Istraživanja i projektovanja za privredu
ISSN 1451-4117
DOI:10.5937/jaes0-47972
www.engineeringscience.rs

iipp publishing

Journal of Applied Engineering Science
Vol. 22, No. 1, 2024
Original Scientific Paper
Paper number: 22(2024)1, 1176, 163-170

IMPACT OF DEVELOPED SOFTWARE PACKAGE APPLICATION FOR THE OPERATION AND MAINTENANCE MANAGEMENT ON IMPROVING THE VEHICLE FLEET ENERGY EFFICIENCY

Nikola Petrović[1]*, Davor Vujanović[2]

[1] SRBOLAB LLC
[2] University of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Serbia
** nikolap.srbolab@gmail.com*

In order to improve the energy efficiency of the vehicle fleets, many countries have introduced laws, regulations and politics that encourage the use of vehicles with lower fuel consumption and lower emissions of harmful gases. Also, many companies have adopted strategies for lowering emissions of harmful gases, maintenance costs and vehicle exploitation, including the use of software packages for operation management and maintenance of vehicle fleets. On the international market there are numerous of already made software packages for the operation management and maintenance of vehicle fleets. Some of the companies, having in mind the specificity of business or vehicle exploitation, have decided to develop their own software packages for operation management and maintenance of vehicle fleets. One of them is the company „SRBOLAB" LLC. This paper analyzed the impact of the developed software package on the energy efficiency of the company's vehicle fleet. Firstly, it describes the structure of the developed software package, and after that, applied measures next to the software package, in order to improve energy efficiency and obtained results in the form of an analysis of the energy efficiency of the observed vehicle fleet before and after the implementation of software and measures. Analysis has shown that, regardless of the increased business, the total fuel consumption (l) and mileage (km) are higher after the implementation of software, as well as the energy efficiency of the observed vehicle fleet per CE groups which is reduced to specific fuel consumption (l/100km). Obtained results show that the differences in the specific fuel consumption (l/100km), before and after the implementation of software per CE groups, are in the range of 0,32 l/100km to 1,26 l/100km, in other words, fuel savings are from 4,1 % to 16,8%, if you look at this in percentages. Obtained results in comparison to the size, spent fuel (l), are showing savings in the range of 89 l to 342 l. Total fuel savings (l) for the observed vehicle fleet in the period of January to April 2023 is 626 l.

Keywords: vehicle fleet, energy efficiency, software package, operation management and maintenance of vehicle fleet, fuel consumption

1 INTRODUCTION

Vehicle fleets of the road transport are an obligatory part of business, for companies whose occupation is the transport of people and goods, and for those companies and other subjects to which they serve as support in the performance of other occupations. They are owned by big public firms, institutions, multinational companies, medium- and small-sized companies, associations of citizens and legal entities. At the same time, vehicle fleets have a negative impact on the environment. In 2021, the transport sector in the EU was a major contributor to greenhouse gas emissions, with road transport alone accounting for over 75% of the sector's total emissions [1]. In addition to the environmental impact, vehicle fleets of companies, especially big vehicle fleets, through maintenance and fuel consumption costs, significantly affect the entire financial operations of companies.

For these reasons, it is not surprising that the energy efficiency of vehicle fleets has become a very important topic at the global level and one of the main strategic goals for achieving sustainable development across the developed world [2]. In order to achieve this goal, many countries have introduced a range of measures such as laws, regulations and politics that encourage the use of vehicles with lower fuel consumption and lower emission of harmful gases, subsidies for buying hybrid and electric vehicles, a ban on the traffic of vehicles with diesel engines in central parts of cities etc.

In the field of the energy efficiency of vehicle fleets of road transport numerous research projects and scientific papers have been published.

Vujanović and others [2], in their paper take energy efficiency as a main criterion for vehicle fleet management, doing so they define measures to improve the logistic efficiency of vehicles, and develop the vehicle management algorithm as the basis for developing software to support decision-making during dispatcher deployment of vehicles. They apply their research on the vehicle fleet of the specific company whose work is the sales and distribution of spare parts for passenger vehicles.

Radosavljević and others [3], in their focus put the energy efficiency of the vehicle fleet from the point of view of the overall effectiveness of the vehicle. They develop the method they apply to specific vehicle fleet and is based on an indicator of the overall effectiveness of the vehicle including the human factor. They conclude that the effectiveness

of the vehicle and therefore the energy efficiency of the vehicle fleet depend on the degree of utilization of the carrying capacity and the degree of utilization of the mileage.

Manojlović and others [4], in their case study of the fleet of city buses in the Republic of Serbia, investigate how much the energy efficiency of the bus fleet would increase, and at the same time reduce the cost of the life cycle of vehicles and emissions of harmful gases if the bus fleet was rebuilt with vehicles of newer generations.

In addition to these research projects and works that consider the possibilities of increasing energy efficiency on specific vehicle fleets, special emphasis is placed on research and works in the field of development and implementation of software for operation management and maintenance of vehicle fleets with the aim of increasing energy efficiency.

Musonda [5] in his project develops a software based on a web application for the management of the vehicle fleet of a transport company. This software is used within the company with the aim of making the most efficient exploitation of the company's vehicles. In addition to this function, the software also enables vehicle tracking, optimizing the consumption of the company's resources through monitoring the consumption of fuel and other resources and preventing abuse and unauthorized use of the vehicle. The results in the form of reducing or completely disappearing problems such as eliminating unnecessary papyrology, human errors when recording data, misuse of vehicles, resources and data, led to more efficient operation of the vehicle fleet, which justified the development and implementation of the software.

Oluwashola and others [6], in their paper provide a description and structure of the software package for monitoring the maintenance and exploitation of the vehicle fleet of a higher education institution in Nigeria. The interface of the software package is developed in the program language Visual Basic 6.0, while Microsoft Office Access 2010 is used for creating a database. To connect the application and the database, a database management system, Structure Query Language (SQL) is selected. After the implementation of the software, it was concluded that the software significantly contributes to the improvement of the quality and efficiency of the management of the observed fleet, as well as the technical correctness of the vehicles, by enabling engineers who maintain the vehicle fleet to make proactive decisions through the collected data on the continuation of vehicle use or vehicle expenditure, in case of increased maintenance and exploitation costs.

Improving the energy efficiency of the vehicle fleet has become the main strategic direction for many companies whose work is road transport, but also for those companies that own their fleet, and practice other activities. Fleet managers in these companies often use software packages (Fleet Management Software) to monitor, track and analyze the operation of fleet vehicles with the aim of reducing emissions of harmful gases and, especially, the maintenance and exploitation costs of vehicles. On the global market there are a number of already made software packages for the operation management and maintenance of vehicle fleet, of which the most famous are: Verzion Connect [7], Motive [8], Azuga Fleet [9], Samsara [10] and others. These software packages generally have similar options that include monitoring drivers and vehicles in real time, monitoring the driver's behavior, collecting data on vehicle maintenance and fuel consumption with the aim of reducing them, assistance during dispatching and selecting the most favorable routes, etc. The most common criteria for selecting the appropriate software package are: company's occupation, fleet size, applied vehicle maintenance system, ease of use of software, capabilities of software for data collection and analysis, etc. A number of companies, taking into account the specifics of the operation or exploitation of the fleet, instead of using ready-made software packages, develop their own software for managing the operation and maintenance of the vehicle fleet.

One of such companies is the company “SRBOLAB” LLC, whose occupation is the control of quality and quantity of goods from agriculture and laboratory testing of seed and mercantile goods, as well as the control and testing of all types of vehicles. The management of this company realized that the existent software packages for the operation management and maintenance of fleet would not contribute to the company's energy efficient operation, due to the specific needs and constant expansion of the company's business, which implies a greater number of employees and the growth of the number of vehicles within the company's fleet, and such a trend further contributes to higher maintenance and especially exploitation costs of the company's fleet. For this reason, an authentic software solution has been developed within this company, which covers not only the operation and maintenance of the vehicle fleet, but also the entire business of the company. In the focus of this research, it will be possible to increase the energy efficiency of the heterogeneous vehicle fleet of this company with the use of a developed software package. In doing so, the structure of the developed software will be presented first, and after that, measures stemming from the use of the software package will be applied in order to improve energy efficiency. The obtained results will be presented in the form of an analysis of the energy efficiency of the observed vehicle fleet before and after the implementation of the software.

2 STRUCTURE OF THE DEVELOPED SOFTWARE

Computer software developed within the company has a primary goal, to contribute to the more efficient management of this company. Within the application are combined: work with vehicle certificates, preparation of reports on vehicle tests, but also administrative processes in the company, which include fuel consumption records and monitoring of the maintenance of the company's fleet and employee records.

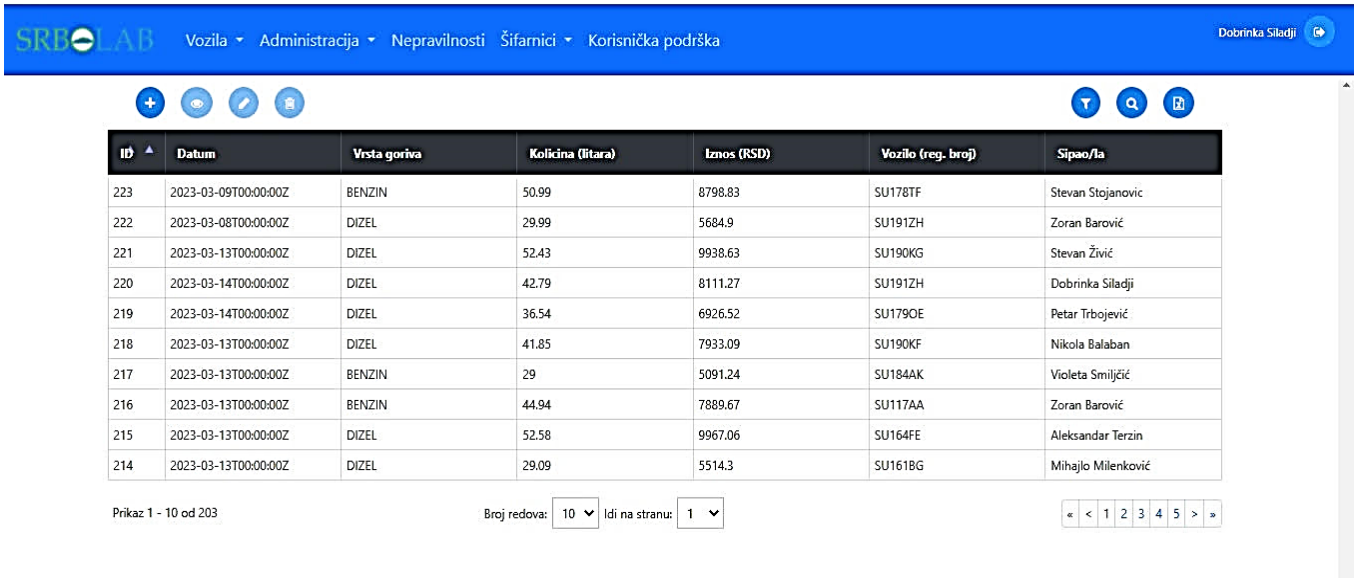
The software itself is derived in the form of a web application that is accessed via a web browser. The application was created as monolithic, in other words, without microservices, and for the backend and frontend communication it is used REST API. The Backend part of the application is built in the Go programming language, while the user interface (Frontend) is built in the progressive JavaScript framework Vue.js. In order to provide a customizable user experience, the application is connected to the database, and for storing the data, PostgreSQL was used as database management system, unlike other software solutions with a similar purpose [11] [12], which works with relational databases and allows added features unavailable in SQL.

The application is located on a server that is physically located on the premises of the company “SRBOLAB” LLC and it is also owned by the company. Access to the application is enabled only by certain IP addresses, which is set on the router located within the company “SRBOLAB” LLC.

The database itself is backed up every day, and the last 5 backups are stored on the server, while once a week the last backup is transferred to a separate server that the company “SRBOLAB” LLC uses for this purpose. This process takes place automatically, that is, on the server there is a tool that runs every day at a certain time and that makes a backup while simultaneously deleting those that are older than 5 days. The application's program code is stored on the GitHub repository, which is private and unauthorized access is impossible. In order to use the application, the user must be registered, and that action must be given by one of the users who is already registered and has the right to do that action. The application is logically divided by drop-down menus. By clicking on each of the drop-down menus, certain activities are accessed (Vehicles, Admins, Irregularities, Admin Panels, Ciphers, User Support). Activities portray permission, which allows a user to see and use certain functionality of the application, so it is possible to grant the user the rights to see and use only parts of the application they need. The Superadmin, that is the application administrator, when creating a user, assigns the necessary activities to the user.

Management of the operation and maintenance of the company's fleet is carried out through the administration menu. Administration menu opens the drop-down menus: Fuel Consumption, Vehicle Fleet, Service of Vehicles, Trip Orders and Analytics. Through these menus you can access to: the activities of monitoring fuel consumption, structural and technical characteristics of vehicles in the fleet, maintenance or servicing of vehicles, entry and monitoring of trip orders and analysis of fuel consumption and mileage.

The activity of monitoring fuel consumption is realized in the Administration/Fuel consumption menu (Figure 1) and implies chronological monitoring of the type and amount of fuel consumed converted into the dinar equivalent value of fuel cards, vehicles and vehicle users. On the upper left side (Figure 1) there are buttons through which it is possible to add new data and view, modify and delete existing data, while on the upper right side there are buttons through which it is possible to filter and search data as well as make reports in PDF format.



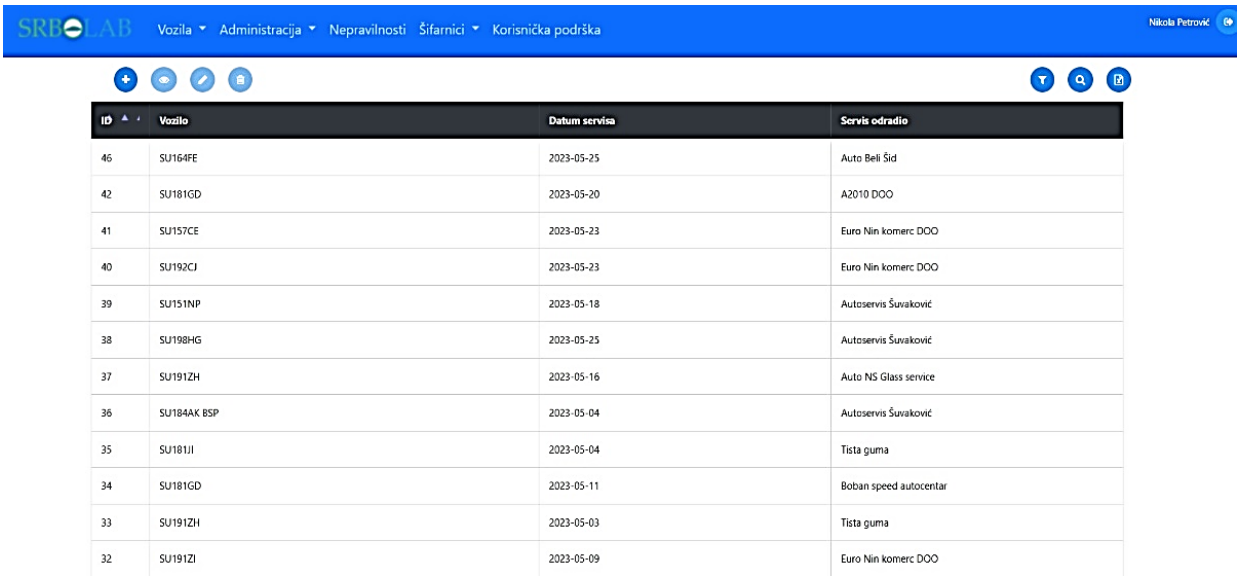
ID	Datum	Vrsta goriva	Kolicina (litara)	Iznos (RSD)	Vozilo (reg. broj)	Sipao/la
223	2023-03-09T00:00:00Z	BENZIN	50.99	8798.83	SU178TF	Stevan Stojanovic
222	2023-03-08T00:00:00Z	DIZEL	29.99	5684.9	SU191ZH	Zoran Barović
221	2023-03-13T00:00:00Z	DIZEL	52.43	9938.63	SU190KG	Stevan Živić
220	2023-03-14T00:00:00Z	DIZEL	42.79	8111.27	SU191ZH	Dobrinka Siladji
219	2023-03-14T00:00:00Z	DIZEL	36.54	6926.52	SU179OE	Petar Trbojević
218	2023-03-13T00:00:00Z	DIZEL	41.85	7933.09	SU190KF	Nikola Balaban
217	2023-03-13T00:00:00Z	BENZIN	29	5091.24	SU184AK	Violeta Smiljčić
216	2023-03-13T00:00:00Z	BENZIN	44.94	7889.67	SU117AA	Zoran Barović
215	2023-03-13T00:00:00Z	DIZEL	52.58	9967.06	SU164FE	Aleksandar Terzin
214	2023-03-13T00:00:00Z	DIZEL	29.09	5514.3	SU161BG	Mihajlo Milenković

Fig. 1. Menu of Fuel Consumption

In the Administration/Vehicle fleet menu, available is information on the characteristics of the fleet such as: VIN[1] mark, registration mark, commercial mark and date of validity of registration. Application allows adding data on new vehicles as well as view, modify and delete existing data.

Activity in the Menu Administration/Service of Vehicles (Figure 2) covers monitoring of maintenance of the vehicle fleet or service of vehicles according to vehicle parameters (registration mark), date of service and authorized person who performed service of the vehicle. Application provides options for adding new data on vehicles’ service, accessing functions to view, modify or delete existing data as well as options for filtering and searching data, along with generating reports in PDF format.

[1] Vehicle Identification Number



ID	Vozilo	Datum servisa	Servis odradio
46	SU164FE	2023-05-25	Auto Beli Šid
42	SU181GD	2023-05-20	A2010 DOO
41	SU157CE	2023-05-23	Euro Nin komerc DOO
40	SU192CJ	2023-05-23	Euro Nin komerc DOO
39	SU151NP	2023-05-18	Autoservis Šuvaković
38	SU198HG	2023-05-25	Autoservis Šuvaković
37	SU191ZH	2023-05-16	Auto NS Glass service
36	SU184AK BSP	2023-05-04	Autoservis Šuvaković
35	SU181JI	2023-05-04	Tista guma
34	SU181GD	2023-05-11	Boban speed autocentar
33	SU191ZH	2023-05-03	Tista guma
32	SU191ZI	2023-05-09	Euro Nin komerc DOO

Fig. 2. Menu Vehicle Service

By utilizing the Administration/Trip Orders menu, it is possible to add, review, modify, and delete trip orders, while also facilitating tracking based on vehicle registration, order period, and driver information.

The analysis from the point of view of fuel consumption and the mileage can be performed through the Administration/Analytics menu. Administration/Analytics menu opens options for filtering data by drivers, vehicles and the period for which the analysis is performed .

After selecting the parameters for which the analysis will be performed, it is necessary to click on the second button on the upper left side, in order for the user to receive the report in PDF format for the entered parameters. The report lists the number of the trip order, the vehicle (registration mark), the driver, the period for which the data were observed, mileage (km) and the specific fuel consumption (l/100km) for that period. If there is a violation of any norm (specific fuel consumption (l/100km) and mileage (km)), the report will indicate this data with red letters and the corresponding note which can be seen in (Figure 3).

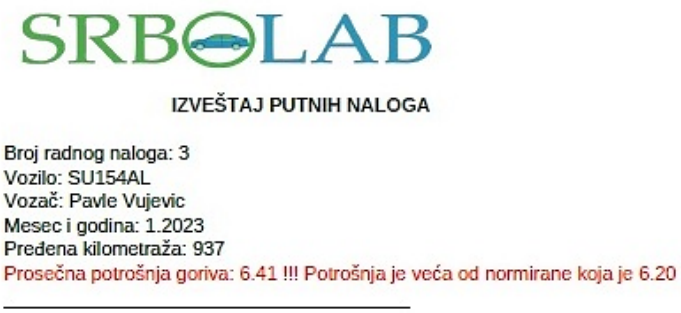


Fig. 3. Report with a note on excess fuel consumption

After using the application, the user should log out.

3 IMPLEMENTED MEASURES

The software for operation management and maintenance of vehicle fleet has been applied in the company “SRBOLAB” LLC since January 1, 2023.

The vehicle fleet of the company “SRBOLAB” LLC was consisted of 19 vehicles, in January 2023, and was heterogeneous in structure. The most common category of vehicles was passenger vehicles of category M_1 with 15 vehicles, while the other vehicles (4 vehicles) were light freight vehicles of category N_1, in other words, the maximum permissible weight up to 3500 kg.The operational task of passenger vehicles within the company is the transport of employees from their place of residence to the workplace or the transport of employees from one business unit of the company to another. Freight vehicles within the company have the operational task of transporting the devices, equipment and processed materials necessary for the company's operations, from the company's headquarters to the company's business entities. Diesel-powered vehicles were the most represented, in percentage at 68%, while gasoline-powered vehicles were 32%. The average age of the company's fleet was 11.8 years. Considering these data as well as other technical characteristics of the vehicle (engine capacity, engine rated power, maximum permissible mass, number of seats, year of production, etc.), the fleet of the company “SRBOLAB” LLC, for the purpose of energy efficiency analysis, is divided into 6 construction-exploitation groups - CE groups.

The exploitation of vehicles by the company “SRBOLAB” LLC was mainly carried out across open roads (major roads and highways), and less so in urban conditions. The vehicles were not used outside the borders of the Republic of Serbia. The dispersion and constant expansion of the company's business, conditioned the exploitation of most vehicles on multiple lines of work. Vehicles operated on 23 different lines of operation, and some vehicles operated on the same lines. The total length of the lines of operation of the vehicle was 3654 km, while the average length of the line was 117.9 km. The altitude at which the vehicles traveled did not exceed 300 m above sea level. The climatic conditions of the vehicle exploitation corresponded to the average annual republic values (average annual air temperature 10.9 °C for areas with an altitude of up to 300 m, normal annual rainfall 896 mm [13]).The time of departure of vehicles on certain lines of work was most often in the morning (7AM-8AM), and the time of completion of the line of work was most often in the afternoon (4PM-6PM).

The collected data on the technical characteristics of vehicles and vehicle exploitation by the company “SRBOLAB” LLC has been loaded into the applied software for operation management and maintenance of vehicle fleet, enabling the selection and adoption of measures, aimed to increase the energy efficiency of the company's fleet. Some of them are**:**

- Revision of existing normalized data for specific fuel consumption (l/100km). In Table 1 data are provided for the norms for specific fuel consumption (l/100km) before and after the implementation of the software. The new norms were adopted based on the analysis of data on the lines of operation of the vehicle, i.e., the characteristics of those lines (road conditions), structural properties, condition of the vehicle and collected data on real specific fuel consumption (l/100km). For vehicles with unfavorable road conditions, the norms remained the same or were increased, while vehicles with more favorable road conditions received stricter norms.
- Introduction of norms for the millage on a monthly basis (km). The reason for the introduction of this norm arises from the collected data on the millage on a monthly basis (km). The analysis of these data led to the conclusion that, despite the real specific consumption (l/100km), which is less than the normalized, certain vehicles travel significant distances on a monthly basis. This case may occur due to the increased business of the company in the observed period or due to vehicle abuse, so this norm was introduced to remove doubts on this issue and prevent any abuse. Norms for the monthly millage (km) (Table 1) are introduced on the basis of collected data on average millage (km) at monthly and annual levels.
- All users of the company's vehicles sign an authorization, a document that undertakes to use the vehicle in accordance with the company's policy regarding the maintenance and exploitation of the vehicle and to take responsibility in case of non-compliance with it. If the vehicle user does not use the vehicle in accordance with the company's policy, the managers in the company have the right to terminate the vehicle user's right to use it.
- The redistribution of vehicles between users depends on: the characteristics of the vehicle from the point of view of consumption, the technical condition of the vehicle, the load on certain lines of operation of the vehicle and the millage.

Table 1: Data on the norms for specific fuel consumption before and after the introduction of the software and the norms for the millage after the introduction of the software

CE group	Description of CE group	Registration mark	Commercial vehicle designation	Normalized specific fuel consumption (l / 100km) before software introduction	Normalized specific fuel consumption (l / 100km) after software introduction	Norm for millage on a monthly basis (km)
CE-1	Passenger gasoline-powered vehicles with an engine displacement of 800-1200 cc	SU 143 KC	Dacia Sandero	8	7,5	2500
		SU 117 AA	Škoda Fabia Ambition	6,5	6	2500
		SU 184 AK	Škoda Fabia Active	6	5,8	2500
CE-2	Passenger gasoline-powered vehicles with an engine displacement of 1200-1600 cc	SU 155 XZ	Citroen C3	7,5	7,5	2700
		SU 178 TF	Opel Astra J	8,3	8	2700
		SU 157 CE	Opel Meriva A	9,5	9	2700
CE-3	Passenger diesel-powered vehicles with an engine displacement of 1200-1600 cc	SU 181 GD	Volkswagen Polo	7,5	7,5	2500
		SU 161 BG	Opel Astra Sports Tourer	6	6	2500
CE-4	Passenger diesel-powered vehicles with an engine displacement of 1600-2000 cc	SU 176 EP	Fiat Bravo	7	7	3000
		NS 369 CS	Fiat Stilo	5	6,7	3000
		SU 151 NP	Fiat Stilo	6,6	6,7	3000
		SU 164 FE	Opel Astra	5,5	5,5	3000
		SU 180 SC	Ford C-Max	8,5	8,5	3000
		SU 154 AL	Peugeot 407	6	6,2	3000
		SU 181 JI	Škoda Octavia	6,2	6,2	3000

CE group	Description of CE group	Registration mark	Commercial vehicle designation	Normalized specific fuel consumption (l / 100km) before software introduction	Normalized specific fuel consumption (l / 100km) after software introduction	Norm for millage on a monthly basis (km)
CE-5	Light diesel-powered freight vehicles with an engine displacement of 1300-1500 cc	SU 179 OE	Toyota Yaris	6	5,5	2500
		SU 190 KF	Ford Courier Trend	6.2	6,2	2500
CE-6	Light diesel-powered freight vehicles with an engine displacement of 1500-2000 cc	SU 181 AK	Opel Astra	7	6,2	2500
		SU 190 KG	Citroen Jumpy	8	7	2500

4 ACHIEVED RESULTS

The application of the software and these measures resulted in the data shown in Tables 2-4.

Table 2: Comparative view of energy efficiency data for the observed fleet for the period January-April 2022 and 2023 by CE groups

CE-group	January						February						March						April					
	Mileage (km)		Fuel consumption (l)		Specific fuel consumption (l/100km)		Mileage (km)		Fuel consumption (l)		Specific fuel consumption (l/100km)		Mileage (km)		Fuel consumption (l)		Specific fuel consumption (l/100km)		Mileage (km)		Fuel consumption (l)		Specific fuel consumption (l/100km)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
CE-1	1802	5445	135	345	7,50	6,33	2441	9534	183	586	7,50	6,15	2299	12216	173	755	7,50	6,18	1764	4874	132	307	7,50	6,30
CE-2	4090	2987	359	249	8,79	8,32	6291	6334	534	519	8,49	8,19	8529	4433	729	356	8,55	8,04	7608	4634	631	379	8,29	8,17
CE-3	0	4050	0	252	0	6,23	0	6694	0	414	0	6,18	0	6081	0	384	0	6,32	0	4613	0	282	0	6,12
CE-4	8062	9936	547	640	6,79	6,44	11587	12387	758	763	6,54	6,16	13916	12250	937	792	6,74	6,46	13117	10477	888	681	6,77	6,50
CE-5	2222	6745	145	381	6,50	5,65	1216	4997	75	284	6,20	5,68	2193	6604	138	372	6,30	5,63	1950	3203	109	180	5,60	5,60
CE-6	0	51370	0	311	0	6,04	0	5931	0	363	0	6,11	0	9116	0	591	0	6,49	0	8821	0	554	0	6,28

Table 3: Display of differences in specific fuel consumption (l/100km) for the period January-April 2022 and 2023

	CE-1		CE-2		CE-3		CE-4		CE-5		CE-6	
	Specific fuel consumption for the period January – April 2022. and 2023.		Specific fuel consumption for the period January – April 2022. and 2023.		Specific fuel consumption for the period January – April 2022. and 2023.		Specific fuel consumption for the period January – April 2022. and 2023.		Specific fuel consumption for the period January – April 2022. and 2023.		Specific fuel consumption for the period January – April 2022. and 2023.	
	Difference (l/100km)	Savings (%)	Difference (l/100km)	Savings (%)	Difference (l/100km)	Savings (%)	Difference (l/100km)	Savings (%)	Difference (l/100km)	Savings (%)	Difference (l/100km)	Savings (%)
January	-1,17	15,6	-0,47	5,35	6,23	0	-0,35	5,16	-0,85	13,08	6,04	0
February	-1,35	18	-0,3	3,53	6,18	0	-0,38	5,81	-0,52	8,39	6,11	0
March	-1,32	17,6	-0,51	5,97	6,32	0	-0,28	4,15	-0,67	10,63	6,49	0
April	-1,20	16	-0,12	1,45	6,12	0	-0,27	3,99	0	0	6,28	0
Average	-1,26	16,8	-0,35	4,1	6,21	0	-0,32	4,77	-0,51	8,29	6,23	0

Table 4: Fuel savings (l) for the observed vehicle fleet in the period January-April 2023

	CE-1	CE-2	CE-3	CE-4	CE-5	CE-6	Total
January	54	13	0	33	50	0	150
February	106	18	0	44	24	0	192
March	133	21	0	33	15	0	202
April	49	6	0	27	0	0	82
Total	342	58	0	137	89	0	626

From the obtained data, the following conclusions can be drawn:

- Vehicles compared to the same period in 2022 have travelled longer distances, so the fuel consumption is higher. Such results are expected, given the higher level of exploitation of the vehicle.
- For both observed time periods, the CE-4 group of vehicles is the most exploited group of vehicles, but the exploitation of these vehicles in 2023 is reduced at the expense of the CE-3 group of vehicles, since both groups of vehicles have engines powered by the same fuel (diesel), while the exploitation of the CE-2 group of vehicles decreased at the expense of the CE-1 group of vehicles, since these two CE groups are also powered by engines with the same type of fuel (gasoline). This is a positive trend from the point of view of energy efficiency given the lower specific consumption (l/100km) of the CE-1 and CE-3 groups compared to the CE-2 and CE-4 groups, respectively. The measure that, in addition to software, contributed the most to this trend is the redistribution of vehicles between users.
- Exploitation of the CE-5 and CE-6 groups of vehicles was greatly increased. The reasons for such a trend arise from the conditions of the company's constant expansion of operations.
- Although the fuel consumption of the vehicle fleet increased in 2023 due to greater mileage, the energy efficiency of the fleet, reduced to specific fuel consumption (l/100km), was increased. For the observed period (January-April), the average fuel savings are the highest for the CE-1 group and are, on average, 1.26 l/100km or 16.8 %, followed by the CE-5 group with an average savings of 0.51 l/100km or 8.29%, while the savings for the CE-2 and CE-4 groups are 0.35 L/100km and 0.32 l/100km, in other words, 4.1 and 4.77%, respectively. CE-3 and CE-6 vehicles were not used or were not part of the fleet in the period of January to April in 2022, so for these groups there is no fuel savings for the observed period.
- The use of the software and the above listed measures despite the greater mileage has contributed to significant fuel savings (l). From Table 4, it can be seen that the largest fuel savings achieved are for CE-1, which is 342 l and after it for CE-4,137. For the reasons listed above, there are no fuel savings for CE-3 and CE-6. The month in which the largest fuel saving (l) for the observed fleet was achieved was March, with 202 l. Total fuel savings (l) for the observed fleet in the period January-April 2023, is 626 l.

It should be noted that the observed period is relatively short, so more complete data will be obtained after a full year of data monitoring, but it is already clear that the developed and implemented software for managing the operation and maintenance of the company's fleet significantly contributes to increasing the energy efficiency of the vehicle flee.

5 CONCLUSIONS

The noticeable lack of energy resources and stricter regulations in the field of environmental protection have made the topic of energy efficiency as one of the most important. Due to its impact on the emissions of harmful gases and the operations of companies, in the field of transport sector, this topic is especially present. In addition to laws, regulations and politics that encourage energy efficiency in the transport sector at the state level, many companies, both those in the field of transport and those for whom transport is only a support for performing other activities, have developed strategies for increasing energy efficiency.

One of the strategies involves using software for operation management and maintenance of vehicle fleet. Most companies use already finished software packages available on the global market, and a smaller number of companies develop their own original solutions due to the need for business. Such is the company “SRBOLAB” LLC, whose structure of developed and implemented software as well as the impact on the energy efficiency of the company's fleet were the subject of this study.

This paper describes and presents the structure and options that the developed software package provides. The developed and implemented software package provides various options for monitoring fuel consumption, structural and technical characteristics of vehicles in the fleet, maintenance or servicing of vehicles, entry and monitoring of trip orders, and analysis of fuel consumption and mileage. Specifically, options for analyzing fuel consumption and mileage, along with generating reports on the specific consumption and mileage for a particular vehicle, driver, and observed period, and providing feedback in case of a violation of any norm, contribute to improving the energy efficiency of the company's vehicle fleet. The mentioned advanced software options have enabled the selection and adoption of measures in order to improve the energy efficiency of the observed fleet of the company “SRBOLAB” LLC, such as the revision of the norms for specific fuel consumption, introduction of norms for the mileage on a monthly basis, redistribution of vehicles and abolition of vehicles to unconscious users.

Analyzed data on the energy efficiency of the observed fleet of “SRBOLAB” LLC before and after the implementation of the software and the above measures show results even in a short period of time (four months). Energy efficiency reduced to the size of the specific fuel consumption (l/100km) of the observed fleet by CE groups has improved (the exception is only CE-3 and CE-6 groups for which there are no comparable data), which is important given the greater exploitation of the vehicle in the same period. Fuel savings range from 0.32 l/100km (CE-4) to 1.26 l/100km (CE-1) if you look at specific fuel consumption (l / 100km) or from 4.1 (CE-2) to 16.8% (CE-1) if you look at this size in percentage. The achieved results in relation to the size of fuel consumed (l) show savings ranging from 89 l (CE-5) to 342 l (CE-1). Total fuel savings (l) for the observed vehicle fleet in the period January-April 2023 is 626 l. In order to obtain more complete data, the observed fleet must be monitored for a longer period (minimum 12 months), but

already on this sample it can be concluded that the implemented software package, especially if it is completed with the above measures, has the potential to significantly improve the energy efficiency of the observed fleet.

6 ACKNOWLEDGEMENT

Support for this research was provided by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant No. TR36010). Special thanks to the employees and management of the company “SRBOLAB” LLC for their selfless assistance in the implementation of this study.

7 REFERENCES

[1] Europe Environment Agency, (2023) Trends and Projections in Europe 2023, https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2023. [Accessed 01 February 2024].

[2] Vujanović D. B., Mijailović R. M., Momčilović V. M., Papić V. D., (2010) Energy Efficiency as a Criterion in the Vehicle Fleet Management Process,Thermal Science, vol. Vol. 14, no. DOI: 10.2298/TSCI090719010V, pp. pp. 865-878.

[3] Radosavljević D. M., Manojlović A. V., Medar O. M., Bojović N. J., (2018) Vehicle Fleet Energy Efficiency – Influence on Overall Vehicle Effectivenes, Thermal Science,Vol. 22 doi.org/10.2298/TSCI170926074R, pp. pp. 1537-1548.

[4] Manojlović A. V., Papić V. D., Filipović S. M., Jovanović V. D., (2011) Fleet Renewal: An Approach to Achieve Sustainable Road Transport, Thermal Science, Vol. 15, DOI: 10.2298/TSCI110504111M, pp. pp. 1223-1236.

[5] Musonda E., (2020) Design and Development of a Web Based Vehicle Management System (VMS), The International Journal of Multi-Disciplinary Research, no. CFP/1588/2020, pp. 1-17.

[6] Oluwashola S.A., Ige O., (2022) Design and Deployment of Vehicle Information System for Data Mining and Management, International Journal of Engineering Research & Technology (IJERT), vol. 11, no. 02, pp. 455-462.

[7] Verzion Connect, https://www.verizonconnect.com/. [Accessed 30 May 2023].

[8] Motive, Motive Technologies, Inc., 2013.https://gomotive.com/solutions/trucking-logistics/. [Accessed 30 May 2023].

[9] Azuga, Azuga, a Bridgestone Company, https://www.azuga.com/fleet-management-software. [Accessed 31 May 2023].

[10] Samsara, Samsara Inc., https://www.samsara.com/. [Accessed 31 May 2023]

[11] Chen X.-M., Wei Z.-H., (2011) Vehicle management system based on multi-node RFID cards, in Proceedings of the 30th Chinese control conference

[12] Fernandez B.S.M., (2021) Vehicle Management System Using RFID, International Journal of Multidisciplinary Research and Analysis, vol.4/2021, DOI: 10.47191/ijmra/v4-i12-22, pp. 1923-1928.

[13] Republic Hydrometeorological Service of Serbia, Republic of Serbia, https://www.hidmet.gov.rs/latin/meteorologija. [Accessed 1 April 2023].

Paper submitted: 30.11.2023.

Paper accepted: 13.03.2024.