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MODEL OF A COMPUTER SYSTEM FOR SELECTION OF OPERATING PARAMETERS FOR TRANSPORT VEHICLES IN THE ASPECT OF THEIR DURABILITY

Abstract

The article presents a new method of selecting operating parameters of vehicles which allows to prolong their useful life. The theoretical and practical aspects of the new approach were discussed. The key methods of optimizing the use of vehicles and their transport routes were analysed. The proposed method of selecting operating parameters of transport vehicles was based on elements of the dynamic programming model using heuristic algorithms. A model and then an algorithm and a computer program for selecting operating parameters for vehicles were developed.

1. INTRODUCTION

Enormous progress and changes in the operation of enterprises occur in two basic ways: one way is the application of modern technology and technique, the other one is the development of the methods of organisation, management, optimisation, as well as efficient technical service (Koralewski & Wrona, 2014; Cisowski, 2016a, 2016b; Hao & Yue, 2016).

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A decision solution through operational research is a kind of procedure consisting of the following more important stages:

- examining the situation and the decision problem resulting from it,
- constructing the model describing a decision issue,
- searching a method of solution and solving the model of decision task,
- assessment of the correctness and feasibility of the obtained solutions, and the possible verification of the model and the method for solving,
- implementation of the solution and observation of the changes occurring under the influence of the said solution (Pawełczyk, 2005; Koralewski, Wrona & Wrona, 2016).

Considering the demand of the transport enterprises, it was deemed necessary to pick the topic of this article and to develop a new and efficient method consisting in the optimal selection of the operating parameters of the vehicles, which consequently leads to the increase of their durability in the utility process (Pires & Frazzon, 2016; Wojciechowski, Cisowski & Pazowski, 2015). It is known that the manner of the operation of a vehicle in any transport company significantly influences the efficiency of its economic activity, and the appropriate technical exploitation of transportation means aims at increasing their technical efficiency, which is necessary to perform their tasks (Rais, Alvelos & Carvalho, 2014; Koralewski & Wrona, 2015; Longwic, Lotko & Lotko, 2016).

2. SUBSYSTEM FOR DETERMINING THE EXTENT OF WEAR OF THE VEHICLES

Heuristics is considerably used by the subsystem for the algorithm used to rationalise the selection of the operating parameters of a motor vehicle.

The calculations start with defining the following sets:

- a set of transport tasks $T = \{T_1, T_2, \dots, T_n\}$, where $n \in N$, where for every task T_i is defined:
  - T_{ipsxy} – starting point (cargo receipt point), where *x* and *y* are longitude and latitude respectively,
  - T_{ipdxy} – end point (cargo delivery point), where *x* and *y* are longitude and latitude respectively,
  - T_{il} (kg) – cargo to be transported in a given task (given in kg),
- a set of vehicles $V = \{V_1, V_2, \dots, V_n\}$, where $n \in N$, where for every vehicle V_i is defined:
  - V_{ipxy} – vehicle's current location, where x and y are longitude and latitude respectively,
  - V_{ic} (kg) – vehicle's carrying capacity (given in kilogrammes),

- V_{iv} (*km/h*) – vehicle's technical speed (maximum speed, given in km/h),
- V_{is} (*1*|*0*) – vehicle's status (*value 1 – available, or 0 – unavailable*),

- a set of considered consumable parts $E = \{E_1, E_2, \dots, E_n\}$, where for every consumable part E_i are defined:
  - E_{iukm} (*%*) – percentage of wear and tear of parts per each kilometre driven,
  - E_{iuh} (*%*) – percentage of wear and tear of parts per each hour driven.

On their basis the following coefficients are determined:

- coefficient of wear and tear of parts per each kilometre driven:

$$E_{ukm} = \frac{\sum_{i=1}^{n}(E_{ukm})}{n}, \tag{1}$$

- coefficient of wear and tear of parts per each hour driven:

$$E_{uh} = \frac{\sum_{i=1}^{n}(E_{uh})}{n}. \tag{2}$$

For the aforesaid sets, the solutions are searched, which are specific allocation $f(T) = V$ (i.e. one car is assigned to perform every transport task, which is to be performed by this car) and:

- $V_{iT} = \{T_a, \dots, T_z\}$ is a set of tasks assigned to a vehicle,
- $V_{iR} = \{P_1, \dots, P_n\}$ is an ordered set of starting points and end points of all the tasks belonging to V_{iT},
- V_{iRt} is a cumulative journey time between the next points: $\{V_{ipxy} \to P_1 \to P_2 \to \dots \to P_n\}$,
- V_{iRd} is a cumulative distance between the next points: $\{V_{ipxy} \to P_1 \to P_2 \to \dots \to P_n\}$,
- Vehicle's initial load: $V_{iLP0} = 0$,
- Vehicle's load in point j is: $V_{iLPj} = V_{iLpJ} - 1 + P_{jT1}$, if P_j is a starting point of the task T_k,

or:

- $V_{iLPj} = V_{iLpJ} - 1 - P_{jT1}$, if P_j is an end point of the task T_k, where:
  - P_{jT1} is the cargo transported in the task T_k, whose starting point or whose end point is P_j, so $P_{jT1} = P_{Tk1}$,
  - In every P_j point the following relation is satisfied: $V_{iLPj} \leq V_{ic}$,
  - Cost value $C = V_{iRt} \times E_{uh} + V_{iRd} \times E_{ukm}$ is as low as possible,
  - Total cost value $C_t = n \sum i \{V_{iRt} \times E_{uh} + V_{iRd} \times E_{ukm}\}$ is as low as possible.

The next step is the optimal task assignment of vehicles and the optimal selection of the order of driving of particular vehicles between the starting points and end points of the tasks assigned to them. This problem is not NP-complete with at least exponential complexity, as it has much higher complexity than the problem of a travelling salesman that is only NP-complete. Therefore, in this method the heuristic algorithm was applied, which guarantees the finding of the solution in polynomial time and which produces a certain probability of finding the solution which is close to the optimum one or which is optimum in polynomial time.

3. SPATIAL DATA SERVER

Geoserver which was used in the algorithm is an open source server which enables geospatial data processing. It may publish data coming from all the leading spatial data sources using open standards. In practice, Geoserver returns the pictures in *.png format with the route alignment marked on them. The pictures generated in such a manner are added to the road map (OpenStreetMap). Thus, the process of generating the routes continues in the following manner:

- calculating the most favourable routes for particular cars on the basis of the data from the routing base;
- for every motor vehicle the further pairs of the route points are sent to Geoserver, with the demand to draw the route with the specified parameters between the said pair of points;
- in response, the next parts of the drawn routes are received in *.png format, which are subsequently marked on OpenStreetMap, as its new layers.

Developing new transport routes with Geoserver involvement was shown in figure 1.

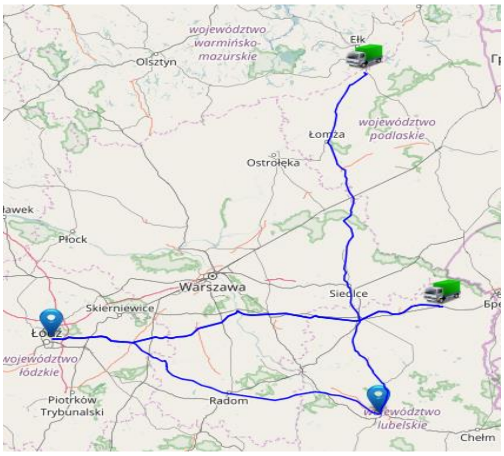

Fig. 1. Developing routes with Geoserver

In figure 2 the possibilities of the combination of the aforesaid tools are shown. It is a zoom of the crossroads of the routes of the vehicles, which perform their transport tasks, from the previous picture. It should be pointed out that the algorithm chooses the optimum routes very precisely and in detail on the basis of their real lengths and maximum permitted speeds.

Fig. 2. Indication of the details of Geoserver map

The level of the data detail of the routes marked on the map is so high that the numbers of the buildings, more important locations in the city, or the numbers of the route on which the vehicle is driving are visible (fig. 3). It makes it possible to precisely locate the sending-receiving points and the position of the transport vehicles. During the application of the logarithm by a transport company, it is possible to analyse the routes chosen by the program.

Fig. 3. Location determination

4. DESCRIPTION OF THE COMPUTER INTERFACES TO ENTER THE DATA AND TO VISUALISE THE RESULTS

On the basis of the developed method of the optimisation of the performance parameters of the vehicle in the aspect of its durability, its simulator was performed in the form of a computer program – “Logistics” application. The program has an interface to enter the data and to visualise the results.

Entering the data includes the actions to specify:

- the data,
- the input parameters,
- the relations between the data,
- the goal function,
- the tasks to be performed,
- the logical objects.

The calculations include solving the given optimisation tasks, depending upon the expected result and the specific criteria and limitations. The presentation of the results is connected with the visualisation of the solutions of the calculations made. After starting the application, the main screen appears with the recently entered tasks of the means of transport operation (fig. 4).

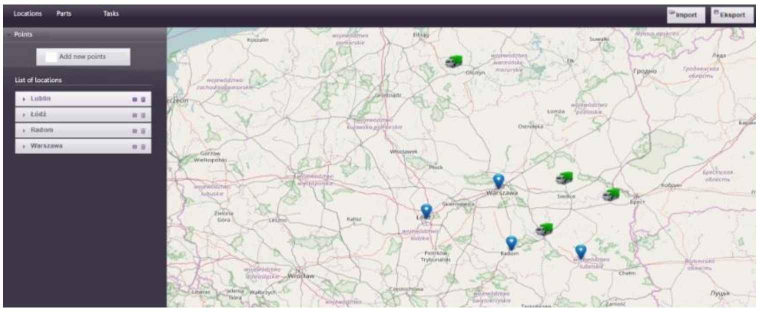

Fig. 4. Visualisation of “Logistics” application

On the left-hand side of the application (see fig. 4) there is a user interface. It contains the respective tabs opening the right windows to enter the data, to specify their parameters, and to implement the calculation tasks. In the tab: “localisations” there are the fields to enter and define the sending-receiving transportation routes and the vehicles. To define the transportation routes their location should be marked on the map or their geographical coordinates should be entered. The identical activities should be performed with all the vehicles. All the added points and routes shall be visible on the map as well as in the list of the objects.

In order to add the means of transport, first, all the data characterising it should be entered (fig. 5).

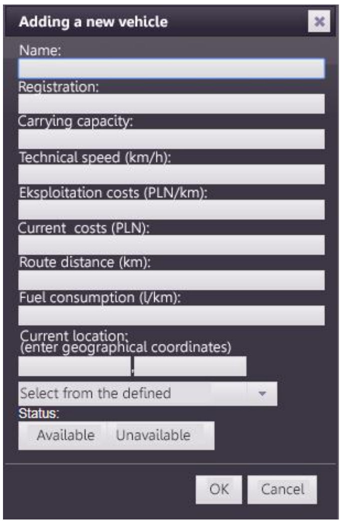

Fig. 5. Interface of adding a new vehicle

In the next tab "parts" (fig. 6) the wear and tear of the vehicles' components in %/km or %/h may be added, i.e. the unlimited list of the parts which define their performance parameters. Depending upon the selected option – whether it is defining the route which is optimum for the transport of the cargo or analysing the exploitation of the vehicle's components, the algorithm finds the most favourable route which meets the imposed boundary conditions. When analysing the wear and tear of the parts of the vehicles, the algorithm examines if the extent of their deterioration was defined the most favourably in %/km or %/h. If their wear and tear is higher in %/km, the application searches for the shortest routes; however, if their wear and tear is higher in %/h – the algorithm chooses the fastest routes.

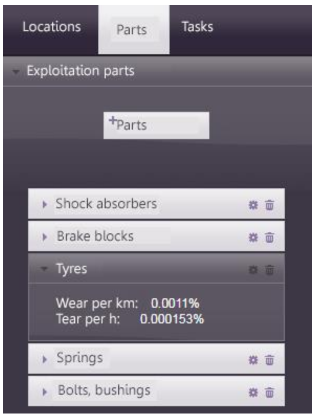

Fig. 6. Interface of adding an exploitation part

Planning the transport routes is placed in the field: "tasks" (fig. 7).

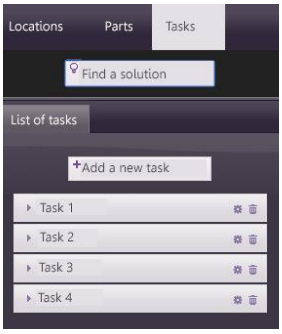

Fig. 7. A set of transport tasks

It is a set of all the transport tasks to be performed by the available vehicles. It defines the volume of the cargo which is to be transported by the vehicles, as well as the places of loading and unloading.

Additionally, the waiting time is added to the journey time and shown as the totalised value or as particular information: the journey time of "x", including the driving time of "y", and the waiting time of "z." In this case it is about the statutory working time of drivers. The algorithm considers it in the calculations and shows where the driver will be located in a given time, which enables to take a decision if they should be given another transport task. Figure 8 presents the visualisation of the calculations.

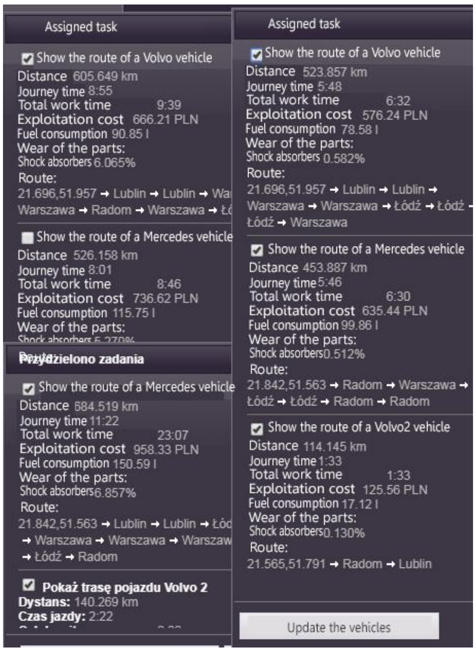

Fig. 8. Presentation of the results of the calculations of the algorithm

The above-mentioned example of the comparison of the final results of the calculations presents the possibility of showing different options of the results of the calculations, which enables any comparison thereof. It is essential for depicting the results of the calculations concerning the shortest, the fastest and the most optimal routes in respect of the defined consumable parts.

The tables of calculations presented in figure 8 are simultaneously visualised on the map (fig. 9), on which the sending-receiving points, the transport vehicles, and different combinations of the routes proposed by the algorithm are placed. Depending upon the criterion taken, the routes are defined in such a manner to optimise the performance parameters of the vehicles.

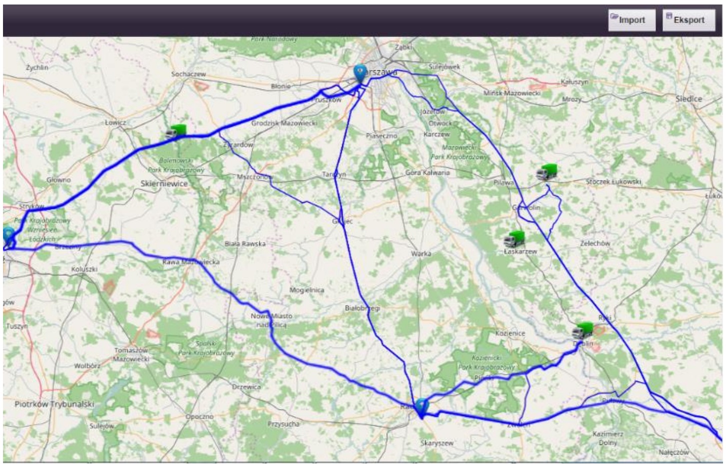

Fig. 9. Visualisation of the generated transport routes

5. VERIFICATION OF THE EXPERIMENTAL RESULTS AND THE REAL RESULTS ON THE EXAMPLE OF A SELECTED TRANSPORT ENTERPRISE

The real operation data on the vehicles from the fleet of the transport company that transports construction materials of homogeneous structure were used.

Table 1 below presents the list of the exploitation costs for three various options: the criterion of time, the criterion of road, and the real data from the company. The following concepts were compared: the route distance in relation to the cargo transported, the loaded distance of the goods, the fuel consumption, and the total exploitation costs. (Route Length Alg. – the calculations of the algorithm with the selection parameter of longer route but faster, Route Shortness Alg. – the calculations of the algorithm with the selection parameter of shorter route but slower, the Company – the real data from the transport activity of the transport company).

Tab. 1. List of the exploitation costs for different options

Option:	Route distance [kilometres]	Cargo transported [tonnes] (Q)	Fuel consumption [litres]	Exploitation cost [PLN]	Loaded distance of the goods [kilometres]
Route Length Alg.	411365.4	34428.59	85915.17	555343.35	27564.31
Route Shortness Alg.	374032.6	30380.05	78045.99	504943.96	25071.81
Company	457572	25803.66	95814.68	617722.22	30619.47

Figure 10 presents the exploitation costs of the vehicles depending upon their selected performance parameters. It should be pointed out that the reasonable selection of the performance parameters will bring the lower exploitation costs, the longer and more efficient work of the vehicle in the same time period.

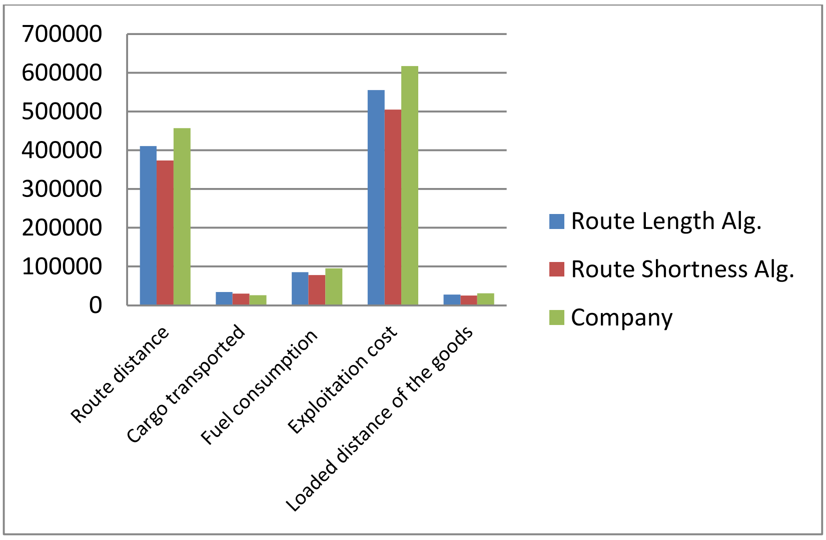

Fig. 10. The influence of the exploitation costs on the transport parameters

The next list shows the percentage wear and tear of selected parts during the exploitation of the motor vehicles. For this purpose, the aforesaid three options of exploitation were compared. As all the cases performed the same transport tasks, with the same number of the work readiness days and the same number of available means of transport, with the same load capacity, the total route distance made by the vehicles for each task could be averaged. For particular options of the calculations the distance of the route was as follows:

– for the real data gained from the transport company – 45757.2 km,
– in the case of the simulation with the criterion of the shortest routes selection – 37403.27 km,
– in the case of the simulation with the criterion of the faster but longer routes selection – 41136.53 km,

As it may be noticed, for all the regular service actions, the highest percentage wear and tear of the indicated parts was received when the transport company did not apply the tools for the optimal selection of the vehicles' performance parameters and the transport task planning. In the said case the wear and tear of the parts for the periodic vehicle inspection conducted every 20 thousand km was 228.79%, which meant around 2/3 time which was left to the third inspection. In the case of the periodic vehicle inspection every 60 thousand km 22.21% was left to the next inspection; in the case of the periodic vehicle inspection every 90 thousand km – 49.16%, and for the replacement of the parts every 150 thousand km – 69.34%.

The simulation of driving with the criterion of short routes showed much lower wear and tear of the parts, and it was respectively: for the replacement period every 20 thousand km – 187.02% (the second inspection is coming), every 60 thousand km – 63.59%, every 90 thousand km – 41.56%, and every 150 thousand km – 25.06%.

The last case of the calculations of the wear and tear of the parts of the vehicles concerned the simulation of driving with the criterion of faster but longer routes. The results of this simulation are as follows: for the replacement period every 20 thousand km – the wear and tear of the parts was 205.68%, for the replacement period every 60 thousand km – 69.93%, for the replacement period every 90 thousand km – 45.70%; whereas for the replacement period every 150 thousand km – 27.56%.

The aforesaid results of the research on the wear and tear of the vehicle's parts influencing its durability were depicted in figure 11.

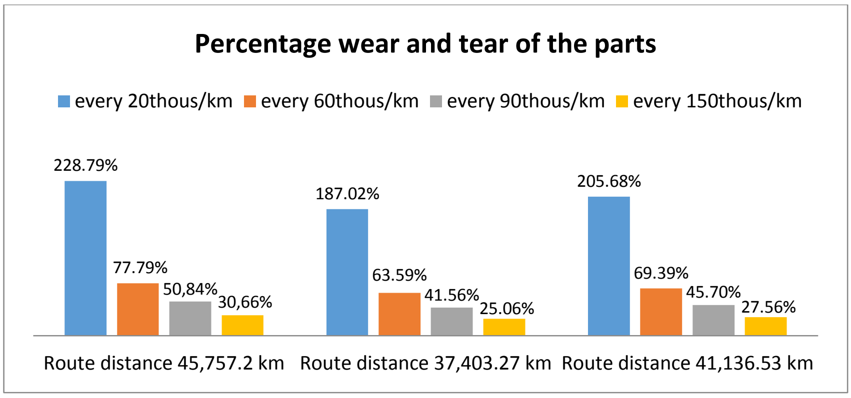

Fig. 11. Percentage wear and tear of selected consumable parts in three options of managing the car fleet

The results of the simulation research, in which the average route distance was 37403.27 km and 41136.53 km, are lower from the route distance of 45757.2 km, gained by the company which did not apply the tools for managing the transport process and the technical service of the vehicles, with the consideration of the appropriate selection of the performance parameters. The research showed that wearing the parts in shorter time results in choosing faster routes, usually longer in distance, the advantage of which is the optimum time of the performance of transport tasks and the bigger volume of the cargo transported. A faster route is usually identified with a shorter route.

6. CONCLUSIONS

This research aimed at presenting the method of optimising the performance parameters of a vehicle in the aspect of its durability, directed to the enterprises dealing with the transport of homogeneous goods. The research which has been conducted proves that optimising the vehicle's performance parameters to prolong the time of its reasonable exploitation is fully justified when using the developed algorithm. It was necessary to know the optimising tasks to be performed and the accepted limitation criteria in order to develop the algorithm correctly.

Therefore, the optimum selection of the performance parameters was found against:

- the delivery time,
- the efficient utilization of the load capacity of the vehicle,
- the reasonable exploitation of a transport unit.

The record of the limitations of the method was made regarding the functions of the criteria optimising the vehicles' performance parameters.

The obtained results allowed to form a reasonable method for optimising the performance parameters of the fleet in order to increase their reliability and efficiency during the performance of the transport tasks.

The practical part showed the selection of the optimum performance parameters which guaranteed the higher reliability of the vehicles in order to obtain the aforesaid assumptions.

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