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ECOLOGICAL ASPECTS OF MOTOR VEHICLE OPERATION

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Key words: operation system, ecology, diagnostic system, maintenance of technical objects, recycling.

Abstract

The paper deals with the problem of environmental pollution reduction with the help of a pro-ecological system of motor vehicle operation, paying particular attention to the algorithm of serviceability control, operation system, and subsystems of vehicle diagnosing and recycling.

SYSTEM EKSPLOATACJI POJAZDÓW MECHANICZNYCH W ASPEKCIE EKOLOGICZNYM

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Słowa kluczowe: system eksploatacji, ekologia, system diagnostyczny, utrzymanie obiektów technicznych, recykling.

Streszczenie

Przedstawiono problem ograniczenia zanieczyszczenia środowiska naturalnego za pomocą proekologicznego systemu eksploatacji pojazdów mechanicznych. Rozpatrzono takie zagadnienia, jak: algorytm sterowania utrzymaniem obiektów w stanie zdatości, system eksploatacji, podsystem diagnostyczny i recykling pojazdów.

Introduction and aim of the study

A rapidly growing number of motor vehicles constitutes a serious threat to ecosystems, especially as regards metabolism, energy conversion and information flow.

Ecosystems are ecological units encompassing living organisms whose interactions with the natural environment (soil, water, atmosphere) result in energy flow enabling matter circulation, i.e. exchange of elements and chemical compounds between the inanimate and animated nature. Environmental hazards accompany particular phases of motor vehicle existence (BOCHEŃSKI 2001, CHŁOPEK 2002, MERKISZ 1995, MODRZEWSKI 2003, NIZIŃSKI 2002, OPRZADKIEWICZ, STOLARSKI 2002):

- 1) Phase of demand. The identification of needs allows to determine technological and economic requirements to be satisfied by a given vehicle. These requirements specify the general quality of a vehicle, and allow to make a feasibility study and estimate the necessity of process continuation, modernization, license purchase or production of a new vehicle. It should be emphasized that according to relevant EU directives, since January 1, 2005, only 15% of non-useable vehicle components may not go to the breaker's yard, and since January 1, 2015 – only 5%.
- 2) Design phase includes mainly selection of construction materials, engine fuels and lubricants and other fluids.
- 3) Production phase includes first of all technological processes of low energy-consumption and toxicity, and vehicle protection against pollutant emission to the natural environment.
- 4) In the motor vehicle operation phase environmental hazards can be divided into (CHŁOPEK 2002):
 - transport accidents – dangers to health and life of humans and animals, and environmental destruction. Major elements of threat are in this case: fuels, brake and cooling fluids, oils and lubricants;
 - exhaust gas air pollution (CO , CO_2 , C_nH_m , NO_x , carbon black);
 - noise and vibration generation;
 - dust generation;
 - fuel leakage and evaporation;
 - electromagnetic radiation from electrical and electronic devices;
 - land and landscape degradation, air, soil and water pollution whose sources are road networks and car service stations.

Taking into account the above threats, the objective of the present study was to analyze the operation system, diagnostic subsystem and recycling subsystem of motor vehicles from the perspective of reducing environmental degradation.

Algorithm of serviceability control in the aspect of environmental protection

Algorithms are indispensable to exercise control over proper maintenance of motor vehicles in terms of their functional serviceability, taking into consideration the principles of environmental protection. The algorithm in Figure 1 comprises three major elements of motor vehicle inspection:

- analysis and evaluation of vehicle condition;
- forecast of vehicle condition changes;
- determination of the reasons for the existing condition.

This indicates that the first step to be taken is to diagnose a given vehicle. If it turns out to be fit for use, it is necessary to forecast the course of changes that are expected to take place. In practice it is limited to fixing the date of the next diagnostic inspection, followed by the usual maintenance and operational actions. In case the vehicle is considered unfit for further use, it is necessary to determine the reasons for this state, which may as follows: the vehicle's service life is over, the vehicle should be qualified for breaking or major overhaul, some parts need to be replaced. If a given vehicle is classified as a scrap vehicle, it should be disposed of through the scrap vehicle management subsystem. In other cases the reasons for its unserviceability should be eliminated, and the vehicle should be diagnosed again.

In the above algorithm (Fig. 1) of serviceability control of motor vehicles classified as fit for use in the aspect of environmental protection, the criterion of vehicle classification was their technical condition. In the algorithm presented in Figure 2 another criterion was introduced, i.e. costs.

According to this algorithm, the vehicle should be subjected to complex diagnosing and maintenance/operation, applying a separate algorithm A1. If the vehicle is fit for use, the date of the next diagnostic inspection and maintenance/operation is fixed, in accordance with algorithm A2. When the date is fixed, all indispensable maintenance and operation steps are to be taken (algorithm B1). Then, depending on the needs, the vehicle may be classified into the operation subsystem or the storage subsystem, for short- or long-term maintenance according to separate diagnostic algorithms A8 and A9, and maintenance/operation algorithms B8 and B9.

Algorithm C1 is applied to estimate the efficiency of vehicle utilization. If the utilization of a given vehicle is considered profitable, it is designed for goods and/or passenger transport. It should be noted that before, during and after task performance the vehicle is diagnosed and maintained/operated according to algorithms (A3, A4, A5 and B2, B3, B4, B5 respectively).

In case the vehicle is considered unfit for further use, it is necessary to determine the reasons for this state according to algorithm A3. These reasons may as follows:

- the vehicle's service life is over and it is qualified for recycling and treated as a scrap vehicle;

- the vehicle is qualified for major overhaul, whose cost is estimated according to algorithm *C3*. If the result is positive, the vehicle undergoes major overhaul according to algorithms *A10* and *B10*; if the result is negative, the vehicle is subjected to breaking according to algorithms *A11* and *B11*.

Motor vehicle operation system

The motor vehicle operation system is aimed at:

- rational utilization of motor vehicles, in accordance with relevant recommendations;
- maintaining vehicle serviceability, enabling their proper functioning;
- minimizing the negative environmental impact of motor vehicles;
- efficient management of motor vehicle operation.

The motor vehicle operation system E_p is described by the following expressions (Fig. 3) (NIZIŃSKI 2002):

$$E_p = \langle E_{TR}, E_{TZ}, R_{ER} \rangle \quad (1)$$

$$E_{TR} = \langle P_U, P_O, R_{OU} \rangle \quad (2)$$

$$C_{ETZ} = \langle E_{ZK}, E_{ZF}, E_{ZI}, R_{KI} \rangle \quad (3)$$

$$P_O = \langle P_{BP}, P_{PP}, P_{SP}, P_{GP}, D_g, R_{GP} \rangle \quad (4)$$

where:

- E_{TR} – operation subsystem;
- E_{TZ} – operation management subsystem;
- P_U – utilization subsystem;
- P_O – maintenance subsystem;
- P_{BP} – maintenance and running repair subsystem;
- P_{PP} – storage subsystem;
- P_{SP} – medium repair system;
- P_{GP} – major overhaul subsystem;
- D_g – diagnostic subsystem;
- E_{ZK} – operation control subsystem;
- E_{ZF} – economic-financial subsystem;
- E_{ZI} – information subsystem of motor vehicle operation;
- $R_{ER}, R_{OU}, R_{GP}, R_{KI}$ – relationships.

As shown in Figures 1, 2 and 3, the diagnostic subsystem is used to control serviceability of motor vehicles in the aspect of environmental protection.

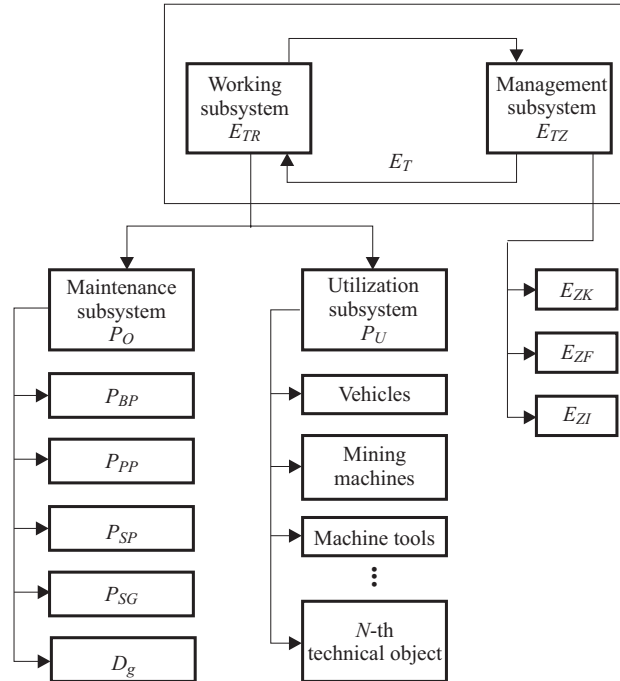


Fig. 3. Motor vehicle operation system

Diagnostic subsystem

The diagnostic subsystem can be defined as follows (NIZIŃSKI 2002). "A diagnostic subsystem comprises a team of diagnosticians, a set of diagnostic, forecasting and original state determining algorithms, methods and devices, designed for testing and evaluating the condition of motor vehicles".

The information collected in the diagnostic subsystem provides the basis for determining:

- the condition of a vehicle at moment t (serviceable/unserviceable);
- the date of the next diagnostic inspection, if the vehicle is classified as fit for use at moment $t+\Delta t$;
- if the vehicle is to be disposed of in the recycling subsystem;
- if the vehicle needs a major overhaul;
- the vehicle's condition at moment $t-\Delta t$, i.e. localization of its damaged parts.

The diagnostic subsystem may be used for scrap vehicle disposal, consistent with the principles of environmental protection, as (NIZIŃSKI, WIERZBICKI 2004):

- 1) an element of the motor vehicle operation system in operating supersystems (Fig. 7).

2) on-board diagnostic subsystem (Fig. 4, 5, 6).

All modern motor-cars are equipped with an on-board diagnostic system (OBD II), where the main criterion for selecting elements for diagnosis is the risk of harmful exhaust emission (Fig. 4). The system cooperates with other systems by means of a CAN-bus (Fig. 5). It should be emphasized that OBD is not a complex diagnostic system.

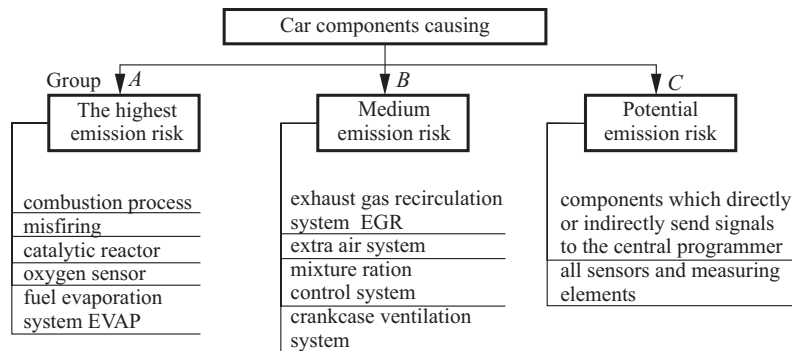


Fig. 4. Graphic illustration of the diagnostic subsystem

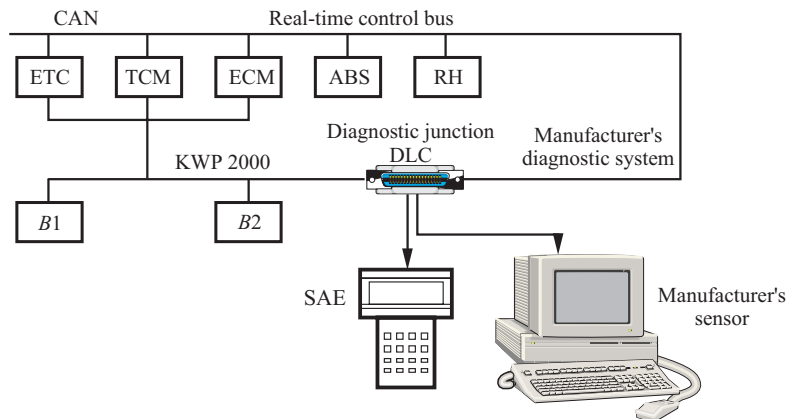


Fig. 5. Example of a configuration of an in-vehicle network. Programmers of: *ETC* – engine, *TCM* – automatic gearbox, *ECM* – servo-motor of the throttling valve position, *ABS* – braking system, *RH* – active suspension, *B1*, *B2* – other on-board programmers, *DLC* – diagnostic junction

The diagnostic subsystem is an element of the integrated information system for motor vehicle control (Fig. 6), proposed by (NIZIŃSKI, WIERZBICKI 2004).

Fig. 7 presents an operating supersystem (e.g. a machine building works, an agricultural cooperative, a service station) that consists of systems of logistics, operation and diagnostics of technical objects, including motor vehicles (NIZIŃSKI 2002).

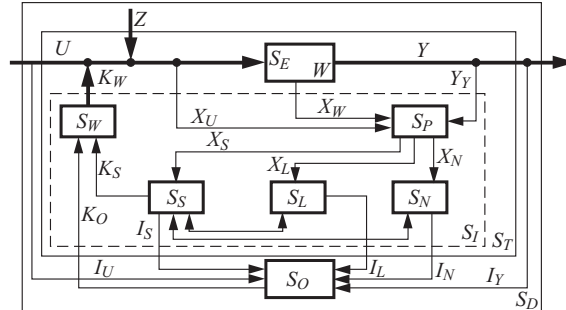


Fig. 6. Graphic illustration of a motor vehicle with an integrated information subsystem of control $S_I S_D$ – vehicle as an operating system, S_P – measuring subsystem, S_S – information subsystem of programmers, S_L – information subsystem of logistics, operation and diagnostics, S_N – information subsystem of navigation, S_W – executive subsystem, S_E – subsystem of functional elements of the vehicle, U, Y, W, Z – sets of inputs, outputs, states and interferences, X_U, X_W, X_Y – sets of parameters of measured signals, X_S, X_L, X_N – sets of values of measured signal parameters, K_O – set of command signals of the operator, K_S – set of command signals from vehicle system programmers, K_W – set of control quantities, I_S, I_L, I_N, I_U, I_Y – information for the operator

Two elements can be distinguished in the controlled subsystem S_1 :

S_{PR} – working subsystem;

S_{LR} – working logistics subsystem.

The working logistics system S_{LR} consists of the subsystems of:

supply – Z_L ;

transport – T_L ;

utilization – E_L ;

distribution – D_L ;

environmental protection – O_L .

The system of utilization E_L of fixed assets, including technical devices, consists of the subsystems of:

utilization – P_U ;

maintenance – P_O .

The system of maintenance of technical devices P_O comprises the subsystems of:

maintenance and running repair – P_{BP} ;

storage – P_P ;

diagnostics – D_G ;

medium repairs – P_{SP} ;

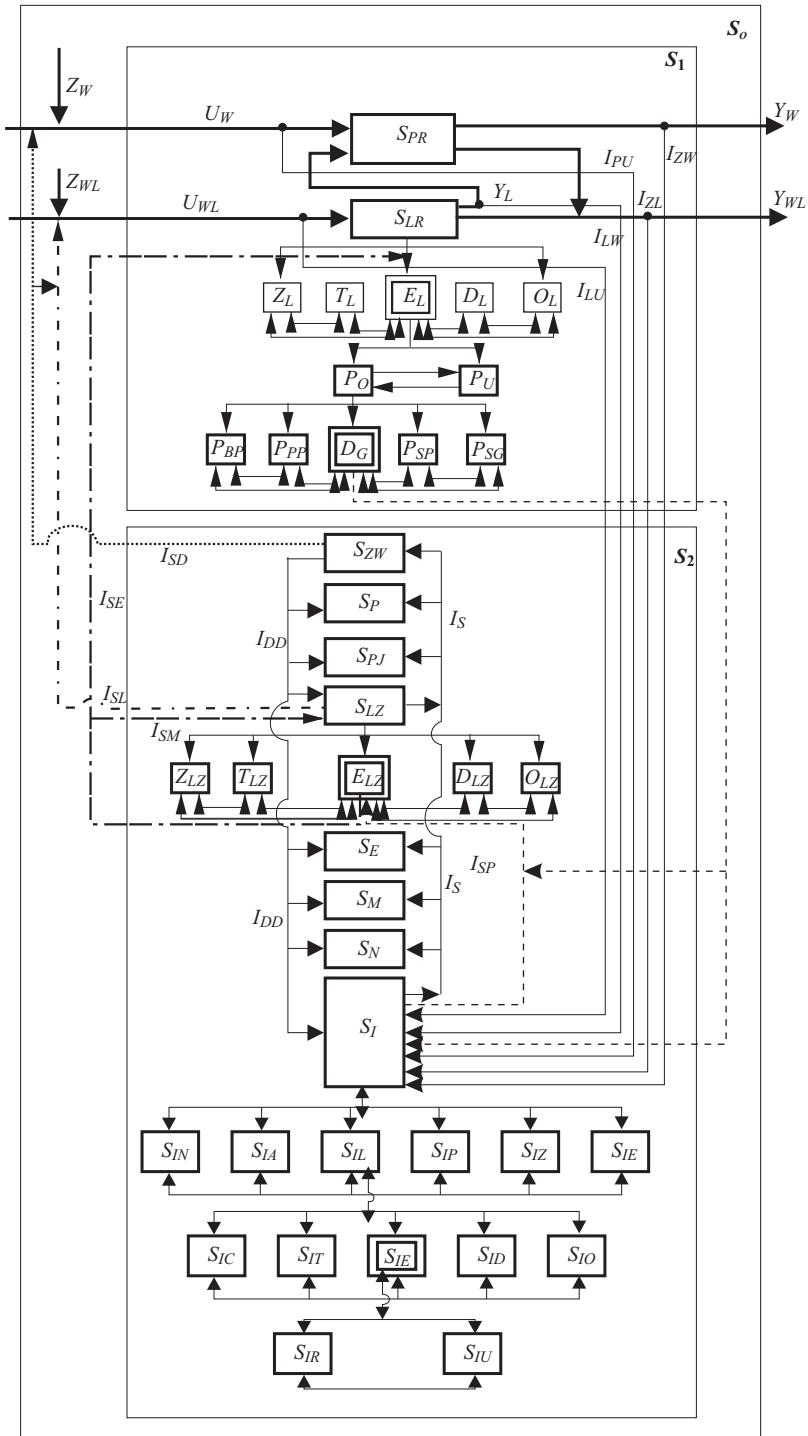
major overhauls – P_{SG} .

The control (management) system S_Z consists of, among other, the subsystems of:

highest-level management – S_{ZW} ;

production management – S_P ;

product quality management – S_{PJ} ;



logistics management – S_{LZ} ;
 economics – S_E ;
 marketing – S_M ;
 other subsystems – S_N ;
 information – S_I .

The logistics management system S_{LZ} consists of the subsystems of management of: supply, transport, utilization, distribution, environmental protection.

The information system S_I of the operating supersystem S_O consists of the information subsystems of the following systems:

economic – S_{IE} ;
 supply – S_{IZ} ;
 production and/or services – S_{IP} ;
 logistics – S_{IL} ;
 administration – S_{IA} ;
 other – S_{IN} .

The information system of logistics S_{IL} includes the following subsystems:

operation – S_{IE} ;
 distribution – S_{ID} ;
 environmental protection – S_{IO} ;
 transport – S_{IT} ;
 supply – S_{IC} .

Fig. 7. Graphic illustration of the operating supersystem including the systems of logistics, operation and diagnostics within the operating system: S_O – operating system (e.g. an industrial plant, an agricultural cooperative, a budgetary unit); S_1 – controlled subsystem (working, executive); S_2 – control (management) subsystem; S_{PR} – working subsystem, e.g. goods production, services, sales; S_{LR} – working logistics system; Z_L, T_L, E_L, D_L, O_L – subsystems of: supply, transport, operation, distribution, environmental protection; P_O – maintenance subsystem; P_U – utilization subsystem; $P_{BP}, P_{PP}, P_{SP}, P_{SG}$ – subsystems of: maintenance and running repairs, storage, medium repairs, major overhauls; D_g – diagnostic subsystem; S_{ZW} – highest-level management system; S_p – production and/or services management subsystem; S_{pJ} – production and/or services quality management subsystem; S_{LZ} – logistics management subsystem; $Z_{LZ}, T_{LZ}, E_{LZ}, D_{LZ}, O_{LZ}$ – subsystems of management of: supply, transport, operation, distribution, environmental protection; S_E – economic subsystem; S_N – other subsystems; S_I – information subsystem; U_W – working subsystem input; Z_W – working subsystem disturbances; Y_{WL} – working subsystem output realized through the distribution subsystem; Y_L – logistics subsystem output; $S_{IE}, S_{IZ}, S_{IP}, S_{IL}, S_{IA}, S_{IN}$ – information subsystems of systems of: economics, management of the operating, production and/or services systems, logistics, administration, other; $S_{IE}, S_{ID}, S_{IO}, S_{IT}, S_{IC}, S_{IU}, S_{IR}$ – information subsystems of systems of: operation, distribution, environmental protection, transport, supply, utilization, maintenance; $I_{LU}, I_{LW}, I_{PU}, I_{ZL}, I_{ZW}$ – information about: state of external logistic supplies, state of logistic production (services) protection, state of environmental impact on production (services), level of task performance; I_S – information processed by the information system; I_{SD}, S_{DD} – decisions of the highest-level management subsystem; I_{SL} – decisions made by the logistics department manager; I_{SE} – decisions made by the operation department manager

The information system of technical device operation S_{IE} comprises the information subsystems of:

- utilization – S_{TU} ;
- maintenance – S_{IR} .

The information system S_I of the operating supersystem contains all information ($I_{LU}, I_{LW}, I_{PU}, I_{ZL}, I_{ZW}$), including logistic information, about its functioning. The information processed in the information logistics system S_{IL} is directed to the logistics management subsystem S_{LZ} , where it is classified and sent to particular management subsystems, including the subsystem E_{LZ} responsible for management of technical device operation. The manager of the operation subsystem makes decisions (I_{SE}) which affect the working element E_L of the technical device operation system, so as to:

- use technical devices in accordance with manufacturer's recommendations;
- maintain technical devices as fit for use;
- obtain a positive result (profit) of the functioning of the technical object operation system;
- eliminate unserviceable vehicles from the subsystem and destine them for recycling.

As regards information flows concerning the condition of technical devices in the operating system, the central position is occupied by the diagnostic subsystem D_g . The diagnostic subsystem D_g collects information about the condition of all technical objects functioning within the operating system. The information I_{ST} about the condition of objects is sent to the information subsystem S_I of the operating system S_O , where the information I_{SP} is processed to the form accepted by the subsystem E_{LZ} of device operation management. It should be stressed that in the diagnostic subsystem D_g information about the condition of motor vehicles may be processed and supplied directly to the information subsystem S_I . This is determined by the organizational structure of the information system of a given operating system.

The subsystem E_{LZ} of technical object operation management supplies reports I_{SM} on the condition of technical devices to the logistics management subsystem S_{LZ} . The decisions I_{SE} concerning maintenance, running repairs, medium repairs or elimination of technical devices are also made in this subsystem. The information I_S about the condition of technical devices is passed from the subsystem S_{LZ} to the other subsystems (e.g. S_P, S_{PJ}, S_E) and to the highest-level management subsystem S_{ZW} . Decisions I_{SL} on maintenance of technical objects as fit for use are also made within the subsystem S_{LZ} . Decisions I_{SD} concerning the above problems should be also made in the subsystem S_{ZW} .

The flow of information about the condition of technical objects in the operating system is indispensable for the maintenance of technical objects (vehicles) in operation. An important task is also to protect the natural environment against the harmful impact of technical objects, including motor vehicles. To attain this goal, the information on the condition of technical objects must be incorporated into the circulation of information about the

operating system functioning, paying particular attention to the decision-making process at the highest level of management. Therefore, it is necessary to develop and implement an effective information subsystem of the operating system, including diagnostic information.

Environmental protection system

The diagnostic subsystem is responsible for eliminating unserviceable vehicles from the operation system E_L and directing them to the recycling subsystem which is an element of the waste disposal subsystem within the environmental protection system O_L . This system is an element of the logistics system of any operating supersystem (Fig. 8) (NIZIŃSKI 2002).

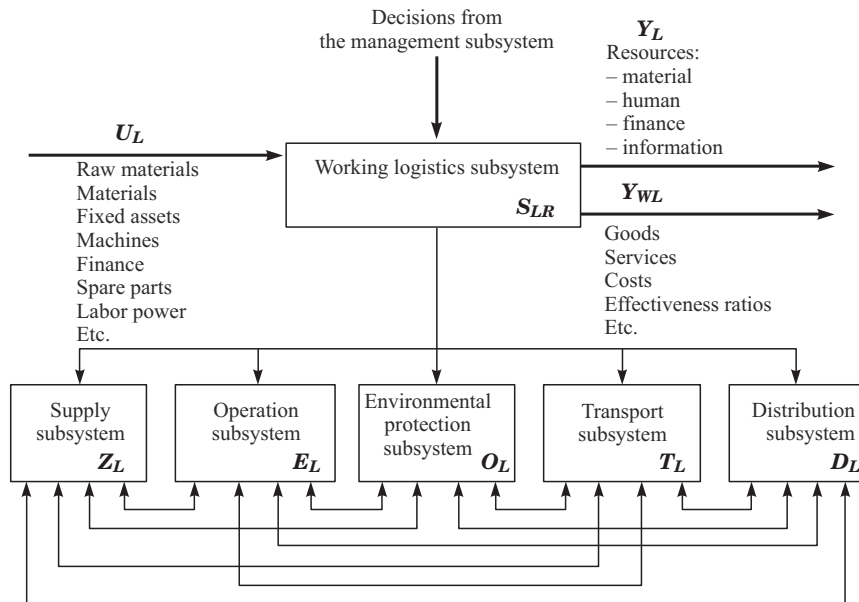


Fig. 8. Working logistics subsystem of the operating system

Generally speaking, the environmental protection system of any operating supersystem may be defined as follows (NIZIŃSKI, LIGIER 2004):

$$O_L = \langle S_Z, S_T, S_W, S_A, S_L, S_U, R_{ZR} \rangle \tag{5}$$

where:

- S_Z – management subsystem;
- S_T – subsystem of land, landscape, soil, plant and animal protection;
- S_W – water protection subsystem;
- S_A – atmosphere protection subsystem;
- S_L – human protection subsystem;

S_U – waste disposal subsystem;
 R_{ZR} – relationships.

The waste disposal subsystem may be defined as:

$$S_U = \langle S_Z, S_K, S_R, R_{KR} \rangle \quad (6)$$

where:

S_Z – management subsystem;
 S_K – municipal wastes subsystem;
 S_R – motor vehicle recycling subsystem;
 R_{KR} – relationships.

The motor vehicle recycling subsystem S_P can be described as:

$$S_R = \langle S_{RZ}, S_{RS}, S_{RN}, S_{RD}, S_{RW}, S_{RB}, S_{RD}, R_{RS} \rangle \quad (7)$$

where:

S_{RZ} – vehicle recycling management subsystem;
 S_{RS} – scrap vehicle storage subsystem;
 S_{RN} – subsystem for vehicle fluids and hazardous materials removal;
 S_{RD} – subsystem for vehicle dismantling and diagnosing;
 S_{RW} – subsystem for vehicle parts recycling;
 S_{RB} – secondary materials acquisition subsystem;
 S_{RD} – useless wastes subsystem;
 R_{RS} – relationships.

The main tasks of the vehicle recycling management subsystem S_{RZ} are as follows:

- to receive unserviceable motor vehicles;
- to minimize the negative effects of scrap vehicles on the natural environment;
- to use at least 95% of the mass of scrape vehicles;
- to make profit on sale of scrap vehicle components.

The storage subsystem S_{RS} is responsible for storing motor vehicles classified by make and type.

The tasks of the subsystem S_{RN} of vehicle fluids and hazardous materials disposal are as follows:

- to dispose, sort and store fuels, oils, lubricants, brake and cooling fluids, glass, windows, batteries, catalysts and other vehicle components;
- to process and reuse the above components, applying the thermal decomposition method, physicochemical biodegradation method and other.

The subsystem S_{RD} of vehicle component dismantling and diagnosing is responsible for:

- vehicle dismantling into units, sets, assemblies, sub-assemblies, mechanisms and components;
- diagnosing, i.e. evaluating the condition of the above parts/components;
- transferring the diagnosed components to the subsystems S_{RW} , S_{RB} and S_{RD} .

The main tasks of the component reuse subsystem S_{RW} are:

- to sort and store assemblies, sub-assemblies, mechanisms and components fit for re-use.
- sort and store scrap metals, non-ferrous scrap, worn rubber parts, tires, waste plastics, waste fabrics, worn wooden parts, paper bags and other;
- process the above components.

The task to be performed by the useless wastes subsystem S_{RD} is to store components before they go to the wastes storage subsystem within the environmental protection system.

Conclusions

Taking into account the proecological aspects of the functioning of the motor vehicle operation system, it may be stated that:

1. Environmental preservation should be the main objective while developing motor vehicle operation systems based on rational bases.
2. Motor vehicles equipped in on-board diagnostic systems may contribute to reducing the atmospheric exhaust emission.
3. The diagnosing subsystem, as an element of the operation system, enables elimination of unserviceable motor vehicles, thus helping to maintain the natural state of ecosystems.
4. Proper organization of the motor vehicle recycling subsystem, as an element of the environmental protection system, allows to limit environmental pollution.

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