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THE CAR FLEET MANAGEMENT MODEL WITH INCLUDING EXPECTATIONS OF THE USERS

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Abstract

The paper presents a certain approach to fleet management in the company, taking into account the mobility of employees and the selection of vehicles for tasks. The main objective is to indicate the factors that significantly affect the proper selection of vehicles for the task, as well as concurrently meeting recipients' needs. The general model for fleet management was presented, taking into account not only the mobility of employees but also the method of obtaining funds for the replacement of greener cars. The current approach is based on the car purchase model in the form of credit, low-purchase leasing, and supervision over the use process and operating costs by the company's internal resources. The problem solved in the article concerns the analysis of entrusting fleet management to specialized Car Fleet Management (CFM) companies. It was pointed out that in this calculation model, CFM companies have to take into account many variables related to vehicle selection and mobility of employees in order to perform tasks. In this article, particular attention has been paid to the areas that CFM analyses when choosing a vehicle for a given company.

Keywords: *Car Fleet Management, assignment of vehicles to tasks, decision-making model of fleet management*

1. Introduction

The process of selecting vehicles for tasks is a complex decision-making process. On the one hand, it is necessary to take into account the requirements of clients covering a wide range of business entities and on the other hand, operators implementing various transport processes, and thus characterized by different nature of transport tasks and employee mobility. The task allocation may be considered in terms of technical, economic, and organizational aspects as well as the qualitative design of service for the area or transport and logistics systems [1], [11], [16], [17], [18].

According to the literature, the classic assignment problem consists of assigning available resources, e.g. vehicles, employees to specified tasks. If it is possible, each task will be assigned to exactly one agent and each contractor has completed only one task. Measures of correctly generated allocation are usually set of a minimum time for all tasks or a minimum cost. The issue is often modified by entering various combinations of the number of tasks assigned to resources, e.g. an equal number of tasks and resources, more tasks than resources, fewer tasks than resources.

Among the many varieties of the assignment problem, the most important varieties can be distinguished [2], [3], [10]:

- the classic assignment problem – one agent for one task,
- the classic assignment problem with defined agents skills,
- the k-cardinality assignment problem,
- the bottleneck assignment problem,
- the balanced assignment problem,
- the minimum deviation assignment problem,
- the lexicographic bottleneck problem,
- the semi-assignment problem,
- the categorized assignment problem.

A comprehensive analysis of assignment models is widely described in [2], [3]. The difference in the presented assignment models consists of different representations of the criterion function, i.e. minimization, maximization of functions, or complex minimax functions.

In recent years, there has been a change in the approach of companies to owning and using a car fleet. So far, the dominant model was the purchase of cars in the form of credit, leasing with low buyout and supervision over the process of use and operating costs by the company's internal resources. Currently, more and more companies decide to entrust fleet management to specialized Car Fleet Management companies (CFM).

In the calculation model, CFM must take into account many variables related to vehicle selection. In this article, we will discuss the areas that CFM analyses when choosing a vehicle for a given company. The decision-making process includes the appropriate selection of the car fleet due to the vehicle's use, useful life and mileage, the current fleet structure divided into car classes assigned to a specific classification of the employee in the company as well as all costs related to vehicle ownership and service options.

As mentioned, one of the important factors that are taken in the selection is the purpose of the vehicle. The company vehicle fleet is generally divided due to functional needs, i.e. service, office, managerial and administrative functions, as well as for commercial departments.

The grading is usually defined in the fleet policy, which regulates the rules of using cars in the company. A fleet policy should also define the levels and scope of possible user-chooser solutions. The experience of CFM companies resulting from work for many recipients (clients) allows adjusting to the current market conditions the permissible range of employee selection [1].

2. Identification of factors relevant to the selection of vehicles for tasks in vehicle fleet managing

When choosing vehicles, the elements of fleet security, the total cost of ownership and current fleet policy trends for the given industry are taken into account [1], [18], [20], [22]. This means that when analysing the needs of the recipient (customer), CFM must obtain the following information:

- current fleet structure with division into car classes assigned to a specific classification of an

employee in the company,
- period of use,
- loss of value of the vehicle,
- estimating the future value of the vehicle,
- vehicle failure,
- operating costs,
- insurance,
- mechanical service,
- tire service,
- event service,
- failure rate and size of service network etc.

Currently, manufacturers offer customers several models of cars, where each model can be in dozens of equipment versions. This results in quite a complexity of the problem being solved. When choosing the fleet structure, the key parameter analysed is the appropriate selection of vehicles for the needs of a given company, both from the view of total cost of ownership (TCO) and the motivational-operational approach. When managing a fleet of vehicles, the current fleet structure with the division into car classes assigned to a specific classification of an employee in the company is very important when choosing vehicles for tasks [4], [5], [6]. For example:

- Level 1 − sales representative − class B car, homologation: passenger, bodywork: hatchback 5 doors, engine displacement up to 1400 ccm and max power 90 HP, minimum equipment: air conditioning, electric windshields, radio, hands-free system, min. 2 airbags. No possibility to adapt the vehicle.
- Level 2 − regional manager − C-class car, homologation: passenger, body: Estate, engine displacement up to 1800 ccm and power max 130 HP, minimum equipment: automatic air conditioning, electric windows front, armrest, lumbar adjustment, radio, hands-free system, min. 4 airbags. No possibility to adapt the vehicle, the ability to choose one of three defined colours.
- Level 3 − office manager − Class C car, homologation: passenger, body: HTB, engine displacement up to 1600 ccm and power max 110 HP, minimum equipment: manual air conditioning, electric windows front, lumbar spine adjustment, radio, hands-free system, min. 4 airbags. No possibility to adapt the vehicle.
- Level 4 − main manager − class D car, homologation: passenger, body: HTB / Kombi, engine displacement up to 2000 ccm and 160 HP max power, minimum equipment: automatic air conditioning, electric windows front / rear, armrest, lumbar adjustment, radio , hands-free, min. 6 airbags, LED lights. The choice of body HTB / Kombi and the ability to choose any metallic colour.
- Level 5 − executive board member – Any car, according to preferences of the user, of monthly rent, not exceeding PLN 4,500 net. Cars with cabriolet excluded from the policy.

One of the key variables affecting the total cost of using and operating vehicles is the right choice of vehicle mileage and its useful life. This parameter affects both the selection of engine power (e.g. for annual runs above 35,000 km the most rational choice is diesel engine), and Total Cost of Ownership (TCO), i.e. all costs associated with owning a vehicle.

The structure of these costs includes, among others: loss of value of the vehicle during the period of use, insurance costs, costs of maintenance inspections and repairs, costs of tires, fuel costs, replacement cars for the duration of repairs, assistance services.

The loss of vehicle value is one of the key costs and risks for CFM. After recognizing the company's needs and taking into account the assumptions of its fleet policy, CFM uses tools to predict the vehicle's value loss, e.g. EUROTAX forecast selects vehicles that after the assumed operational period and the number of kilometres driven will have the lowest loss after use.

As mentioned, estimating the future value of the vehicle (sometimes for 3 or 4 years) is one of the key risks for CFM. Therefore, the valuation takes into account a number of variables that relate to the number of cars to be leased. The greater the number of vehicles, the price at the time of sale may be lower.

The second aspect is the motor power supply. Currently, due to ecological factors, the value of diesel cars has dropped considerably. Vehicle selection due to ecological aspects significantly changed the offer of vehicles for companies.

Another element is the vehicle's equipment. Higher-class cars must be equipped with automatic transmission, because the manual gearbox in this type of vehicles makes it practically impossible to sell them on the secondary market. Like the colour of the vehicle. The metallic colour increases the value of the car on the secondary market.

Another important component of the monthly payment. At the height of insurance, the greatest impact has accident ratio. Accidents in the company can be controlled by appropriate provisions in the fleet policy, e.g. the users own contribution to any damage. The choice of the right vehicle has a big impact on the reduction of claims (valuable).

In the case of insurance, it is important to know the costs of the body parts. The lower they are, the lower the cost of liquidating the damage, and thus the lower the accident ratio (in terms of value). Due to the scale effect and coordination of the claims handling process by qualified CFM employees, the resulting risk is managed from irregularities in the process of claim settlement and the process for the user is fast and friendly.

The last factor that is taken into account when choosing vehicles for tasks concerns the service. At the same time, mechanical service, tire service, event handling as well as failure rate and size of the service network are taken into account.

Depending on the choice of the fleet, the cost of service for the expected mileage will be included in one instalment. It is a photo of the risk on the part of the client, and the CFM Company, having a number of data and economies of scale, is able to analyse and take into account the risk in the selection of specific brands, models and engines.

The cost of mechanical servicing consists of predictable costs, i.e. inspections and typical operational repairs resulting from the assumed mileage, as well as unpredictable costs, the occurrence of which is estimated by the CFM Company based on the experience and scale of the vehicles served.

In the case of tire service, CFM must choose the right class of tires that will ensure safety and low wear. The average mileage of the tire is 45 − 50 thousand kilometres.

As previously mentioned a very important aspect is the cost of ownership. Fuel consumption has a decisive impact on TCO. It is assumed that it constitutes about 25-30% of all costs of owning a vehicle. After losing the value of the vehicle, it is the second largest cost item. Therefore, it is extremely important to select the right vehicle for the task, in particular, the power supply and the engine displacement.

An important factor in the selection of vehicles for tasks is the handling of events. Thanks to the specialization, CFM companies are able to use the scale effect, low unit cost, manage any events that occur during the contract. This reduces the involvement on the part of the client, both in the administrative departments and directly with fleet drivers. One should also mention the aspect regarding the failure rate and the size of the service network. This parameter affects the continuity of mobility in the company. A dense service network ensures competitive prices as well as the speed of action in the event of a breakdown.

3. The procedure of car fleet management support in the aspect of assignment tasks

3.1. General remarks of multi-criteria decision support in transport systems

Decision-making problems regarding the analysis, evaluation and optimization of systems, including transport systems, transport services and selection for tasks are described in many publications. For example, the optimization of transport and distribution systems is determined by the author of the work [12] as a tool to assess the effectiveness of individual system components. The author points out the problems of modern distribution systems as the proper adaptation of the transport network infrastructure elements to the demand for transport, the appropriate selection of the type and number of means of transport and the organization of transport. At the same time, it is pointed out that the optimization of transport systems can be carried out by way of modelling and simulation, formulation and solving of optimization tasks with precise methods and solving optimization tasks with heuristic methods and approximate algorithms. One of the optimizing tools solving of transport tasks is mathematical programming. In addition, the author proposes the MAJA method for the analysis, evaluation and selection of the variant of adapting the transport systems infrastructure to the tasks being performed. The method consists of using detailed assessments of project variants and taking into account the relative importance factors of the partial criteria. The solution consists in calculating the compliance indicators and non-compliance of criteria assessments and using the dominance relation to determine the non-dominant variant in the task. Such a procedure allows choosing the best variant from a set of variants.

However, in the works [8], [9] while analysing the transport service of the area or the technical service system for the transport company, the authors formulate an optimization task. In the case of work [9], the problem concerns the determination of cargo delivery routes and the allocation of transport means for deliveries to routes. When solving the problem, the author created a search of the solution space, the proposed algorithm optimizes both the selection of routes and vehicles, i.e. selects vehicles for the planned route, so that the cost is as minimal as possible.

Author of the work [23],[24] considers the problem of choosing a new vehicle, where it analyses the technical specification of means of transport as a multi criteria assessment, scheduling and the final selection of a means of transport dedicated to servicing passengers on long-distance bus routes. The characteristics of the vehicles include dimensions of the means of transport, number of seating positions, maximum speed, type of gearbox and clutch, steering system, elements of equipment that affect the comfort of the driver and passengers. On the other hand, the partial criteria include vehicle price, operating costs, travel comfort, travel safety, vehicle reliability, durability of the vehicle, warranty period, service availability, dynamics and modernity of the vehicle. The author made relevant analyses using the method based on the Electre surpassing relationship and the method based on the multi-attribute theory of usefulness (AHP) [13].

Decision-making problems that companies with a fleet of vehicles solve are usually complex and require analysis of many areas, giving them a multi criteria character. There are few universal algorithms that can be used in their entirety to solve problems and at the same time effective. Currently, algorithms in the area of multi criteria decision support methods consisting in scheduling project variants are very applicable [14], [15], [19].

The input data for the multi criteria evaluation (ultimately building the ranking) are objects and their features that will be evaluated. These features are characterized by the fact that they are not comparable in any way, i.e. they do not have the same order of magnitude or unit, and therefore it is necessary to carry out appropriate operations to obtain the possibility of comparing. It is important, however, to divide diagnostic variables (accepted for assessment) into subsets, referred to as *stimulant, destimulant, nominant*.

Stimulant is a diagnostic variable the increase of which is associated with an increase (decrease with a decrease) in the assessment of the phenomenon; as a result, the higher values of the diagnostic variable are desirable.

Destimulant is a diagnostic variable the increase of which is related to the decrease (decrease with increase) of the evaluation of the phenomenon; as a result, lower values of the diagnostic variable are desirable.

Nominant is the most favourable variable (value or range) from the point of view of the evaluation of a given phenomenon as the optimal level of the assessed feature.

The set of diagnostic variables is the sum of the disjoint subsets: stimulant, DE stimulant and nominant. When identifying a set of diagnostic variables, stimulants, destimulants and nominants can occur simultaneously. From the point of view of conducted analyses in the field of fleet management, it is important:

– variable range (unitization):

$$f(r,k)=\frac{o(r,k)}{\max_{r\in\mathbf{R}}\{o(r,k)\}-\min_{r\in\mathbf{R}}\{o(r,k)\}},\quad \max_{r\in\mathbf{R}}\{o(r,k)\}>\min_{r\in\mathbf{R}}\{o(r,k)\}, \tag{1}$$

$$f(r,k)=\frac{o(r,k)-\min_{r\in\mathbf{R}}\{o(r,k)\}}{\max_{r\in\mathbf{R}}\{o(r,k)\}-\min_{r\in\mathbf{R}}\{o(r,k)\}},\quad \max_{r\in\mathbf{R}}\{o(r,k)\}>\min_{r\in\mathbf{R}}\{o(r,k)\}, \tag{2}$$

where:

$f(r,k)$ − values of the assessment criteria r − th variant relative to k − th criterion,

$o(r,k)$ − is a value r − th variant relative to k − th criterion,

$\mathbf{K}=\{1,...,k,...,\overline{K}\}$ − set of criteria,

$\mathbf{R}=\{1,...,r,...,\overline{R}\}$ − set of variants,

– maximum or minimum value of the variable:

$$f(r,k)=\frac{o(r,k)}{\max_{r\in\mathbf{R}}\{o(r,k)\}},\quad for\ o(r,k)\neq 0, \tag{3}$$

$$f(r,k)=\frac{\min_{r\in\mathbf{R}}\{o(r,k)\}}{o(r,k)},\quad for\ o(r,k)\neq 0. \tag{4}$$

3.2 Description of the stages of the procedure of supporting car fleet management

Multi-criteria decision support is a field of knowledge that equips the decision maker with tools to solve complex decision problems in which different points of view are taken into account [7], [12], [13]. The obtained solutions, so-called compromise solutions include, on the one hand, the decision-maker's preferences and, on the other hand, the analysis of profit and loss in relation to the adopted criteria. The compromise solution depends on the decision-maker's knowledge and skills as well as the circumstances in which the decision is made and the decision support methods chosen. In general, six basic stages of the procedure for solving multi-criteria decision problems for car fleet management are mentioned (fig 1.)

The first stage of the procedure is to identify the research problem, analyse the needs of recipients (clients) and identify all the factors necessary to make the right decision regarding the selection of vehicles for tasks taking into account the needs of the customer in terms of mobility and minimization of maintenance and operation costs. At the level of this stage, all elements, vehicle parameters, etc. are identified − elements and relations occurring in the identified system of the supported enterprise.

Stage II is the construction of a decision model. At this level of the procedure, the decision problem is written in the form of a mathematical model. In the problematic literature, in general, three types of multi criteria decision problems are mentioned [7], [12], [13], that is:

- choice − determining the variant considered as the best,
- classification − dividing variants into specific classes,
- ranking (ranking) variants from the best to the worst.

At the level of stage III − an algorithm or algorithms are developed that effectively solves the decision problem.

The next stages concern the implementation of the proposed algorithm of the decision model in the form of a computer implementation and the analysis of the sensitivity of matching the algorithms to the problem being solved. The last stage is the verification of the procedure for supporting vehicle fleet decision-making − analysis of results and selection of a compromise solution, i.e. suboptimal. In general, six basic stages of the procedure for solving multi-criteria decision problems for car fleet management are mentioned (fig. 1.)

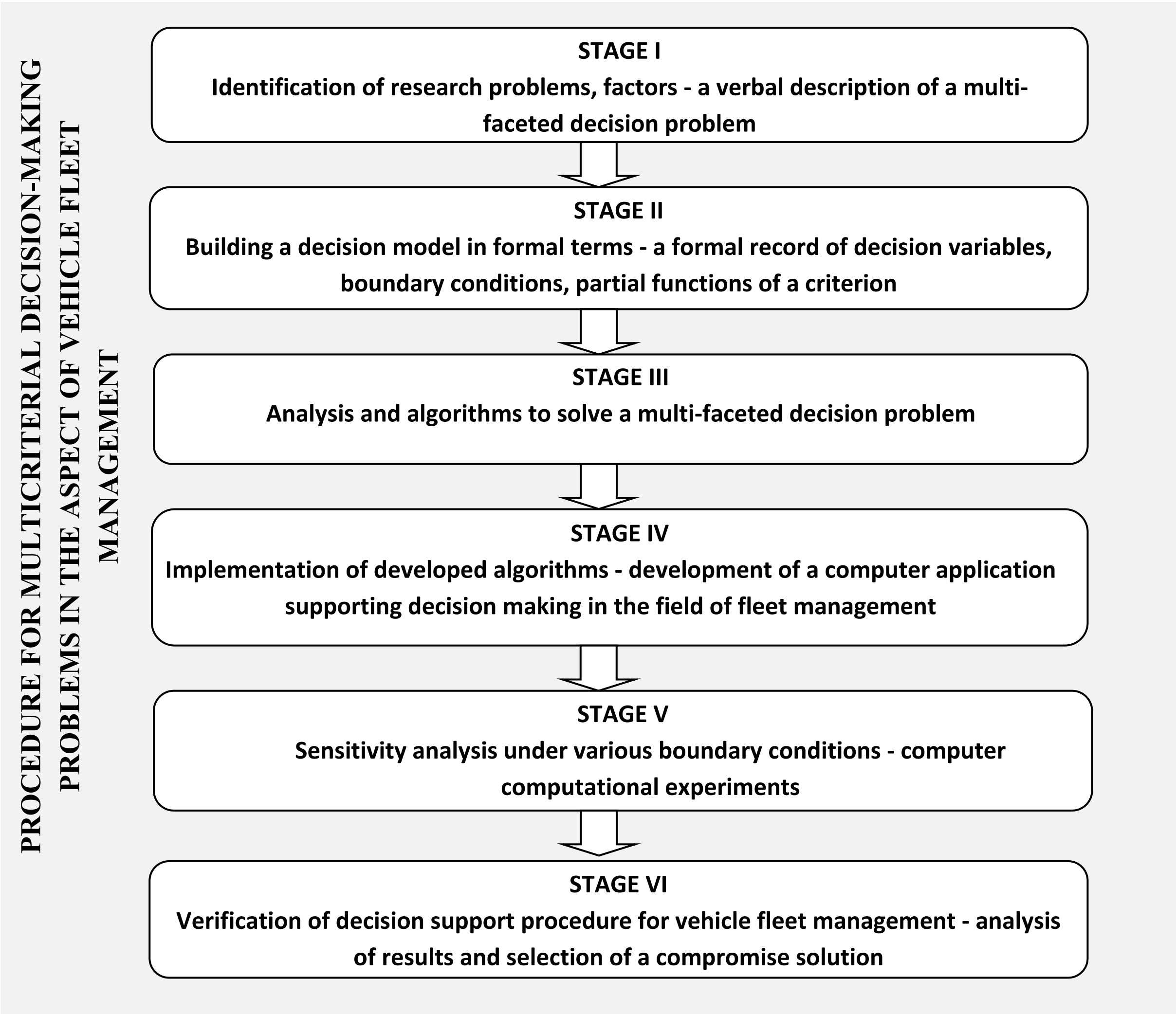

Fig. 1. The procedure of supporting of the vehicle fleet management

4. The main elements of the car fleet management model in the enterprise

4.1 Description of the model

For the purposes of research, it is assumed that the Model of Car Fleet Management in Enterprise will be written as an ordered five:

$$\mathbf{MCFME} = <\boldsymbol{TPOJ}, \mathbf{QPOJ}, \mathbf{QU}, \boldsymbol{CWK}, \boldsymbol{MFP}, \boldsymbol{FKO}, \boldsymbol{PWDFM}>, \quad (5)$$

where:

MCFME – Model of Car Fleet Management in Enterprise,
TPOJ – a set of available vehicle types,
QPOJ – vector of technical and operational parameters of vehicles taken during the assessment
QU – the vector of tasks carried out in the enterprise, including those resulting from the mobility of employees,
MFP – a set of methods of financing the replacement of vehicles in an enterprise,
FCPZ – a set of sub criteria for assessing the vehicles assignment for tasks,

PWDFM – decision making procedure in car fleet management.

Therefore, in order for the fleet management to be properly processed, it is necessary to determine:

– a set of available vehicle types ,
– vector of technical and operational parameters of vehicles taken during the assessment,
– the vector of tasks carried out in the enterprise, including those resulting from the mobility of employees,
– a set of methods of financing the replacement of vehicles in an enterprise,
– a set of sub criteria for assessing the vehicles assignment for tasks,
– decision-making procedure in car fleet management.

The basic criterion for decision-making in the field of vehicle fleet management, taking into account the selection of vehicles for tasks and issues of employee mobility, is meeting the expectations of the recipient (enterprise), while minimizing the costs of vehicle maintenance and operation.

4.2. Vector of technical and operational data of vehicles and expectations of the customer in the car fleet management model

The problem of proper management of the car fleet in the company, taking into account the selection of vehicles for tasks, mobility issues and minimizing the costs of vehicle maintenance and operation, should be carried out in accordance with a specific procedure.

Therefore, it is necessary to choose vehicles that will carry out specific tasks resulting from the mobility of staff in the enterprise, while the cost resulting from their maintenance and operation should be minimal. It is assumed that the data for the decision model is:

- fixed data resulting from available vehicle types,
- variable data − defined as the recipient/company's expectation vector.

Fixed data α_i while $i = 1, \ldots, n$ are vehicle technical data such as:

α_1 − type of body,
α_2 − permissible gross vehicle weight,
α_3 − number of doors,
α_4 − type of fuel,
α_5 − displacement of the engine,
α_6 − engine power,
α_7 − emission standard,
α_8 − type of gearbox,
α_9 − average fuel consumption per 100 km,
α_i − other technical data.

For a given type of vehicle *tp* these data can be formulate as a vector **q(tp)** with elements as above, i.e .:

$$\mathbf{q(tp)}=[\alpha_1(tp), \alpha_2(tp), \alpha_3(tp), \alpha_4(tp), \alpha_5(tp), \alpha_6(tp), \alpha_7(tp), \alpha_8(tp), \alpha_9(tp), \ldots, \alpha_i(tp), \ldots, \alpha_n(tp)]. \quad (6)$$

The second type of data, the knowledge of which is necessary in determining the model of fleet management is the vector of expectations of the recipient (enterprise), which specifies, among others:

- type of tasks carried out,
- time of vehicle use,
- assumed yearly vehicle mileage,
- expected vehicle technical data as β_j, while $j=1, \ldots, m$.

The above data can be written in the form of a recipient's (enterprises) expectation vector from the point of view of *tp*-th type of vehicle i.e.:

qodb(*tp*)=

$=[q(zd,tp),t(tp),rp(tp),sf(tp),rn(tp),dmc(tp),nd(tp),rf(tp),ps(tp),ms(tp),nes(tp),rsb(tp),ssp(tp)]$, (7)

qodb(tp) − vector of recipient's expectations (enterprises),
$q(zd,tp)$ − type of implemented zd -th task by tp − th type of vehicle,
$t(tp)$ − assumed time of completing tasks by tp − th type of vehicle,
$rp(tp)$ − assumed yearly mileage tp − th type of vehicle being traversed during the implementation of tasks,
$sf(tp)$ − assumed method of financing tp − th type of vehicle,
β_1 − expected type of body,
β_2 − expected permissible gross vehicle weight,
β_3 − expected number of doors,
β_4 − expected type of fuel,
β_5 − expected displacement of the engine,
β_6 − expected engine power,
β_7 − expected emission standard,
β_8 − expected type of gearbox,
β_9 − expected average fuel consumption per 100 km,
β_j − other expectations.

Only selected technical and operational parameters of vehicles have been presented above. Vehicles that are selected to perform tasks are characterized by a much larger number of parameters. On the one hand, this is expected by the recipient, the scope of tasks (mobility aspects) and available methods of financing and the offer of vehicles by dealers. The data required to determine the recipient's vector of expectation is indispensable for their correct assessment in the context of the tasks being performed, to which the vehicle will be dedicated and the very nature of the task.

4.3 Algorithm for decision support in car fleet management

The algorithm for supporting vehicle fleet management decisions in the aspect of selection of resources for tasks can be written as follows:

Step 1. Specification the data on technical and operational data of vehicles resulting from the technical specification.

Step 2. Specification of criteria (goals) for the assessment of the selection of resources for tasks by the recipient (enterprise):

- the cost of maintaining and operating vehicles resulting from the vehicle's disposal and loss of its value over time and the course of the task,
- the cost of service repairs and tire service while the vehicle is in service,
- the cost of ownership resulting from the average fuel consumption of the vehicle.

Step 3. Adoption of the assumptions of the tasks carried out in the enterprise:

- type of task being carried out,
- assumed time of completing the task, i.e. the time for which the vehicle will be at the user's disposal,
- the assumed yearly mileage of the vehicle that will be performed during the implementation of tasks.

Step 4. Determination of the recipient's expectations (expected technical data of the vehicle).

Step 5. Determination of weights for partial criteria.

Step 6. Determining the number of variants of vehicle assignment.

Step 7. Determination of the value of the utility function − the ratio of the total cost of the task implementation by vehicles per 1 km (taking into account the weight of individual criteria),

Step 8. Calculation of the integrated quality indicator for the selection of vehicles for tasks

Step 9. Determining the order of the variants of the assessment of the selection of vehicles for tasks.

Fig. 2 presents a schematic diagram of the vehicle fleet management model in the enterprise, taking into account the expectations of the customer and available methods of financing the replacement of vehicles.

5. Conclusions

The presented considerations in the article deal with the significant problem of fleet management. Nowadays, effective resource management is a key aspect of the operational activity of every enterprise, but also in the long-term strategic activity. This applies in particular to vehicle management.

Appropriate selection of the vehicle to the needs is from the point of view of the quality of services provided, as well as the ability to complete the tasks for which the resource was provided. For large enterprises in which fleet management is an important element of business, making decisions in this area requires adequate support. Such a support is precisely the proposed model, which specifically undertakes the allocation of resources for tasks in the aspect of vehicle fleet management in the enterprise.

The proposed decision support procedure in the field of fleet management in the company allows you to choose a rational solution based on a number of criteria relevant to the enterprise. It allows for individual adjustment of the decision-making process in a multi-aspect approach and with different preferences in the context of the importance of individual criteria.

This article is an introduction to a broader research into the selection of vehicles for tasks. The upcoming work will focus on the development of a simulation model with regard to vehicle failures and the development of procedures based on artificial intelligence methods to respond to emerging disorders.

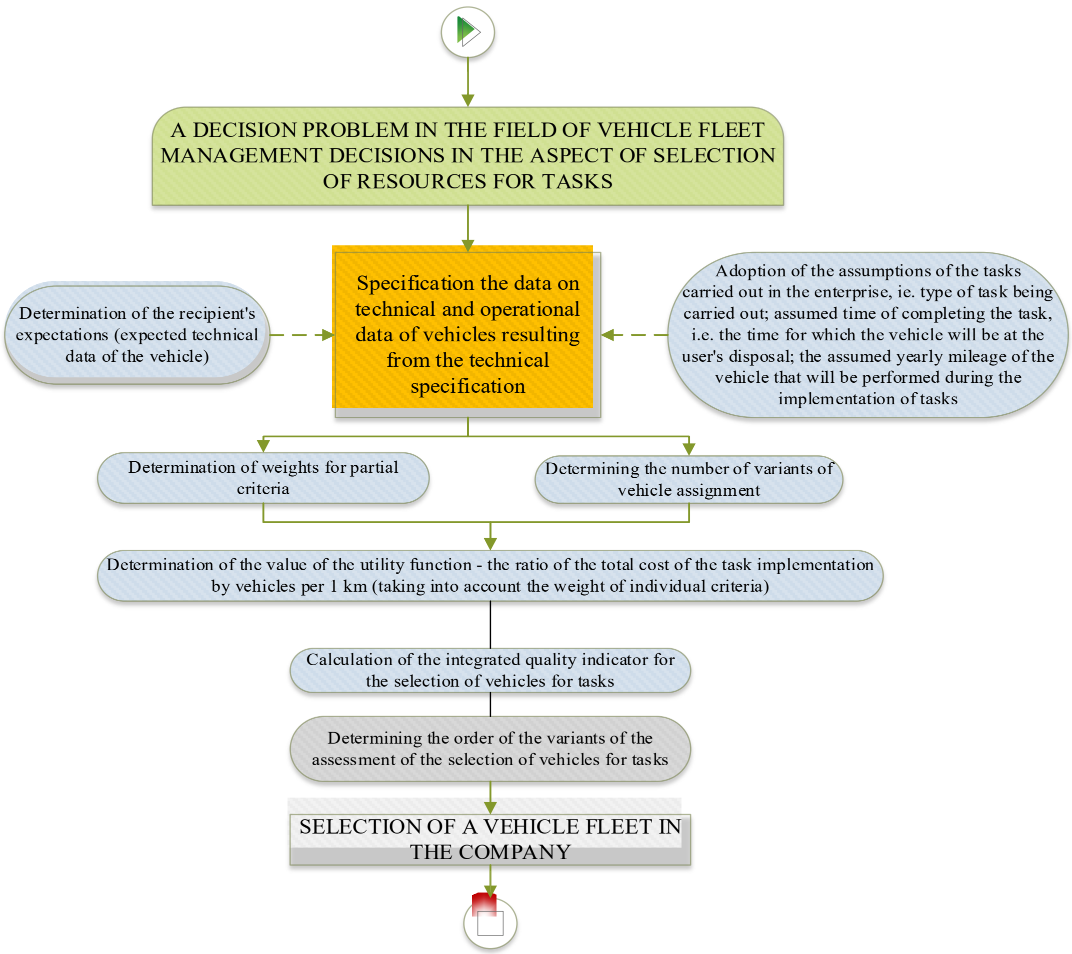

Fig. Fig. 2. Scheme of the algorithm for defining a decision problem in the selection of the vehicle fleet

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