INFLUENCE OF AN INTEGRATED MAINTENANCE MANAGEMENT ON THE VEHICLE FLEET ENERGY EFFICIENCY

Davor VUJANOVIĆ, Vladimir MOMČILOVIĆ, Olivera MEDAR*

University of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Serbia

Abstract: Integrated fleet maintenance management represents implementation of measures, actions and decision making with the aim of decreasing total maintenance costs and increasing energy efficiency fulfilling requirements of three interdependent components: transport, maintenance and their environment. Therefore, a methodology for integrated fleet maintenance management is developed and presented in this paper. The purpose of the methodology is to contribute in increasing fleet's energy efficiency and evaluate managers' fleet maintenance management efficiency. The methodology was implemented in the company with own light and medium goods vehicle fleet. According to realized values of defined indicators, the maintenance management has become more efficient in the observed period. It contributed to specific fuel consumption reduction per transport volume, thereby increasing fleet's energy efficiency. Further, the fleet size was reduced, which affected the rational realization of the given transport volume in the observed period.

Keywords: *energy efficiency, vehicle fleet, maintenance management indicators, maintenance management methodology*

1. Introduction

Transport has become the fastest growing energy consuming sector worldwide [1]. In 2014 the transport sector in European Union has a share of 33% in final energy consumption [2]. This trend is also represented in Serbia, where transport has a share greater than 50% in the consumption of final energy obtained from oil derivates [3]. In transport sector, road transport has a dominant role. According to [4], a share of road transport is 82% of total transport energy use in USA in 2014. Road freight transport in European Union has a share of 49% in total freight transport (in ton-kilometers) and road passenger transport has a share of 82% in total passenger transport (in passenger-kilometers) in 2014 [2]. In this respect, it is analyzed a number of strategies, policies and scenarios with the aim to reduce fuel consumption, i.e. to increase energy efficiency of road vehicle fleet [5-7].

The research objective of this paper are companies with own goods vehicle fleets acquiring profit for supplied transport services. Their profit is mostly influenced by transport and maintenance costs. In this sense, the objective of observed companies is to accomplish all planned transport tasks in observed period with as low as possible transport and maintenance costs.

*Corresponding author; e-mail address: d.vujanovic@sf.bg.ac.rs

The main idea is that integrated maintenance management (*MM*) has an influence on fleet energy efficiency increase. In addition, integrated *MM* affects rational realization of transport process. It will allow an overall reduction of transport and maintenance costs, thus increasing company profit. In this sense, a methodology for integrated fleet *MM* is developed.

The remainder of paper is structured as follows. A literature review in this field is presented in the Section 2. The methodology of integrated *MM* is described in Section 3. The realized effects from the implementation of proposed methodology in the observed company is shown in Section 4. Concluding remarks are given in Section 5.

2. Literature review

In the last three decades the significant efforts are made in order to decrease the energy consumption, and CO_2 emission of road transport. In this respect, the vehicle manufacturers are influenced by environmental protection legislations in the aim to produce energy efficient vehicles with lower emissions. On the other hand, different operational measures affect the vehicle fleet owners to accomplish all planned transport tasks with as low as possible fuel consumption. According to [8], the main measures related to increasing the energy efficiency of freight vehicle fleet are: a) engine improvements and emission regulations; b) non-engine technological improvements on vehicle and changes in fleet composition; c) operational measures. In order to evaluate the vehicle energy efficiency, authors in papers [9,10] use the specific fuel consumption per transport volume (energy intensity)-q_t [lit/100ton-km] and specific fuel consumption (fuel economy)-q [lit/100km].

The engine improvements in the early 1990s contributed to emissions decrease and engine power and energy efficiency increase. In the 2000s, the use of Exhaust gas recirculation system influenced fuel economy decrease from 3 to 9% [8]. Nevertheless, in the last couple of years important investments in engine improvements were needed to get negligible improvements in energy efficiency.

The non-engine technological improvement, such as use of aerodynamic devices on the trucks and trailers for long-haul operation can increase the energy efficiency for about 10.8%, compared to those without devices [11]. Reducing rolling resistance can be made by using wide-based tires, which reduce vehicle weight and can improve fuel consumption by up to 5% compared to dual tires [8]. Reduction of vehicle weight can also be achieved by using lightweight materials, which increase energy efficiency for about 1.8% for a long-haul freight truck [12]. It allows weight-limited trucks to increase load capacity and improve fuel economy [5,11]. An increase of average cargo in vehicle has an influence in lowering total vehicle distance traveled, increasing their energy efficiency [13]. Well-conceived fleet renewal in accordance with European environmental and energy recommendations and constraints could influence a further decrease in energy consumption [14-19].

Nevertheless, for many authors the operational measures play a much greater role to increase the energy efficiency than non-engine technological vehicle improvements. According to [20], the operational measures such as supply chains efficient planning, vehicle utilization optimization, empty runs minimization, right vehicle size and type choice for each operation and motivating efficient driving have a great potential in road freight transport energy efficiency. As stated in [20], a decrease of energy efficiency of Finnish road freight transport for about 1.5% was mostly caused by the drop in average vehicle payload and vehicle utilization rate on laden trips from 14.7t and 77.6% to 13.3t and 73.8%. The significant reductions in energy use of trucks will come from operational measures such as better logistics and driving, higher load factors, and better matching of truck capacity to load [21]. Authors in paper [22] claim that potential for the fuel consumption improvements is located in the improvements of operational measures because of low level of vehicle utilization and load factor, scarce use of lightweight vehicle design, poorly selected vehicles and a high proportion of empty runs. According to paper [23], the heavy goods vehicles load factors in the United Kingdom, Denmark and the Netherlands have remained stable or declined between 1990 and 2004, and they are on average less than 50%. Authors in paper [10] show that specific fuel consumption-q [lit/100km] increases with the increase of cargo weight, but not proportionally. In this respect, the specific fuel consumption per transport volume-q_t [lit/100ton-km] decreases with vehicle load factor improvement. In paper [24], authors proposed a model based on fuzzy logic that assigns different types of vehicles to planned transport tasks. The important savings of transport costs can be achieved through the vehicle routing improvements [25,26]. According to [13], many of operational measures involve use of more advanced systems of Information Technology, which can support and improve vehicle routing, scheduling operations and return loading.

From the abovementioned, it can be concluded that the analyzed operational measures with the aim to increase fleet's energy efficiency mostly belong to the fleet operation management field. However, based on research, it has been noted that a special attention should be given to the quality of maintenance and "client" satisfaction [27,28], which emphasizes the *MM* importance [29]. The main authors' idea is that efficient *MM* can increase fleet's energy efficiency. As stated by authors of [29], for an efficient fleet *MM*, managers should integrally observe the transport process, the vehicle maintenance process, as well as the environment. In this respect, integrated *MM* affects the energy efficient and rational accomplishment of given transport volume. Thus, the observed companies make a higher profit and have a lower environmental impact, while achieving their objective. For this reason, methodology for integrated *MM* of vehicle fleet is presented in the next Section.

3. Methodology for integrated fleet *MM*

The methodology for integrated *MM* takes integrally and comprehensively into account the transport process, the vehicle maintenance process, as well as the environment. Transport process requirements are defined by the "*Operational Plan*" (*OP*), which according to [24] represents a collection of transport tasks that the fleet should accomplish in a given period. Environment requirements represent the legislation for the safe road traffic, the environmental protection legislation, the warranty period conditions, the vehicle manufacturers' recommendations in terms of preventive maintenance, the vehicle service centers' locations and quality in the region, and many more. The vehicle maintenance process requirements are defined by maintenance workload to be realized in a given period, in accordance with *OP* and environment requirements. For the methodology, "*Process Based Maintenance*" (*PBM*) concept proposed by authors in paper [30] has an important role. The *PBM* concept requires defining appropriate indicators for measuring the effects of specific measures during the *MM*, monitoring indicators value in relation to the adopted thresholds, as well as making decisions in case of indicator values deviation from threshold values, among others.

The methodology for integrated *MM* consists of five phases and is presented in fig. 1 [31]. In the first phase of the methodology, a reference (initial) state of management has to be defined. Based on technical and operational vehicle characteristics, a fleet structure according to the defined construction-operation (*CO*) groups is determined. Based on fleet operation data analysis, the approximate cargo volumes allocated by type and destination (route) are determined. As a result, working days, departure times, planned return times and the suitable *CO* vehicle groups for each route were identified, which represent the *OP* requirements on a daily, weekly, monthly or other basis. Based on maintenance system data analysis, the maintenance interventions' structure by maintenance groups and locations, as well as scope of maintenance work in the reference state are determined.

According to *PBM* concept, in tab. 1 are shown the defined indicators of fleet *MM* [29]. In tab. 1 are also presented indicators' relative weights in relation to the defined company objective realization, which were obtained by *DEMATEL* and *ANP* methods [29].

Table 1. Vehicle fleet *MM* indicators and their relative weights [29]

Interdependent groups	Indicators	Indicator definition	Relative weights
Transport process (T_P)	*OP* Realization Percentage-T_1	T_1 =(amount of realized ton-km/amount of planned ton-km) ·100	0.195
	Vehicle Payload Utilization-T_2	T_2 =consignment mass/cargo capacity	0.169
	Fleet Utilization Rate-T_3	T_3 =required vehicles number for operation/total vehicles number	0.108
Maintenance process (M_P)	Mean Time Between Failures-M_1	M_1 =vehicle realized working hours (or km)/number of failures	0.044
	Mean Vehicle Downtime-M_2	M_2 =vehicle hours "unready for operation"/number of failures	0.122
	Maintenance Plan Realization-M_3	M_3 =number of realized work orders from Maintenance Plan/ total number of planned work orders in Maintenance Plan	0.233
	Planned Maintenance Percentage-M_4	M_4 =(labor working hours on planned maintenance work orders/total labor working hours) ·100	0.032
Environment (E)	Percentage of Fleet Roadworthiness-E_1	E_1 =(number of vehicles complying with minimum requirements/ total vehicles number controlled on technical inspections) ·100	0.051
	Percentage of Vehicle Roadworthiness in Accidents-E_2	E_2 =(number of vehicles in accidents that complied with minimum safety requirements/total vehicles number in accidents) ·100	0.046

Based on defined indicators' relative weights (tab. 1), for certain observation period the "*Overall management score*" (*S*) could be calculated. Each of the defined indicators is evaluated regarding their realized value in company by scores from 1 to 5 (1 for the lowest value and 5 for the highest value), according to expert determined score scale. The experts are experienced maintenance and transportation managers. In this regard, the score *S* can be calculated according to [29], as presented in the expression (1):

$$S= O_1 \cdot g_{T1}+O_2 \cdot g_{T2}+O_3 \cdot g_{T3}+O_4 \cdot g_{M1}+O_5 \cdot g_{M2}+O_6 \cdot g_{M3}+O_7 \cdot g_{M4}+O_8 \cdot g_{E1}+O_9 \cdot g_{E2} \quad (1)$$

where: O_1, O_2, … O_9 – evaluation scores of the indicators (from 1 to 5);
g_{T1}, g_{T2}, g_{T3}, g_{M1}, g_{M2}, g_{M3}, g_{M4}, g_{E1}, g_{E2} – relative weights of the indicators (tab. 1).

The value of *S* determines the efficiency level of managers regarding fleet *MM* [29]. According to the indicator definitions given in tab. 1, the initial values of *MM* indicators for the reference state (T_{1i}, T_{2i}, T_{3i}, M_{1i}, M_{2i}, M_{3i}, M_{4i}, E_{1i}, E_{2i}) were calculated. Based on the indicators relative weights (tab. 1) and expression (1), the initial score S_i in the reference state was obtained.

The second phase prepares the integrated *MM* conditions. According to the established *OP* requirements and in accordance with the environment, managers from the middle management level need to determine the required number of vehicles for operation (A_r) and allowed number of non-operational vehicles in the status "unready for operation" (D_{no}) per defined *CO* groups, in function of time. The managers' duty is also to establish the threshold values for indicators (T_{1h}, T_{2h}, T_{3h}, M_{1h}, M_{2h},

M_{3h}, M_{4h}, E_{1h}, E_{2h}) to be achieved. Thereby, each established threshold value should be better or equal to the initial (reference) value of indicators, i.e. the expression (2) should be fulfilled:

$$T_{1h} \geq T_{1i};\ T_{2h} \geq T_{2i};\ T_{3h} \geq T_{3i};\quad M_{1h} \geq M_{1i};\ M_{2h} \geq M_{2i};\ M_{3h} \geq M_{3i};\ M_{4h} \geq M_{4i};\quad E_{1h} \geq E_{1i};\ E_{2h} \geq E_{2i} \qquad (2)$$

In the third phase, managers of middle management level have to respect the integrated management criteria, while planning and scheduling the maintenance work. The criteria of integrated *MM*, described in detail in paper [31], are shown in expressions (3) and (4):

$$A_o^k(t) \geq A_r^k(t); \qquad k = (1,2,3,...,T), \quad t \in \{0, p\} \qquad (3)$$

$$D_{no}^k(t) \geq A_{no}^k(t); \qquad k = (1,2,3,...,T), \quad t \in \{0, p\} \qquad (4)$$

where: $A_o^k(t)$ - current number of operational vehicles ("ready for operation") from k^{th} *CO* group with m vehicles, in moment t; $A_r^k(t)$ - required number of vehicles for operation from k^{th} *CO* group with m vehicles, in moment t according to the established *OP* requirements and in accordance with the environment; T - total number of *CO* groups; p - period of vehicles operation, according to the established *OP* requirements; $D_{no}^k(t) = m - A_r^k(t)$ - allowed number of non-operational vehicles from k^{th} *CO* group with m vehicles, in moment t according to *OP* requirements and in accordance with the environment; $A_{no}^k(t) = m - A_o^k(t)$ - current number of non-operational vehicles ("unready for operation") from k^{th} *CO* group with m vehicles, in moment t.

By respecting the criteria given in expressions (3) and (4) within operational *MM* activities, it is also necessary in the third phase to periodically calculate the actual (realized) values of indicators (T_1, T_2, T_3, M_1, M_2, M_3, M_4, E_1, E_2) for a certain observation period (daily, weekly, monthly, etc.) and then to compare them to the defined threshold values for each indicator. For an effective implementation of integrated *MM*, the expression (5) should be fulfilled.

$$T_1 \geq T_{1h};\ T_2 \geq T_{2h};\ T_3 \geq T_{3h};\quad M_1 \geq M_{1h};\ M_2 \geq M_{2h};\ M_3 \geq M_{3h};\ M_4 \geq M_{4h};\quad E_1 \geq E_{1h};\ E_2 \geq E_{2h} \qquad (5)$$

Depending on the results of comparing actual and threshold values for each of the indicators, managers of the middle management level make different decisions within the fourth phase. If the criteria in expression (5) are fulfilled, managers need to determine new enhanced threshold values for indicators, and return to the third phase of methodology. When one or more indicators do not meet the criteria from expression (5), managers should make a decision whether the set threshold values for the indicators could be achieved by improvement measures at the operational *MM* level, or not. The improvement measures at operational level are made with the aims of increasing the utilization of own maintenance facilities and resources, reducing the total fleet non-operational time (in the status "unready for operation"), better implementation of the planned maintenance, increasing the vehicle cargo capacity utilization, reducing the transport and maintenance costs per transport volume, etc. After each implementation of a new set of improvement measures, managers should set up the *MM* to the new state, until all indicators meet the criteria shown in expression (5).

If the application of several different sets of improvement measures at the operational level cannot meet the criteria in expression (5), the procedure passes to the fifth phase, where managers at the top management level make decision to implement the improvement measures at the strategic and tactical *MM* levels. These measures are made with the aims of increasing planned transport tasks' realization, vehicle fleet utilization, vehicle cargo capacity utilization, quality of transport services, while reducing the total cost of transport and maintenance per realized transport volume.

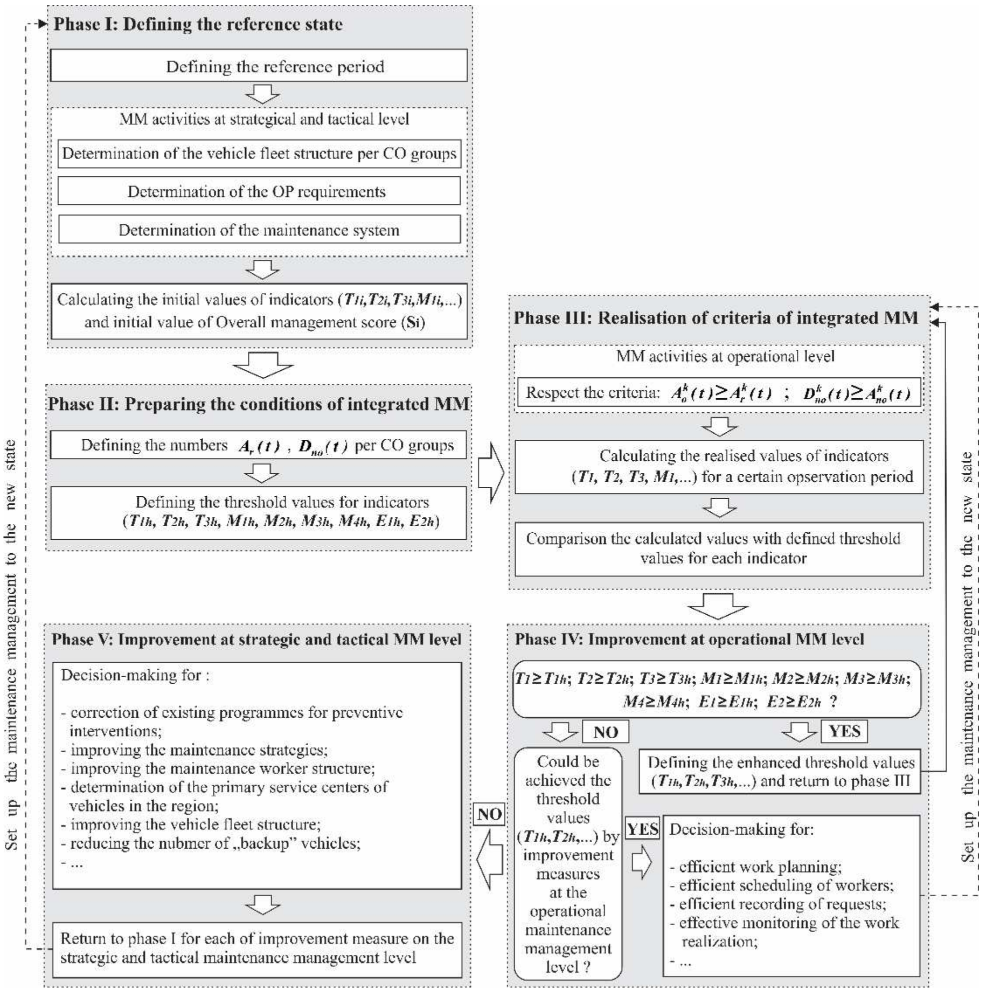

Figure 1. Scheme of the methodology for integrated fleet *MM* [31]

The purpose of the developed methodology is in finding potential areas for improvement as well as in measuring of effects of the implemented improvement measures in the fleet *MM*. In this sense, the realized values of defined indicators were calculated, monitored and compared to the expert established (threshold) values. The implementation of the integrated *MM* allows to fleet managers to dispose with vehicles from the most suitable *CO* group for transport tasks realization in the required periods, according to *OP* and environment requirements, thus increasing vehicle cargo capacity utilization. Better vehicle cargo capacity utilization influences the increase of fleet energy efficiency, for a given transport volume. In addition, the integrated *MM* implementation causes a reduction in the number of "backup" vehicles, which would substitute the vehicles held in maintenance. By reducing the number of "backup" vehicles total fleet size decreases, making it more rational. In this sense, integrated *MM* has an influence on reduction of total transport and maintenance costs.

4. Application of the proposed methodology in company with vehicle fleet

The proposed methodology was implemented in the company “Delmax” Ltd. in the period from January to July 2016. The company’s core (primary) activity is selling and distribution of the automobile spare parts. Distribution of spare parts takes place on daily basis on defined routes on the territory of the Republic of Serbia, using company’s own vehicle fleet. The main objective of the observed company is to deliver certain amount of spare parts to customers at previously agreed time, with the lowest possible costs of transport and maintenance.

According to the first phase of the methodology, a reference state of *MM* in the company was defined. The vehicle fleet was composed of 33 vehicles in the reference period (January 2016), with the largest share of vehicles from the group CO_2 amounting to 66.67% (tab. 2). The *OP* requirements in accordance with the environment requests in the entire methodology implementation period were determined (tab. 3). According to *OP* requirements in tab. 3, the suitable *CO* vehicle groups for each route and each working day are known. Within the maintenance system in the reference period, it was determined that all maintenance interventions have been realized in the defined "priority" vehicle service centers in the region. According to definition in tab. 1, initial values of indicators (T_{1i}, T_{2i}, T_{3i}, M_{1i}, M_{2i}, M_{3i}, M_{4i}, E_{1i}, E_{2i}) in January 2016 were calculated (fig. 3).

Table 2. Vehicle fleet structure according to *CO* groups in observed company

Reference Period	*CO* groups	Definition of *CO* group	Number of vehicles in each *CO* group
January, 2016	CO_1	Heavy goods vehicles (small trucks) of total permissible weight up to 15t	3
	CO_2	Vans of total permissible weight up to 3.5t	22
	CO_3	Small pickup vehicles (smaller vans) of total permissible weight up to 2.5t	8

Based on the determined *OP* requirements, in the second phase of the methodology the required number of vehicles for operation A_r and the allowed number of non-operational vehicles D_{no} upon defined *CO* groups were defined for every day of the week, in function of time. On fig. 2 an overview of number of vehicles $A_r(t)$ and $D_{no}(t)$ upon defined *CO* groups at hourly intervals for every Tuesday in the period January-July 2016 is presented. Besides, managers have determined the indicator threshold values, i.e. T_{1h}, T_{2h}, T_{3h}, M_{1h}, M_{2h}, M_{3h}, M_{4h}, E_{1h}, E_{2h} in accordance with expression (2).

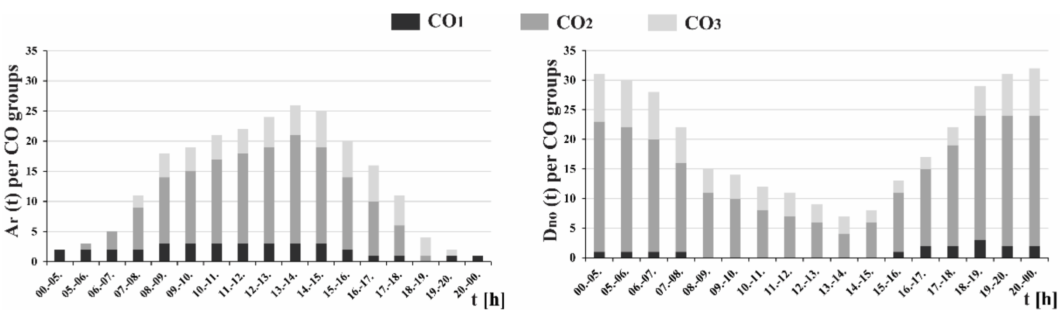

Figure 2. Overview of number $A_r(t)$ and $D_{no}(t)$ per *CO* groups in observed company, at hourly intervals for every Tuesday in the period January-July 2016

By beginnings of February 2016 it has been initiated the realization of criteria given in expressions (3) and (4), within the third phase of methodology. It has allowed managers to dispose of vehicles from the most suitable *CO* group for transport tasks realization in the required periods, according to *OP* and environment requirements. It resulted in improvement of indicators T_1 and T_2 in February 2016, compared to the referent period (fig. 3).

In order to further improve the indicators during March 2016, managers started to plan efficiently the maintenance work by insisting on respecting the predefined timeframes for maintenance intervention realization in the vehicle service centers in the region. It resulted in further increase of values of indicators M_3 and T_2 compared to the previous month (fig. 3).

Since the realized value of indicator M_1 in March 2016 was worse than the set threshold value for previous period and since indicator M_1 could not be improved by measures at operational management level, managers have made a decision at tactical level to add some control interventions within preventive maintenance.

Table 3. The requirements of vehicles' *OP* in observed company

Route name	Working days	Departure time [h]	Planned return time [h]	Suitable *CO* vehicle group
"Zvezdara I"	(Mon.-Fri.); (Sat.)	(07.15); (10.15)	(12.00); (14.00)	CO_3
"Voždovac I"	(Mon.-Fri.); (Sat.)	(07.30); (10.00)	(12.00); (13.30)	CO_3
"Pančevo I"	(Mon.-Fri.); (Sat.)	(07.30); (10.30)	(13.30); (14.30)	CO_2
"Obrenovac I"	(Mon.-Fri.); (Sat.)	(07.30); (10.00)	(13.30); (13.00)	CO_2
"Stara Pazova"	(Mon.-Fri.); (Sat.)	(08.00; 10.00; 12.30; 15.00; 17.30); (08.00)	(09.30; 12.15; 14.15; 16.30; 19.00); (09.30)	CO_3
"Nova Pazova"	(Mon.-Fri.); (Sat.)	(08.00; 11.15; 13.45; 16.15; 18.45); (08.00)	(10.15; 12.45; 15.45; 17.45; 19.30); (10.00)	CO_3
"Beograd zapad I"	(Mon.-Fri.); (Sat.)	(08.15); (10.15)	(12.00); (13.00)	CO_2
"Grocka I"	(Mon.-Fri.); (Sat.)	(08.00); (10.00)	(13.15); (15.00)	CO_2
"Novi Sad I"	(Mon.-Fri.); (Sat.)	(08.30); (10.30)	(13.30); (15.00)	CO_2
"Kikinda-Bečej"	(Mon; Wed.-Fri.); (Tue.)	08.30	(16.00); (17.30)	(CO_2); (CO_1)
"Sombor"	Mon.-Fri.	08.45	16.30	CO_2
"Šabac-Šid"	(Mon.); (Tue.-Fri.)	(08.00); (09.00)	(17.00); (15.00)	(CO_1); (CO_2)
"Zvezdara II"	Mon.-Fri.	10.15	14.00	CO_2
"Voždovac II"	Mon.-Fri.	10.15	14.15	CO_2
"Novi Sad II"	Mon.-Fri.	11.00	16.00	CO_2
"Zvezdara III"	Mon.-Fri.	12.15	16.00	CO_2
"Voždovac III"	Mon.-Fri.	12.15	16.45	CO_2
"Grocka II"	Mon.-Fri.	12.30	18.00	CO_3
"Beograd zapad II"	Mon.-Fri.	13.00	16.45	CO_2
"Novi Sad III"	Mon.-Fri.	13.00	18.00	CO_2
"Pančevo II"	Mon.-Fri.	14.00	17.30	CO_3
"Delmax MP I"	Mon.-Fri.	12.00	18.30	CO_3
"Delmax MP II"	Mon.-Fri.	12.00	17.00	CO_3
"Obrenovac II"	Mon.-Fri.	14.30	17.45	CO_2
"Zvezdara IV"	Mon.-Fri.	14.15	18.00	CO_2
"Voždovac IV"	Mon.-Fri.	14.15	18.15	CO_2
"Kraljevo-Kruševac"	Mon.-Fri.	05.30	17.00	CO_2
"Novi Pazar"	Mon.-Fri.	12.30	18.00	CO_2
"Niš"	(Mon.-Tue.); (Tue.-Wed); (Wed.-Thu.); (Thu.-Fri.); (Sat.-Sat.)	(Mon.20.00); (Tue.19.00); (Wed.18.00); (Thu.19.30); (Sat. 08.30)	(Tue.16.00); (Wed.16.30); (Thu.15.30); (Fri.17.30); (Sat.18.30)	CO_1
"Bor-Zaječar"	Tue; Fri.	07.00	15.00	CO_2
"Pirot"	Tue; Fri.	11.00	16.00	CO_2
"Vranje"	Mon; Thu.	07.00	15.00	CO_2
"Leskovac"	Mon; Thu.	11.00	16.00	CO_2
"Niš-Prokuplje"	Mon.-Fri.	07.00	10.45	CO_2
"Subotica"	Mon.-Fri.	06.00	15.00	CO_2
"Vrbas-Kula"	(Mon.-Wed; Fri.); (Thu.)	06.00	(11.30); (16.00)	(CO_2); (CO_1)
"Prijepolje"	(Mon.-Tue.); (Thu.-Thu.)	(Mon.06.00); (Thu.05.30)	(Tue.15.00); (Thu.19.00)	(CO_1); (CO_2)
"Loznica"	Wed; Sat.	06.00	16.00	CO_2
"Čačak"	Wed; Sat.	06.00	16.30	CO_2

It affected the improvement of indicator M_1 in April 2016 compared to the previous month (fig. 3). In addition, in the same period one vehicle from the group CO_2 was sold in order to decrease the number of “backup” vehicles. It improved the value of indicator T_3. This measure at strategic management level influenced as well an improvement of indicators M_2 and M_4 (fig. 3), because of the lower maintenance work due to unplanned failures, but it contributed also to lowering maintenance costs per realized transport volume. In May 2016, managers have made a decision at tactical management level to change some "priority" vehicle service centers in the region. It influenced the improvement of indicators M_2 and M_3. The increase of the value of indicator M_3 resulted in improving the value of indicators T_1 and T_2 compared to the previous month (fig. 3). In June 2016 managers have decided to exclude from transport process one vehicle from the group CO_3. It resulted in further improvement of indicators T_3 and M_4 (fig. 3), compared to the previous period. In order to further improve the maintenance planning, in July 2016, managers have made a decision to better control the predefined timeframes for maintenance work realization in the vehicle service centers. It improved the indicators M_2 and M_3, thereby further improving indicator T_2 (fig. 3). The values of indicators E_1 and E_2 were at their maximum levels during the methodology implementation period (fig. 3).

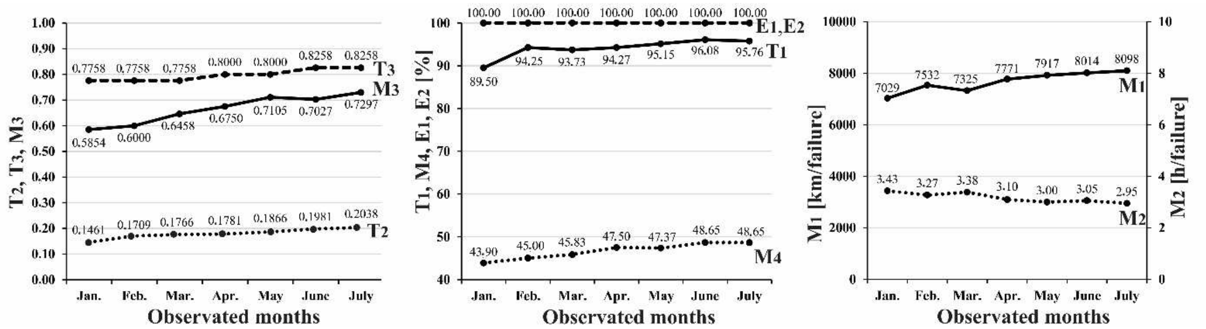

Figure 3. Overview of the fleet *MM* indicators in observed company in the period January-July 2016

By implementation of the methodology, the fleet *MM* in observed company became more efficient. The score *S*, representing the level of managers' efficiency regarding the *MM* was enhanced in the observed period. (tab. 4). The implementation of integrated *MM* has influenced an improvement of indicator M_3, among others, for 24.65% in July 2016, in relation to the reference period (tab. 4). This has enabled fleet managers to choose vehicles from suitable *CO* group, especially in terms of payload capacity utilization, for the realization of given transport volume. As a result, the realized value of indicator T_2 in July 2016 was 0.2038, which represents an improvement of 39.5%, compared to the reference period (tab. 4). By improving the majority of indicators and the score *S* in the observed period, lead to decreasing value of q_t by 20.4% in July 2016 amounting to 28.13 lit/100ton-km (tab. 4).

Table 4. An overview of accomplished transport and maintenance results in observed company, in the methodology implementation period

Observation period	January, 2016	April, 2016	July, 2016
Realized transport volume [ton-km]	45 875	56 547	54 073
Fuel consumption [lit]	16 212	16 557	15 210
Maintenance Plan Realization - Indicator M_3	0.5854	0.6750	0.7297
Vehicle Payload Utilization - Indicator T_2	0.1461	0.1781	0.2038
Overall management score - S	2.4710	2.9750	3.2800
Specific fuel consumption per realized transport volume - q_t [lit/100ton-km]	35.34	29.28	28.13
Total number of vehicles	33	32	31

In this respect, the integrated *MM* has influenced an increase of the fleet energy efficiency in the observed period. Thus, the vehicle transport costs per realized transport volume were lowered. Furthermore, the integrated *MM* implementation enabled a realization of greater transport volume, with a lower number of vehicles in July 2016 in relation to the reference period (tab. 4). It made the vehicle fleet more rational and contributed to reducing transport and maintenance costs per realized transport volume.

5. Conclusion

This paper demonstrates the impact of the integrated *MM* on the vehicle fleet energy efficiency. A methodology for integrated *MM* of vehicle fleet was developed and implemented in a company with own vehicle fleet for distribution of spare parts. In the methodology implementation period, the *MM* in observed company has become more efficient. Improvement of the majority of *MM* indicators and the score *S* in the observed period, have contributed to the reduction in specific fuel consumption per realized transport volume for 20.4% amounting to 28.13 lit/100 ton-km with respecting all transport and environmental requirements. Thus, the most efficient CO vehicle groups have been selected for the transportation tasks realization. If we would take into account the enhancement of specific fuel consumption per realized transport volume, the fuel savings in July 2016 in relation to January 2016 would amount to 3899 lit. In addition, the vehicle fleet was reduced for two vehicles, which has not adversely affected the realization of given transport volume. In this respect, a greater transport volume with a lower number of vehicles was realized in July 2016, in relation to January 2016.

Based on the accomplished results in observed company it can be concluded that the integrated *MM* contributes in increasing energy efficiency of vehicle fleet and in achieving rational realization of given transport volume. Further research will be directed towards the implementation of the developed methodology in public enterprises with large fleets. According to the fleet size the methodology implementation period would be longer especially in beginning phases due to more important data needed for decision making. Eventually, it is expected to attain significant energy savings in those large public enterprises. This could additionally highlight the importance of the integrated *MM* as an important factor for increasing fleet's energy efficiency and therefore for achieving higher profit in the observed companies.

Acknowledgments

The research presented in this paper has been realized within the project "Development of the Model for Managing the Vehicle Technical Condition in Order to Increase its Energy Efficiency and Reduce Exhaust Emissions" (No. 36010), supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia. The authors are grateful to managers in the company "Delmax" for providing all the necessary information for this research.

Nomenclature

$A_{no}^{k}(t)$	–	Current number of non-operational vehicles from k^{th} *CO* group in moment t [–]
$A_{o}^{k}(t)$	–	Current number of operational vehicles from k^{th} *CO* group in moment t [–]
$A_{r}^{k}(t)$	–	Required number of vehicles for operation from k^{th} *CO* group in moment t [–]
$D_{no}^{k}(t)$	–	Allowed number of non-operational vehicles from k^{th} *CO* group in moment t [–]
E_1	–	Percentage of Fleet Roadworthiness [%]
E_2	–	Percentage of Vehicle Roadworthiness in Accidents [%]
$g_{T1}, g_{T2},\ldots, g_{E2}$	–	Relative weights of indicators [–]
m	–	Total number of vehicles from the k^{th} *CO* group [–]
M_1	–	Mean Time Between Failures [km/failure]
M_2	–	Mean Vehicle Downtime [h/failure]
M_3	–	Maintenance Plan (MP) Realization [–]
M_4	–	Planned Maintenance Percentage [%]
$O_1,O_2,\ldots,O_9$	–	Evaluation scores of the indicators [–]
p	–	Period of vehicles operation, according to the established *OP* requirements [h]
q	–	Specific fuel consumption [lit/100km]
q_t	–	Specific fuel consumption per transport volume [lit/100ton-km]
S	–	Overall management score [–]
t	–	Time [h]
T	–	Total number of *CO* groups [–]
T_1	–	Operational Plan Realization Percentage [%]
T_2	–	Vehicle Payload Utilization [–]
T_3	–	Fleet Utilization Rate [–]

Acronyms

CO	–	Construction-operation
CO_1, CO_2, CO_3	–	Defined construction-operation groups of vehicles in observed company
MM	–	Maintenance management
OP	–	Operational Plan
PBM	–	Process Based Maintenance

Subscripts

i	–	Initial values for indicators and Overall management score
k	–	*CO* group index
no	–	Non-operational vehicles index (in the state "unready for operation")
o	–	Operational vehicles index (in the state "ready for operation")
r	–	Required vehicles index
H	–	Threshold values for indicators

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Submitted: 09.02.2017
Revised: 05.04.2017
Accepted: 22.04.2017