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Methods of Aggregated Vehicle Ownership Cost Estimation

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***Abstract* — The article is devoted to the issue of a reasonable choice of a vehicle by a consumer on the basis of its aggregated ownership cost. The developed method of estimating the aggregated vehicle ownership cost provides an opportunity to compare different types of vehicles and choose vehicles with the lowest cost in the conditions of intended operation. Wherein, the method can be used either by private vehicle individual owners or by commercial organizations. Theory of car operation; theory of transportation costs; probability theory and mathematical statistics; mathematical modeling of processes. The specific indicators to estimate the aggregated cost of the full cycle of vehicle ownership have been determined. A universal methodology to estimate the aggregated vehicle ownership cost has been developed to provide possibility to compare various types of vehicles and choose vehicles with the lowest cost in the conditions of intended operation. The model for estimating the aggregated vehicle ownership cost has been theoretically justified. The algorithm to calculate specific indicators of the aggregated vehicle ownership cost has been developed. The method to estimate the aggregated vehicle ownership cost has been proposed to make calculation and evaluation of the specific indicators of the aggregated vehicle ownership cost, depending on its type and annual mileage, possible.**

Keywords* — *cost of ownership, vehicle, operating costs, motor carrier, carrier cost

I. INTRODUCTION

Currently, the level of vehicle-to-population ratio is increasing year-by-year in Russia; the fleet of passenger and cargo vehicles is being updated intensively due to modern domestic and foreign models. Taking in consideration such variety of vehicles, to make the best choice is very difficult for a private or corporate customer. The price often determines the result of selection that is not quite reasonable, since subsequently one should bear expenses on the operation of vehicles that depend on the resource of power units, main components of a vehicle, frequency of maintenance, the prices of spare parts and lubricants, etc.

II. METHODS OF AGGREGATED VEHICLE OWNERSHIP COST ESTIMATION

Currently, the level of vehicle-to-population ratio is increasing year-by-year in Russia; the fleet of passenger and cargo vehicles is being updated intensively due to modern domestic and foreign models. Taking in consideration such variety of vehicles, to make the best choice is very difficult for a private or corporate customer. The price often determines the result of selection that is not quite reasonable, since subsequently one should bear expenses on the operation of vehicles that depend on the resource of power units, main components of a vehicle, frequency of maintenance, the prices of spare parts and lubricants, etc.

The issue of purchasing a vehicle should be considered more reasonably. From the point of view of transportation companies, maximizing profits is the key determiner of the efficiency of operating a vehicle in commercial traffic. The amount of collected profit depends on the efficiency of the operation of a vehicle and carrier prime cost; both of which depend on the aggregated vehicle ownership cost. Nowadays, there is no unified methodology to estimate the aggregated vehicle ownership cost, while the specific indicators of the cost of ownership can be called one of the most important characteristics of the vehicle.

At present, the major problems in the field of transportation by road in Russia are as follows: the rapid aging of the fleet; the steady rise in fuel and fuels and lubricants price; poor quality of roads. These problems can be called theoretical assumptions to estimation of the cost of ownership; in connection with the current situation in the transportation industry, consumers are beginning to show some interest in the cost of owning a vehicle [1, 2].

Conducted by the authors study of the vehicle ownership cost in Russia and abroad led to the conclusion that the issue of the vehicle ownership cost has been studied insufficiently. There are many different online mathematical calculators that give anyone an opportunity to calculate the vehicle ownership

cost by just entering some basic data, such as region of operation, make, model, modification, year of manufacture and annual mileage. But the results of such calculation are far from accurate ones and not even indicative, since they do not take into account many other factors. One and the same significant drawback is typical for all the materials: significant simplification of the estimated cost-of-ownership model by excluding certain types of costs that are unreasonably attributable to non-material ones. In this paper, a useful to potential and actual vehicle owners technique is proposed to provide methodological support to get reliable estimates of the aggregated vehicle ownership cost.

The algorithm to calculate the specific indicators of the aggregated vehicle ownership cost was developed as the basis of the methodology for estimation of the total cost of ownership of a vehicle (hereinafter referred to as the Methods). The algorithm is based on the initial data (Fig. 1).

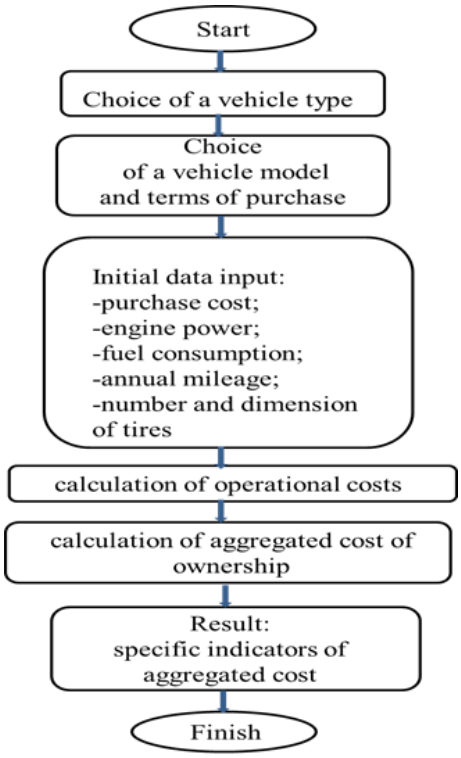

Fig. 1. Algorithm to estimate the aggregated vehicle ownership cost

Let us consider in detail the specific indicators of the aggregate methodology at each stage of the calculation.

The first stage. Choice of a vehicle type. At this stage, it is necessary to choose the type of vehicle stock to estimate the cost of ownership to be performed: in relation to a passenger car or a cargo vehicle.

The second stage. Choice of a vehicle model and terms of purchase. At this stage, it is necessary to choose a specific manufacturer and a model of a vehicle, as well as where and under what terms it will be purchased. One should pay attention to the following parameters: the seller (dealer, intermediary, individual); vehicle equipment; auxiliary vehicle equipment; maintenance capability of an authorized dealer.

The third stage. Initial data input. It is necessary to select the parameters points and enter them into the calculation program. The following variables are the main parameter points of calculation: purchase cost; engine power; fuel consumption; annual mileage; number and dimension of tires; load capacity. We think, term “vehicle purchase cost” means a vehicle purchase made at one’s own expense, without support of a financial program (loan, leasing and payment in installment). This cost is non-recurring expenses for the entire period of owning a vehicle, and do not depend on the period of ownership.

During the purchase process, additional costs may arise and affect the aggregated cost of ownership. They include, for example: travel to the place of purchase of a vehicle, payment for the services of specialists, transportation, purchase of a trailer, etc. Moreover, additional costs may increase due to auxiliary equipment and imposed services if they are not reflected in the sales offer.

The fourth stage. Calculation of operational costs. They consist of several groups: paperwork cost fuel, lubricants and fluids purchase cost, components with a limited service life purchase cost maintenance and repair cost, additional expenses, other expenses.

To calculate operational costs accurately is not possible, only approximately, due to impossibility to predict the precise time of wearing of parts.

Paperwork cost. Paperwork is considered as implementation of all requirements of the traffic regulations at the time of entry into a title of the ownership of a vehicle. Costs under this article are determined as sum registration cost, insurance cost, equipment cost, technical inspection cost, expenses to pay transport tax, expenses to pay charges for emissions of harmful substances.

The cost of state registration of the vehicle is determined: duty for issuing a certificate of state registration of a vehicle, duty for issuing vehicle registration plates, duty for entering amendments into a vehicle’s passport.

According to this method, a vehicle is registered only once per vehicle ownership cycle, which means that its costs are counted only once; but it also necessary to take into account that the trailed equipment is recorded separately.

Insurance cost (MTPL) are recurring, as insurance is valid for a period of 3 months to one (1) year (depending on the wishes of the insured). All insurance companies use one and the same technique to calculate MTPL cost.

Auxiliary vehicle equipment cost, required by the traffic regulations, includes the following: every passenger car shall be equipped with an emergency stop sign, a first aid kit and a fire extinguisher [5–7]. It is necessary to take into account that a first-aid kit and a fire extinguisher are goods with a limited shelf life; on the expiration date, a first-aid kit shall be renewed and a fire extinguisher maintained. However, if we consider a one-year operational cycle, we can simply take into account the cost of the first-aid kit and fire extinguisher.

Technical inspection cost. To apply for an insurance policy, a vehicle shall go through a technical inspection

procedure, the results of which are issued in the form a diagnostic card that gives right to operate the vehicle. However, new vehicles, up to 3 operational years, are not subject to technical inspection and a diagnostic card is not issued in relation of them. In relation of vehicles been operated during 3 to 7 years, the validity period of the diagnostic card is 2 years, and in relation of vehicles been operated during the period above 7 years old – 1 year. Cargo vehicles with a permitted weight of more than 3.5 tons are required to undergo the maintenance procedure annually [8, 9]. Prices for this procedure are fixed and depend only on the type of vehicle.

Expenses to pay transport tax. Every vehicle owner shall pay annual transport tax according to the Tax code of the Russian Federation. The tax amount depends on the engine power. Taxpayers are persons whose vehicles are registered in accordance with the legislation of the Russian Federation. Tax rates are set by the subjects of the Russian Federation.

The following expenses may be included in expenses on fuel and lubricants, and working fluids, depending on the design and equipment of a particular vehicle: on fuel; on engine oil; on transmission oil; on working fluids (brake fluid, power steering fluid, coolant, air conditioning refrigerant, etc.); AdBlue (urea).

Fuel cost is determined by the amount of fuel consumption and depends on the mileage and price of 1 liter of fuel. In a simplified form. The base rate and correction factors are determined according to the tables presented in the Order of the Ministry of Transport of the Russian Federation [12]. In the case of absence of data on consumption in relation a particular model, the average value of costs in the urban and mixed cycles.

The base rate and correction factors are determined according to the tables presented in the Order of the Ministry of Transport of the Russian Federation [12]. It is also necessary to take into account the additional fuel consumption in the winter period (formula 16) and fuel consumption for inside garage run and technical needs of motor transport enterprises (technical inspections, adjustment work, run-in of engine parts and other vehicle units after repair, etc.).

Life-limited parts (LLP) cost are determined by the manufacturer's recommendations and included in the maintenance program. They include components with significantly shorter lifetime limit than the resource of larger and more durable units, such as car body and engine, for example, filters, brake pads, tires, plugs, etc. [12]. The resource of these components can be expressed by mileage or lifetime.

The rate for the restoration and repair of vehicle tires is determined on the basis of 90% of the cost of tires, 10% of the cost is considered residual. The rate for the restoration and repair of vehicle tires is calculated by dividing the share, expressed as a percentage of the cost of a tire, by the service life of tires (thousand km.).

Maintenance and repair cost (M&R). All types of such work are associated with payments for the services of enterprises providing vehicle maintenance services (РТОиР). These costs are determined by the complexity of the work performed and depend on the cost of labor established by an enterprise.

In relation to a new vehicle, an authorized dealer provides pre-scheduled set of works for each event of routine maintenance; and the cost of each inspection is calculated, including purchase cost of spare parts, technical fluids, lubricants, labor cost and other necessary expenses.

Auxiliary equipment cost. When operating the vehicle, some auxiliary equipment may be required, depending on the experience and preferences of the driver, as well as the operating conditions. These costs include the cost of an audio system (radio), a full or additional spare wheel, towing cable, alarm, roof rack, canister, etc.

Other expenses. All necessary costs that are not included in any of the items discussed earlier can be considered as other expenses. For example, the cost of storing a car in a paid guarded parking lot, washing, seasonal storage of winter tires and others.

Cargo vehicles with allowed maximum weight of more than 12 tons is affected by the Platon's toll system for compensating for the damage they cause to the road surface [13].

Sale cost is determined by vehicle's condition. If a vehicle is in good condition and free of defects in the body and paintwork, then, accordingly, it is not necessary to prepare it for resale. Such a vehicle can be sold in the secondary market at no cost, taking into account only depreciation value; and a new owner of a vehicle has not to bear renewal costs.

The fifth stage. Calculation of aggregated ownership cost. The tenure is limited and consists of three stages: purchase, operation and sale. Accordingly, the expenses can be divided into three groups: purchase cost, operating cost and resale cost.

The combination of these three stages (purchase, operation, and sale) is the limited cycle of ownership of the vehicle: the moment of entry into a force of the vehicle ownership title as a starting point and the moment of losing the vehicle ownership title. The aggregated vehicle ownership cost includes all costs incurred by the owner during the entire cycle of ownership of the vehicle minus its cost and expenses reimbursed for the resale of the car.

The sixth stage. Calculation of specific indicators of aggregated vehicle ownership cost.

III. Conclusions

The calculation of the depreciation was made on the basis of an analysis of the report "Depreciation of Used Cargo Cars Been Operated for more than 10 years" prepared by the Russian Automotive Market Research marketing agency [14], as well as monitoring of the market of used special equipment.

Operating a vehicle over a long period of time shows that the specific indicators of the aggregated cost of ownership decrease simultaneously with the increase in the age of a vehicle. The decrease in specific indicators can be explained by the fact that some expenses are counted only once

(registration, etc.), and the valid period of some of them is about five years, therefore, in calculations for a shorter period, the share of these items will decrease simultaneously with increase in the age of a vehicle, that would entail a decrease in specific indicators.

The developed method has been used to identify the following patterns:

- the specific indicator of prime cost of one kilometer of mileage of a vehicle decreases simultaneously with an increase in annual mileage, but at the same time, the specific indicator of prime cost of one full day and one hour of ownership of a vehicle increases.
- the specific indicator of prime cost of one kilometer of mileage of a vehicle, one full day and one hour of ownership of a vehicle decrease simultaneously with an increase in the tenure (if annual mileage is constant).

The developed methods to estimate the aggregated cost of ownership of a vehicle give one an opportunity to compare different types of vehicles and choose the that ones that provide the lowest cost in the process of intended use. It provides a possibility to estimate the costs associated with owning vehicle stock to potential consumers and vehicle owners.

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