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SOFTWARE APPLICATION FOR OPTIMAL FUEL SUPPLY OF TRANSPORT ACTIVITY

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Abstract:
Determination of optimal petrol station selection and the optimal quantity of the amount of refilled fuel during long transport loops is not defined by a central decision making process at forwarding companies, but it depends on the individual decision of the camion driver. Therefore the total cost of the burned fuel is not optimal. The aim of this study is to elaborate a method for planning the optimal fuel supply for transport activities and develop a software application.

Key words:
Transport, Fuel supply, Optimization, Software

1 STRUCTURE OF TRANSPORT LOOPS

The aims of the transport loop planning are to ensure a more efficient operation and to realize higher profit, which require the integration of more transport tasks into one transport loop as shown in Fig. 1. It means that the vehicle departs from the parking lot of the company to the first dispatch station where the products to be transported are loaded in. Then the vehicle goes to the first discharge station, where the products to be transported are loaded out and then proceeds to the next dispatch station. The number of dispatch and discharge stations can be i and a discharge station can be a dispatch station simultaneously [1,2]. After the last discharge station the vehicle returns to the parking lot of the company.

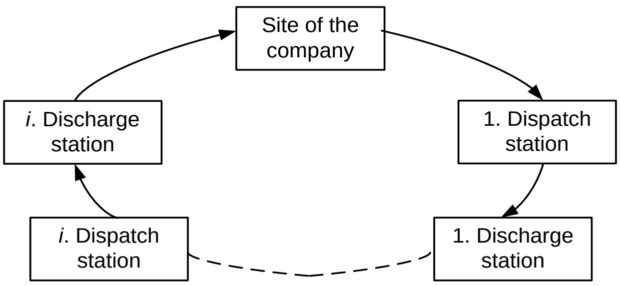

Fig. 1. *Structure of transport loops*

2 CALCULATION OF TOTAL PRIME COST

At first we have to define the total prime cost of a transport loop to find the possibilities of cost reduction. It is suggested to define the sections of the total loop. A section is a way between a dispatch station and a discharge station. The cost components of the sections are different due to the different volume of transported goods, the fuel consumption depends on topography, etc.

Total prime cost of the α–th transport loop ($C_{P\alpha}$) can be calculated [1,2]:

$$C_{P\alpha} = C_{L\alpha} + C_{UL\alpha} + C_{WT\alpha} + C_{A\alpha} + C_{W\alpha} + C_{M\alpha} \quad (1)$$

where: $C_{L\alpha}$ - a cost of transport way with useful load; $C_{UL\alpha}$ - cost of transport way without useful load; $C_{WT\alpha}$ - cost of waiting time; $C_{A\alpha}$ - total additional costs (fee of motorway usage, parking fee, …); $C_{W\alpha}$ - wage cost of drivers; $C_{M\alpha}$ - maintenance cost of own vehicles; α - identifier of the loop.

Because the aim of the optimization is the minimization of the cost of fuel consumption, we only examined the $C_{L\alpha}$ and $C_{UL\alpha}$ cost components, the other components can be neglected.

3 DETERMINATION OF THE IDEAL PETROL STATION AND THE OPTIMAL AMOUNT OF REFILLED FUEL

Determination of optimal petrol station selection and the optimal amount of refilled fuel during a long transport loop is not defined by a central decision making process of the forwarding companies, it depends on the individual decision of the camion driver. Therefore the total cost of the burned fuel is not optimal.

The aim of the study is to elaborate a mathematical model that allows the elimination of losts arising from the mentioned problems. Therefore the task is to define the location of the optimal petrol station from the preferred (t_i) stations if it is required in case of a transport task from point F_{i+1} (dispatch station) to point L_{i+1} (discharge station), and to define the volume of fuel to be refilled (Q_T).

All of the petrol stations and dispatch- and discharge stations can be defined by (x, y) coordinates.

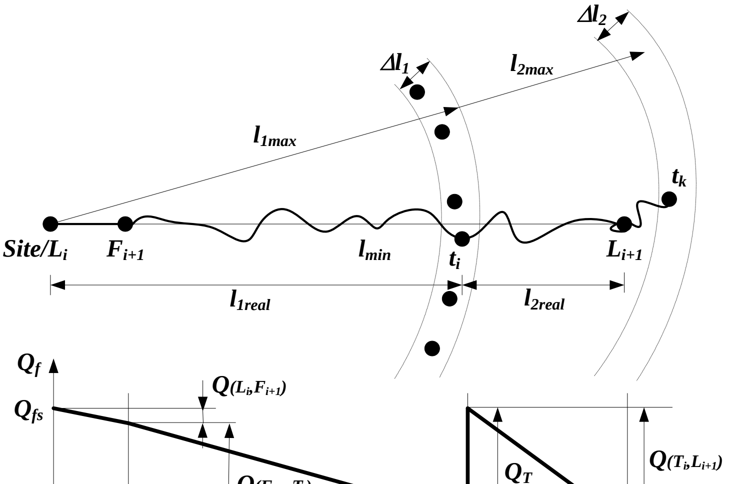

***Fig. 2.** Determination of possible petrol stations,*

Monitoring of the changes in the fuel level of the camion during the transport way

At the beginning of the transport task the starting point is known (which could be the site of the transport company (site/parking lot) or the *i*-th discharge station (L_i)), the dispatch station (F_{i+1}) and the destination discharge station (L_{i+1}) (Figure 2.).

The task is to determine whether the vehicle is able to complete the transport task with the available amount of fuel (level of fuel is known at starting position, Q_{fs}) or the vehicle have to refill fuel between the dispatch- and discharge stations. If refilling is required the ideal fuel station (t_i) and the amount of fuel to be refilled should be defined (Q_T).

Most of the transport companies – due to the huge amount of fuel consumption – can buy fuel on a discounted price at a contracted fuel selling company. Transport companies prefer those fuel suppliers which have a world-wide patrol station network.

The contracted fuel selling company provides the GPS coordinates of the available petrol stations and the actual fuel price at the individual stations. Accordingly the *x*, *y* coordinates of the petrol stations can always be defined. Digital maps convolute the road network to short, strait sections [4]. This allows the determination of the length of the shortest way between any two chosen points (between dispatch/discharge station and petrol station, between the dispatch and the discharge station, etc.). This can be achieved by the use of an A* algorithm [3], or with the aid of roadmap sheets (data sheets) [5]. Furthermore topological information is also provided, which is also valuable since fuel consumption is different on flat roads than uphill or downhill conditions.

In the following sections thee possible petrol stations will be chosen from every possible petrol stations, which can contribute to the resolution of the task. This significantly decreases the number of variables in the final model.

The total cost of a transport loop is the sum of costs of sections:

$$C_\alpha = \sum_\beta l_{\alpha\beta} \cdot c_{\alpha\beta} \; [euro] \tag{2}$$

where: $l_{\alpha\beta}$ - the distance of β-th section of α-th transport loop [*km*]; $c_{\alpha\beta}$ - specific cost of the β-th section of α-th transport loop $\left[\frac{euro}{km}\right]$; β - section identifier, α - transport loop identifier.

The fuel consumption of a vehicle depends on the consumption of vehicle without useful load (characteristics of the engine) and the weight of the transported useful load. The specific cost can be calculated by equation 2.

$$c_{\alpha\beta} = p_{\alpha\beta}\left[f_f + \varepsilon^L \cdot q_{\alpha\beta} \right] \left[\frac{euro}{km}\right] \tag{3}$$

where: $p_{\alpha\beta}$ - price of fuel $\left[\frac{euro}{liter}\right]$; f_f - specific fuel consumption in case of empty vehicle $\left[\frac{liter}{km}\right]$;

ε^L - correction factor for different loading conditions (every additional tons of useful load results 0.5 liter extra fuel consumption) $\left[\frac{liter}{ton \cdot km}\right]$; $q_{\alpha\beta}$ - transported useful load [*ton*].

The fuel level of the vehicle is known at starting point (Q_{fs}), the fuel consumption can be calculated continuously between dispatch- and discharge stations (Figure 2.).

There is a constraints relating to the emergency amount of fuel capacity (Q_{B1}, Q_{B2}) which has to be available. Q_{B1} emergency amount covers the extra consumption resulting from diversion, traffic jam, missed way, etc between points L_i and t_i , Q_{B2} emergency amount covers the consumption of the vehicle after the L_{i+1}-th discharge station to find the next petrol station.

The maximal distance (l_{1max}) which can be completed by a vehicle is calculated as follows (Fig. 2.):

$$l_{1\max}^{\alpha\beta} = \frac{Q_{fs} - Q_{B1}}{f_f + \varepsilon^L \cdot q_{\alpha\beta}} \tag{4}$$

Distance (l_{1max}-$\Delta 1_1$) defines the coordinates of possible t_i petrol stations. The ideal station should be chosen from these stations. The value of $\Delta 1_1$ can be defined, which means the distance of beginning of search of petrol station before the exhaustion of fuel (searching zone).

4 SOFTWARE CONCEPTION FOR OPTIMAL FUEL SUPPLY

Based on the above mentioned optimization concept our research team developed a software application for the optimal fuel supply of transport activities.

The software is written in Java programming language. Java is a general-purpose computer programming language that is concurrent, object-oriented, and class-based. Java is a platform free programming language. This is a big advantage comparing other languages, it means our written software is independent to operating systems. [6,7]

Microsoft Visual Studio Eclipse software framework was used to develop the software.

5 OPERATION AND MAIN SCREENS OF THE SOFTWARE APPLICATION

The software has two menu points which are the "**Definition of new data**" and "**Optimization**".

5.1. Menu "Definition of new data"

In the menu "Definition of new data" we can define:

- new petrol stations (Fig. 3.),
- new dispatch stations and discharge stations (Fig. 4.), and
- new transport vehicles (Fig. 5.).

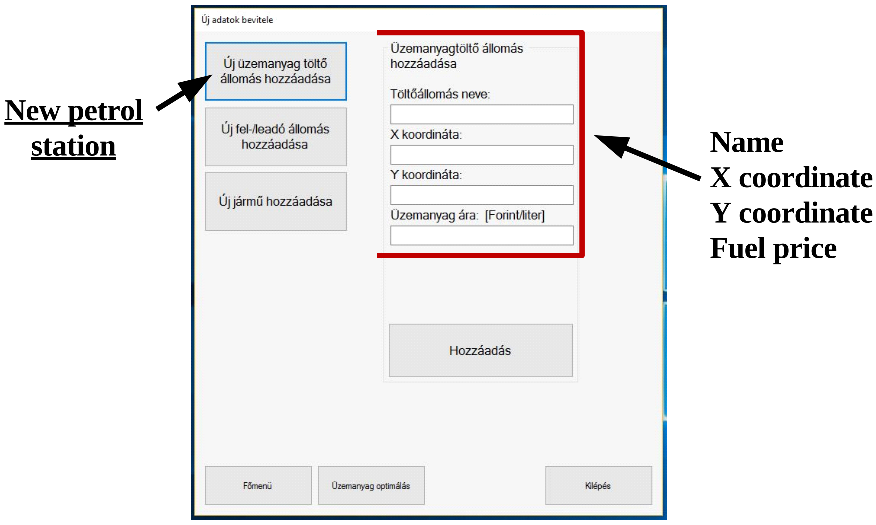

Fig. 3. *Definition of new petrol stations*

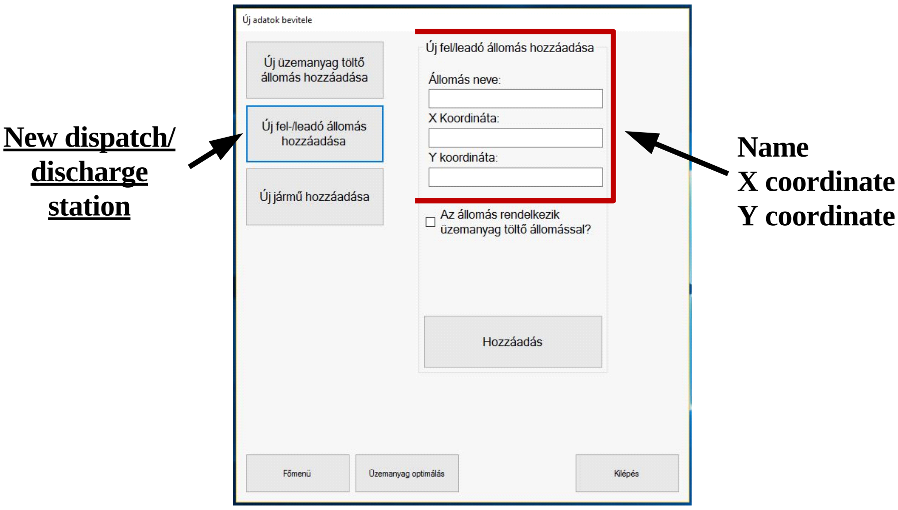

Fig. 4. *Definition of new dispatch stations and discharge stations*

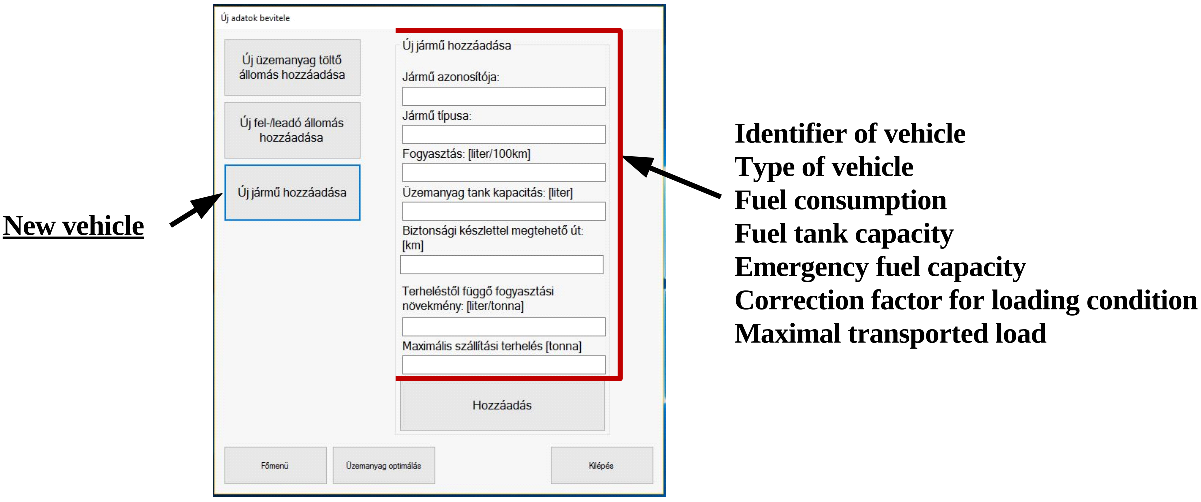

Fig. 5. *Definition of new transport vehicles*

5.2. Menu "Optimization"

Part **5.a** of the screen (Fig. 5.) provides the possibility of selection of a given transport vehicle for a given transport task. In this menu also can be defined the actual fuel level of the vehicle [litre] at the beginning of the transport loop and the fuel price [HUF/litre] of this existing fuel.

Part **5.b** of the screen (Fig. 5.) provides the possibility of determination of the transport loop, the dispatch stations and discharge stations and the loading conditions [ton] (transported weight and the changing of loading conditions at the dispatch- or discharge stations).

Part **5.c** of the screen (Fig. 5.) shows the results of the optimization. The total cost of the transport loop [HUF], the total fuel consumption of the transport way [litre] and the remaining fuel volume [litre] at the end of the way are listed.

Part **5.d** of the screen (Fig. 5.) shows the graphical display of the transport way and the location of the optimal petrol station where the driver have to refill the vehicle.

Part **5.e** of the screen (Fig. 5.) lists the name and location of the optimal petrol station and the volume of fuel [litre] to be refilled. The actual fuel price [HUF/litre] of the ideal station and the total cost [HUF] of the fuel to be refilled also listed.

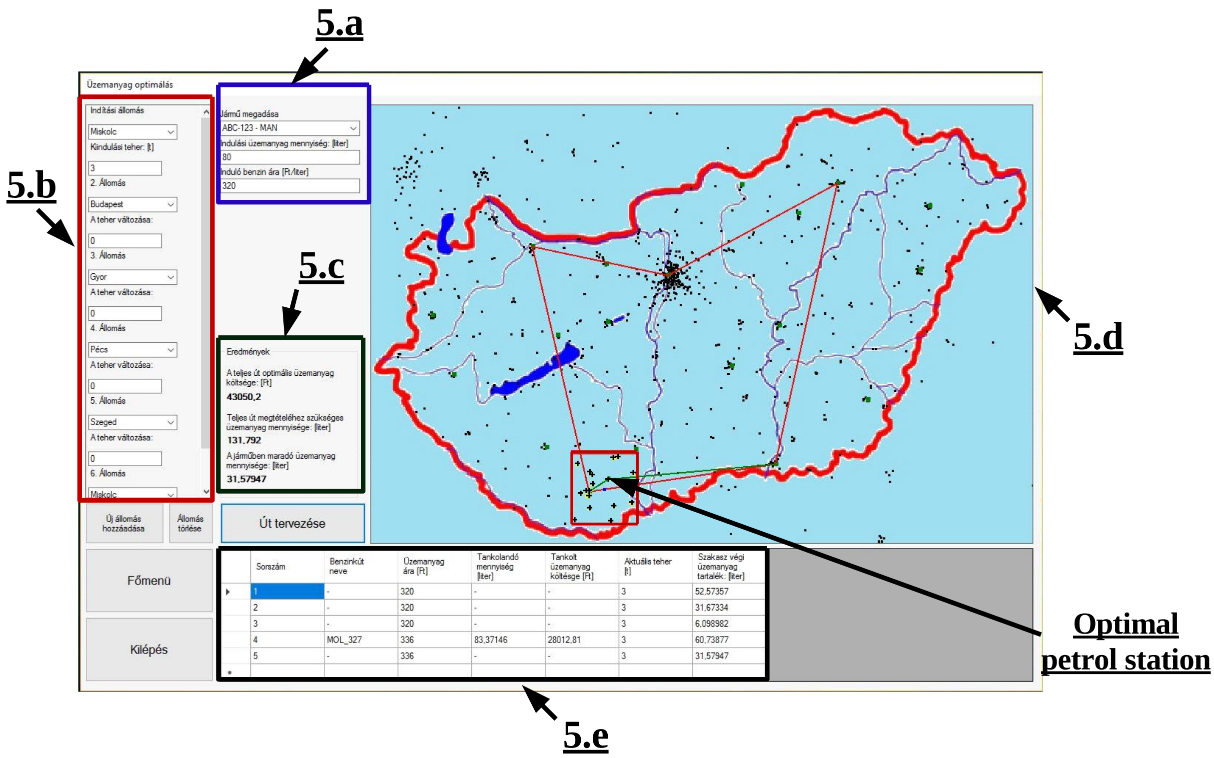

***Fig. 5.** Screen of "Optimization" menu*

The developed software is capable for selection of the optimal petrol station and the determination of the optimal amount of refilled fuel during a long transport loop. Based on this information the camion drivers can make the best decision and the total cost of the transport loop can be minimized.

There are lot of possible petrol stations during the transport way and the selection of the petrol station where the driver refill the vehicle is depends on the individual decision of the driver. Therefore the total cost of the burned fuel is not optimal, because the fuel prices are different at different petrol stations. In Hungary for example the difference of fuel prices at the cheapest and at the most expensive petrol stations can be 50-70 HUF/liter. It can be seen that if the decision making of the driver could be supported by our software the total cost of the transport way can be reduced significantly. This reduction is 13,5-19% in case of one liter of fuel. It can be calculated that in case of a long transport way the cost reduction can be significant.

Recently the software is under testing, but we hope that in the near future more and more companies will apply it and the transport cost can be reduced in this way.

6 CONCLUSIONS

The main goal of this study was to elaborate a precise and reliable mathematical model for the determination of optimal fuel refill points and the amount of fuel to be refilled during the execution of international transportation tasks. The main parameters were given for the determination of the optimal refill conditions.

The research group developed a software application for optimal fuel supply of transport activities which was introduced in this article. By the application of the developed software the location of the optimal petrol station can be defined and the adequate volume of fuel to be refilled can be calculated. The objective function of the optimization was the minimization of the total cost of a given transport loop. By the fuel optimization of transport activities the total transportation cost can be reduced significantly.

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