to measure the efficiency of working time at a service center. At present, the charge for labor hours is defined by the manufacturer, and the actual time it takes to replace a part is significantly less than the standard time defined by the manufacturer. Since RFID technology is available and utilized in the vehicle industry, a reader can be installed in work stations to track electronic tags installed on cars. Herein we calculate actual working time at the service center as the difference between the time at which the car arrives at the work station and the time at which it leaves the work station.

Problem definition

The purchase of car service contracts may be motivated in part by the desire to reduce risks, and customers may be more likely to purchase car service contracts for more expensive vehicles.

In a competitive market the contract price is determined by the market, and all competitors adapt themselves to the market price. As a result, car suppliers whose major goal is to get as many vehicles as possible on the road may not be able to examine the sales prices of their service contracts in depth. We suggest that service contracts that adhere to prices determined by the market, and for which maintenance costs are known, may inflict losses on car importers. Specifically, the maintenance cost of the vehicle may be higher than the revenues received from the customer.

3. Assumptions and Notation

3.1 Assumptions

1. The service contract applies to a period T.
2. All failures follow a two-stage failure process as defined by the delay-time concept discussed above, that is, from new to the initial point of identification of a hidden defect, and then from this initial point to an eventual failure caused by the defect if not attended to. The duration of the second stage is called the delay time (Christer and Waller 1984).
3. Delay times of all defects follow the same probability distribution function (pdf), denoted by $f(h)$, and the same cumulative distribution function (cdf), denoted $F(h)$.
4. The rate of emergence of defects is constant, denoted by λ. Thus, the emergence of defects

follows a Homogeneous Poisson Process (HPP).

5. Whenever a failure occurs, a corrective repair is carried out.
6. The inspection interval, if it exists, is constant.
7. The inspection process is perfect in that any defects present can be identified.
8. Corrective repairs of failures are minimal repairs in that they bring the equipment to a condition as good as before.
9. Repairs at inspection are also minimal in that they can always rectify the defects and bring the equipment to as good a condition as before. These repairs include addressing defects reported by vehicle drivers.

3.2 Notation

Ep1	Profit or loss of the contract without subsidies
Ep2	Profit or loss of the contract with support from the service center
Ep3	Profit or loss of the contract with subsidies
Z	Income from the contract
Mp	Inspection cost
Md	Defect repair cost
ENd	Expected number of defects
Ms	Cost of service (parts)
Mf	Cost of repair failure
ENf	Expected number of failures
α	Penalty cost per unit time
Df1	Downtime per failure
K	Required failure downtime limit
T	Service contract period
t1	Inspection interval
PT	Sales price of the vehicle for the customer
CT	Total cost of buying a vehicle for the importer

S1	Subsidies from spare parts department
S2	Subsidies from car sales department
Km	Number of kilometers in the contract
Pk	Price per kilometer
Hp	Time for inspection
R	Cost per hour of the service center
Co	Efficiency factor
Hd	Repair time - defect
Pd	Cost of parts for repairing defect
Dw	Discount from service center for parts
Hf	Repair time - failure
Pf	Cost of parts for repairing failure
Ps	Cost of parts for service
Pp	Gross profit from parts - parts department
B1	Profit from parts - parts department
Dp	Discount granted to service center for parts
Cp	Cost of parts (units of 100 NIS)
P	Price of parts (units of 100 NIS)
XX1	Subsidy as percentage of parts profit - parts department
XX2	Subsidy as percentage of vehicle profit – car sales department

4. The Model

The model portrays a process of loss prevention in a service contract, using the principle of delay time. The service process of a car includes regular inspection of the car as predetermined by the car manufacturer. This inspection can be considered preventive maintenance of the car. Since the service is performed at regular times it is possible to use the concept of delay time.

In addition, we assume that technologically advanced RFID systems will be used to help monitor the cost of a labor hour of the service center. The aim is to determine the cost of a labor hour at the service center on the basis of actual measurement by the RFID system. We analyze the model in two stages: In the first stage we will run the model in the present state, in which the various departments set their prices regardless of the terms of the service contract. In the second stage we will run an expanded model that includes the use of RFID technology and in which the various departments cooperating with the service department subsidize some of their services.

1. Profit or loss of the service contract in the present state *Ep1* will be calculated as the difference between incomes from the contract minus the cost of car service, including payment of compensation in the case of delay in repairing the car.

$$Ep1 = Z - \frac{(Mp + MdENd + Ms + MfENf + ENf\,\alpha \max(0, Df1 - K))T}{t1}$$

2. Income from contract *Z* is calculated by price per km multiplied by the number of km in the contract (*Pk*).

$$Z = KmPk$$

3. The car service cost is composed of several components that include the cost of labor and the cost of parts as well as compensation payments for any delay in delivering the car beyond the time period defined in the contract. The cost of service includes the following components: *Mp* (inspection cost), *Md* (defect repair cost), *Ms* (cost of service – parts), *Mf* (cost of repair failure).

4. *Mp* (inspection cost) is calculated by the total number of hours necessary to carry out the inspection (*Hp*), multiplied by the cost of a labor hour at the service center (*R*), multiplied by the efficiency factor (*Co*) expected from the service center. The efficiency factor represents the difference between the official time standard for repair, determined by the manufacturer, and the actual time to repair.

$$Mp = HpRCo$$

5. *Md* (defect repair cost) includes two main components: the cost of work at the service center and the cost of the parts. The sum of these two components is the defect repair cost. This is calculated as follows: the cost of the work equals the total number of labor hours required to repair the defect (*Hp*), multiplied by a labor hour at the service center (*R*), multiplied by the efficiency factor (*Co*) expected from the service center, plus the cost of the parts (*Pd*). The cost of parts charged to the contract by the service center is the net price after a discount of *Dw*.

$$Md = HdRCo + Pd(1 - Dw)$$

6. *Ms* (cost of service – parts) includes the total cost of the parts replaced during servicing, where the price charged by the service center for the parts is the net price after a discount of *Dw*.

$$Ms = Ps(1 - Dw)$$

7. *Mf* (cost of repair – failure) includes two main components: the cost of work at the service center and the cost of the parts. The sum of these two components is the cost of repair failure. This is calculated as follows: the cost of the work equals the total number of hours required to repair a defect (*Hf*), multiplied by cost per hour at the service center (*R*), multiplied by the efficiency factor (*Co*) expected of the service center, plus the cost of the parts (*Pf*). The price charged by the service center for the parts is the net price after a discount of *Dw*.

$$Mf = HfRCo + Pf(1 - Dw)$$

When a car enters the service center for repair of a failure, the sides agree upon a reasonable time frame until repair of the failure. Since the service center has knowledge and experience in repairing cars, the customer expects the car to be ready after repair in a period of time predefined in the contract (downtime per failure – *Df1*). If this period deviates from that defined in the contract, there is a mechanism for compensating the customer. The compensation mechanism is calculated as follows:

$$ENf\,\alpha \max(0, Df1 - K)$$

ENf (expected number of failures) is multiplied by *α* (expected penalty) in cases in which the downtime per failure (*Df1*) is higher than the time defined in the contract *K* as the maximal time that the car should be in the service center for repair of a failure.

8. *ENf* is the expected number of failures over (0, *t1*), and *ENd* is the expected number of defects identified and rectified at *t1* and given in Wang (2008) as

$$ENf = \int_0^{t1} \lambda F(h)dh$$

and

$$ENd = \int_0^{t1} \lambda(1 - F(h))dh$$

and

$$F(h) = 1 - e^{-\beta h}$$

The above equations are formulated under the assumption of perfect inspections and minimal repairs at inspections, such that *ENd* and *ENf* during each inspection interval are the same (Wang 2010).

9. With the aim of preventing loss, we integrate a subsidy process into the model. Profit or loss as a result of the service contract in a state of subsidy *Ep3* will be considered as the difference between the income from the contract minus the car service cost plus subsidies of *S1* and *S2* from two departments in the organization, the spare parts department and the care sales department, respectively. Once subsidies are integrated into the model, the model will appear thus:

$$Ep3 = Z - \frac{(Mp + MdENd + Ms + MfENf + ENf\,\alpha \max(0, Df1 - K))T}{t1} + S1 + S2$$

10. *S1* is the subsidy received from the spare parts department with the aim of preventing loss as a result of the service contract. The subsidy is calculated as a percentage *XX1* of all profit from the sale of parts to the service center as part of the contract. The income derived from the sale of parts to the service center includes the following variables: *Pd* (cost of parts for repair of the defects), *Ps* (cost of

parts for service), *Pf* (cost of parts for repair of failures). It is important to clarify that the sale of parts within the contract is defined as income for the spare parts department on one hand and as a cost to the service contract management department on the other.

As stated, the total income that the spare parts department derives from the sale of parts is the sum of *Ps* plus *Pd* plus *Pf*. Multiplying this total income by the mean percentage representing the spare parts department's gross profit gives the profit of the parts department from this contract. This sum will be multiplied by *XX1*, which represents the subsidy percentage from the parts department. The final value *S1* represents the sum at which the parts department subsidizes the service contract.

$$S1 = B1XX1$$

$$B1 = ((Ps + Pd + Pf)(1 - Dp))Pp$$

$$Pp = \frac{P(1 - Dp) - Cp}{P(1 - Dp)}$$

Combining all the formulas together, we can represent S1 as follows:

$$S1 = \frac{(Ps + Pd + Pf)(P(1 - Dp) - Cp)XX1}{P}$$

11. *S2* is the subsidy received from the car sales department. The subsidy will be calculated as a percentage *XX2* from the total profit that the car sales department receives from the sale of a new car to a customer.

$$S2 = (PT - CT)XX2$$

The profit from the sale of a car is calculated as the price for the customer (*PT*) minus the importer's cost of purchasing the car (*CT*).

5. Numerical example

The numerical example presented below is based on a very light truck that is extremely popular in the market and very common in the distribution industry. The demand for service contracts for these models is very high, and most importers are prepared to offer service contracts for these models. Due to the high competition in the market, all importers offer the same price per km.

The following are the basic data for running the model:

IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 3, Issue 4, Aug-Sept, 2015
ISSN: 2320 – 8791 (Impact Factor: 2.317)
www.ijreat.org

Numerical data

Variable	Description	Value in NIS
Km	Number of kilometers in the contract	**240,000**
Pk	Price per kilometer	**0.18**
T	Service contract period	**792**
t1	Inspection interval	**132**
Ps	Cost of parts for service	**2,950**
Pf	Cost of parts for repairing failure	**2,300**
Pd	Cost of parts for repairing defect	**4,485**
DP	Discount granted to Service center for parts	**30%**
P	Price of parts (one hundred NIS)	**100**
Cp	Cost of parts per one hundred NIS	**37**
R	Cost of the service center per hour	**285**
Hf	Repair time – failure	**1.1**
Dw	Discount from the service center for parts	**0%**
Hp	Time for inspection	**3.5**
Hd	Repair time – defect	**4.1**
Co	Efficiency factor	**1**
Df1	Downtime per failure	**1.5**
α	Penalty cost per unit time	**800**
K	Required failure downtime limit	**1**
PT	Sale price of the vehicle to the customer	**160,000**
CT	The total cost to the importer of buying a vehicle	**130,000**

Numerical example, without subsidies:

Using the data presented above, we ran the model with the aim of examining the present state of affairs, assuming that the income per kilometer is a constant value of *NIS* 0.18 due to the competitive market in which the various brands all offer about the same service for a cost of *NIS* 0.18 per kilometer.

On the basis of these data and after running the model, we see that the profit or loss of the contract is *NIS* -15,960, i.e. in the present state, selling a vehicle with a service contract results in a loss to the service contract management department.

$$Ep1 = -15{,}960$$

Numerical example, with support from the service center only:

As stated in the previous sections, when a customer signs a service contract, he is required to use authorized service centers to service the vehicle. If the customer sends cars to a service center of his own volition, this spares the center marketing and advertising costs aimed at promoting customer visits. We may say that the service center benefits when the customer arrives of his own volition, and this creates additional income for the center. Customers who do not have a service contract may use any service center they wish. When a given service center wishes to convince such a customer to use its services, it might offer a discount for servicing or repairing the vehicle, with the aim of retaining the customer and encouraging him to use the center's services.

As an intermediate stage before running the model with subsidies, we will check the outcome for the case in which the service center offers customers with contracts the same discount that it offers customers who do not have service contracts. The purpose of this check is to see if the contract will be profitable without any support from the parts department and car sales department. The same discount is given to all preferred customers whom the center is interested in retaining for the long term.

This stage is defined as *Ep2*, and we assume that the service center offers vehicles with a service contract a discount of 5% for parts required for repair.

After running the model with the basic data presented above plus a 5% discount for the parts required for repair, we reach a loss of *NIS* -13,684 for the contract.

$$Ep2 = -13{,}684$$

Numerical example, with subsidies from all parties:

We can see that even in the intermediate situation in which the service center awards a 5% discount for parts for vehicles with a service contract, the contract still inflicts losses on the management department. Therefore, at this stage we will run the *Ep3* model, which includes subsidies from the spare parts department and from the car sales department, together with an efficiency factor of the service center, which is monitored by an RFID system. We find that when the efficiency factor (*Co*) is 8%, the discount for parts needed for the vehicle (*Dw*) is 10%, the subsidy from the spare parts department is approximately 35% of the department's profits, and the subsidy from the car sales department is 30% of profits, we reach a balanced situation of no losses to the contract.

$$Ep3 = 0$$

The data presented incorporate all factors involved in the process of vehicle sale and maintenance. In a situation in which the service contract with the customer is balanced and does not inflict loss, the import company will be able to continue marketing other vehicles that contribute to its development and to increasing its activity in the market.

6. Conclusions

Today, more and more companies are interested in implementing car service contracts. In order to be profitable in this new business operation, vehicle importers need to develop a new model that will take into consideration all expenses that they might incur during the period of the contract. Most importers are prepared to offer their customers service contracts that provide comprehensive coverage of the vehicles' maintenance needs. The customer agrees to pay per kilometer. In a competitive market, the price is determined by the market. A car import company that tries to sell service contracts at a higher-than-market price will find it difficult to attract customers, who will prefer cheaper alternatives that offer identical service.

The sale of a vehicle together with a service contract benefits several parties. First, in putting more vehicles on the road, sale of a vehicle promotes the brand and raises the revenues of the car sales department. In addition, vehicles sold with a service contract are obligated to use the importer's authorized service centers, thus enabling these centers to increase their scope of activity and, of course, their profits. Finally, the spare parts department, responsible for managing and providing parts to service centers, increases its revenue in direct proportion to the number of vehicles serviced.

The service contract management department is the only party that stands both to benefit and to lose from the sale of a service contract. The revenues of this department come from the sale of service contracts to customers, and its expenditures are payments to the network's service centers. As noted above, to stay competitive, the management department may have to set prices that ultimately cause it to incur loss. The current paper proposed a model that aims to prevent this situation, on the basis of the notion that the various parties that benefit from the sale of the contract can assist in subsidizing the costs of the contract.

The model presented in this paper draws from the delay-time concept presented in many articles (most notably, Wang 2010), which considers the failure process as a two-stage process: a stage from "new" to an initial point when the defect can be identified by an inspection, and a second stage from that point to failure if the defect is not addressed. By using this principle and adding a process of subsidy, involving all parties that benefit from the sale of the service contract, as well as technological use of an RFID system aimed at measuring the efficiency of work time at the service center, we show that it is possible to reach a state of balance and to prevent losses in service contracts.

Future research can expand this model by analyzing the parts needed for vehicles with a service contract and reaching a state of optimization of necessary inventory. Efficiency in inventory levels will result in more savings for the company and will contribute to its profitability.

7. References

Ashgarizadeh, E., Murthy D. N. P. (2000). Service contracts: A stochastic model. *Mathematical and Computer Modelling 31,* 11-20.

Blischke, W. R., Murthy, D. N. P. (2000). *Reliability Modelling, Prediction and Optimization.* John Wiley & Sons Inc., New York.

Baker, R. D., & Wang, W. (1991). *Estimating the delay-time distribution of faults in repairable machinery from failure data.* IMA Journal of Management Mathematics, 3(4), 259-281.

Chun, Y. H., Tang, K. (1995). Determining the optimal warranty price based on the producer's and customer's risk preferences. *European Journal of Operational Research, 85*, 97-110.

Christer, A. H., Waller, W. M. (1984). Reducing production downtime using delay-time analysis. *Journal of the Operational Research Society 35*(6)*,* 499-512.

Christer, A. H., Wang, W. (1973). Innovatory decision making. In D. L. White and K. C. Brown (Eds.),: *The Role and Effectiveness of Theories of Decision in Practice*. Hodder & Stoughton, London.

Golmakani, H. R., Moakedi, H. (2012), Periodic inspection optimization model for a multi-component repairable system with failure interaction. *The International Journal of Advanced Manufacturing Technology 61* (1-4), 295-302.

Karmarkar, U. S. (1978). Future costs of service contracts for consumer durable goods. *AIEE Transactions 10*, 380-387.

Murthy D. N. P., Kim (2001). Warranty and preventive maintenance. *International Journal of Reliability, Quality and Safety Engineering 8*(2).

Murthy D. N. P., Ashgarizadeh, E. (1995). Modelling service contracts. Presented at the INFORMS Meeting in New Orleans.

Murthy D. N. P., Jack, N. (2003). Warranty and maintenance. In H. Pham (Ed.), *Handbook of Reliability Engineering,* 305-314.

Murthy D. N. P., Yeung (1995). Modelling and analysis of service contracts. *Mathematical and Computer Modelling 22*(10-12), 219-225.

Rinsaka, K., Sandoh, H. (2006). A stochastic model on an additional warranty service contract. *Computers & Mathematics with Applications, 51*(2), 179-188.

Wang, W. (2008). Delay time modelling. In *Complex System Maintenance Handbook.* Springer, London, pp. 345-370.

Wang, W. (2010). A model for maintenance service contract design, negotiation and optimization. *European Journal of Operation Research, 201* (1), 239-246.

Wang, W. (2012). An overview of the recent advances in delay-time-based maintenance modeling. *Reliability Engineering & System Safety 106,* 165-178.

Wang, W., & Christer, A. H. (2003). Solution algorithms for a nonhomogeneous multi-component inspection model. *Computers & Operations Research, 30(1), 19-34.*