PROACTIVE MAINTENANCE OF MOTOR VEHICLES

ПРОАКТИВНОЕ ОБСЛУЖИВАНИЕ АВТОТРАНСПОРТНЫХ СРЕДСТВ

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Abstract:
In this article the author describes particular maintenance systems used in the past, some of which are used also at present. The basic maintenance systems include maintenance after use, preventive maintenance with predetermined intervals, and conditioned-based preventive maintenance - predictive maintenance. The current trend in the field of vehicle maintenance tend to continous monitoring of their actual status. By the help of a vehicle monitoring in use, it is possible based on current operating parameters to determinate the technical condition of the vehicle parts. Ideally to prevent the failure or damage of groups of vehicle. Tracking of vehicles in use can be effected through the telemetry. Telemetry is a technology that allows remote measurement and reporting of information.
KEY WORDS: *PREVENTIVE MAINTENANCE, PROACTIVE MAINTENANCE, PREDICTIVE MAINTENANCE, TELEMAINTENANCE, ON-BOARD DIAGNOSTICS.*

1. Introduction

Quality and reliability control and the choice of optimal maintenance methods cannot be realised at present without properly functioning technical diagnostics. Thanks to the use of technical diagnostics, the maintenance itself has reached a new level which in a sense may be labelled as a completely new, generation different maintenance system.

Technical literature provides a number of definitions of "maintenance", more or less influenced by their authors or by the A vehicle is either in usable or unusable condition. Our aim is to maintain the vehicle in usable condition, which means to prevent its failures and limiting condition. This aim shall be achieved upon the lowest vehicle life cycle costs possible while keeping inherent reliability of the vehicle for the whole operating time. This is manifested in particular maintenance systems since the 1930's until the present, which is shown in Figure 1. In general, maintenance system approaches may be divided as follows:

force of a norm upon which they are based. For the purpose of this article, the following definition according to [1] is used: "Maintenance is a combination of all technical, administrative, and managerial activities during a life cycle of an item aimed at maintaining the item in condition, or returning it to condition, in which it can perform a required function."

2. Development of maintenance approaches

1. Corrective maintenance system.
2. Preventive maintenance system – schedule based.
3. Preventive maintenance system – condition based:
   a) Predictive maintenance system.
   b) Proactive maintenance system.

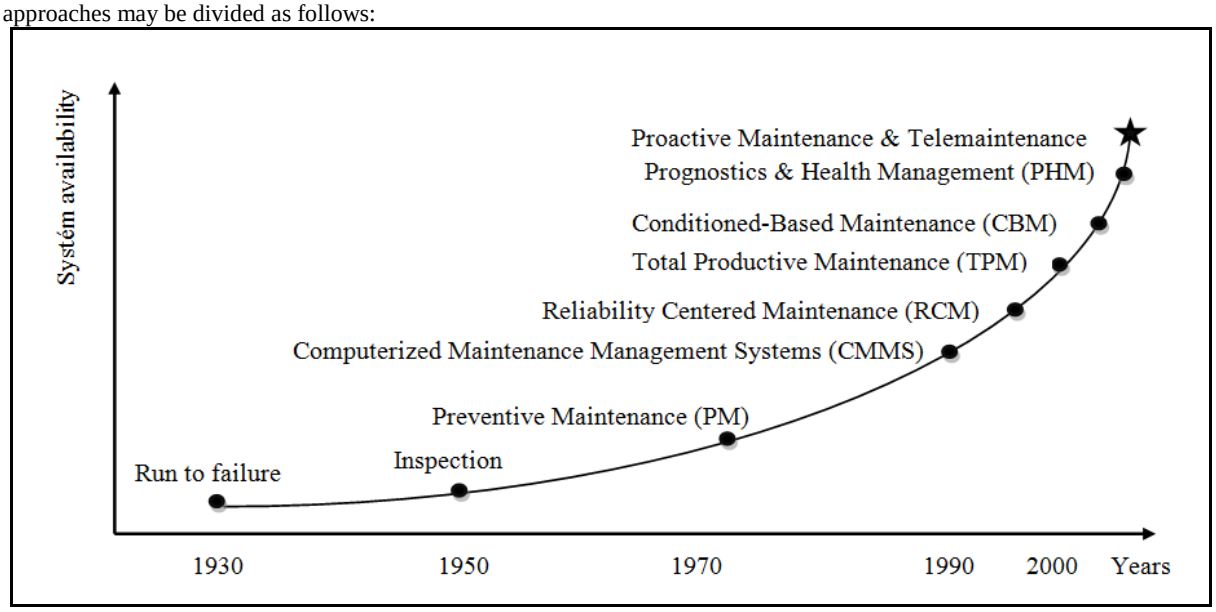

Fig. 1. Development of maintenance approaches since the 1930's [3]

2.1 Corrective maintenance system

This maintenance system represents the lowest level of the maintenance approach. It is maintenance performed after failure condition has been detected and aimed at bringing the item to condition in which it can perform required functions of the given equipment. In practice this means that the equipment is operated without supervision for its whole durability and maintenance is performed only when a failure occurs. In this case repair costs are high, including loss due to the vehicle being out of operation.

Corrective maintenance (1st generation maintenance) may be applied to simple and cheap machinery in which 100% backup and prompt repair or replacement may be provided. This type of maintenance is obviously suitable only in these cases:

- The broken part may not be repaired or is not worth repairing.
- The machinery is cheap compared to maintenance costs.
- The part replacement is very fast, technically feasible and economically acceptable.
- No other maintenance method is possible to be performed.

In later years, corrective maintenance started to be completed with so called ***Inspection***, the aim of which is to verify the compliance by measuring, monitoring, checking or comparing significant characteristics of the vehicle performed during the primary failure removal.

2.2 Preventive maintenance system with predetermined interval

This system is still frequently used since in principle it comes from the theory of reliability. Upon theoretical reliability and practical experience from a similar technique fixed time intervals are set for performing the "service maintenance", it is so called "schedule-based maintenance". Preventive maintenance is maintenance performed in predetermined intervals or according to specified criteria, and aimed at reducing the probability of failure or degradation of the item operation. [1].

An advantage of this system is the prevention of failure and thus reduction of corrective maintenance costs. However, preventive maintenance costs will increase. The aim is to keep the maintenance costs as low as possible. In practice the total maintenance costs are relatively high, but in the overwhelming majority of cases lower than for "corrective maintenance". Another advantage is even distribution of costs in time, and the fact that costs incurred by a vehicle dropout are lower and mostly planned in advance.

A fundamental drawback of scheduled maintenance is the fact that the period (maintenance interval) is often shortened due to the reduction of failure risks and the action is performed on a vehicle which does not exhibit wear signs. Therefore maintenance costs increase and actions performed reduce planned durability of the vehicle. It is true that every useless dismounting and mounting of a part or assembly, or disassembling and assembling the whole vehicle, changes distribution of clearances and brings further unknown static and dynamic loads to the run-in vehicle. This leads to its increased wear and fatigue damage occurrence.

This maintenance system was gradually developed and completed in order to achieve maintenance costs reduction and keep inherent reliability of the vehicle. Higher efficiency was achieved by introducing so called "***Computerized maintenance management system - CMMS***" which leads to significant improvement of the maintenance efficiency by making information on performing individual types of maintenance more available [2].

The schedule-based preventive maintenance system was further completed with so called "***Reliability centred maintenance – RCM***". This method is based on a systematic approach for the identification of purposeful and effective tasks of preventive maintenance which are performed in compliance with a specific set of procedures for determining intervals between the maintenance tasks. The aim is to improve overall safety, availability, and efficiency of the operation. It is also based on monitoring the total vehicle life cycle costs.

Further improvement of the schedule-based preventive maintenance system brings so called "***Total productive maintenance – TPM***". The performance of each organisation depends especially on work organisation, utilisation of basic equipment, and qualification level of its employees. To achieve maximal performance the organisation must utilize optimally the vehicle productivity. In terms of losses, the vehicle maintenance represents a significant area where productivity should be increased and resources for cost reduction sought. TPM utilizes abilities and skills of all employees with the aim to significantly reduce downtimes of vehicles and individual losses in their usage. On this account, organisations are strongly advised to use this progressive approach [3].

2.3 Preventive maintenance system – condition based

Technical condition based maintenance was gaining importance in past decades with the expansion of technical diagnostics. It is preventive maintenance comprising of monitoring performance or parameters and of consequent measures. Its main benefit resides in consistent removal of failures. Particular worn parts and parts or whole assemblies in the risk of failure are repaired or replaced optimally in advance. Thus failure occurrence is prevented. This technical condition-based maintenance system may be divided to:

a) Predictive maintenance
b) Proactive maintenance.

ad a) Predictive maintenance

This is condition-based maintenance performed upon a prediction derived from an analysis and evaluation of significant parameters of the item degradation. An action is performed on the item only when it is technically and organisationally justified sufficiently enough to maximally exhaust technical durability of the critical part, and at the same time unexpected accident was prevented. In other words, this is maintenance residing in a statement that only that is necessary to be repaired on the item and only then if it is indispensable. The maintenance itself is based on periodical evaluation of technical condition. Maintenance mechanisms applied to the vehicle allow yielding information on the change of technical condition of monitored parts. Such information is processed with the aim to estimate remaining durability, and thus to commence the process of a technical action (remedy). For monitoring signs of developing damages "Condition Monitoring", usage of specialised instruments is required, designed for collecting and evaluating information. These instruments utilize so called technical diagnosis. The equipment is to be monitored and evaluated constantly, or at least periodically.

Costs of the maintenance itself are several times lower than in the previous alternatives. The vehicle downtime for the time required for preventive maintenance is usually negligible in comparison with corrective maintenance. However, initial costs of purchasing the diagnostic systems are relatively high. Therefore it is necessary to consider whether these costs of purchasing the technical diagnostics instruments together with maintenance costs will/will not be higher than maintenance costs without using technical diagnostics [8].

ad b) Proactive maintenance

Proactive maintenance is considered another higher level of maintenance. It is completely based on the previous predictive maintenance which it further improves so that its basis is the utilization of more complex technical diagnostics. Basically it is the top current version of predictive maintenance based upon actual condition of the item operated. It is analysed in detail in the following chapter.

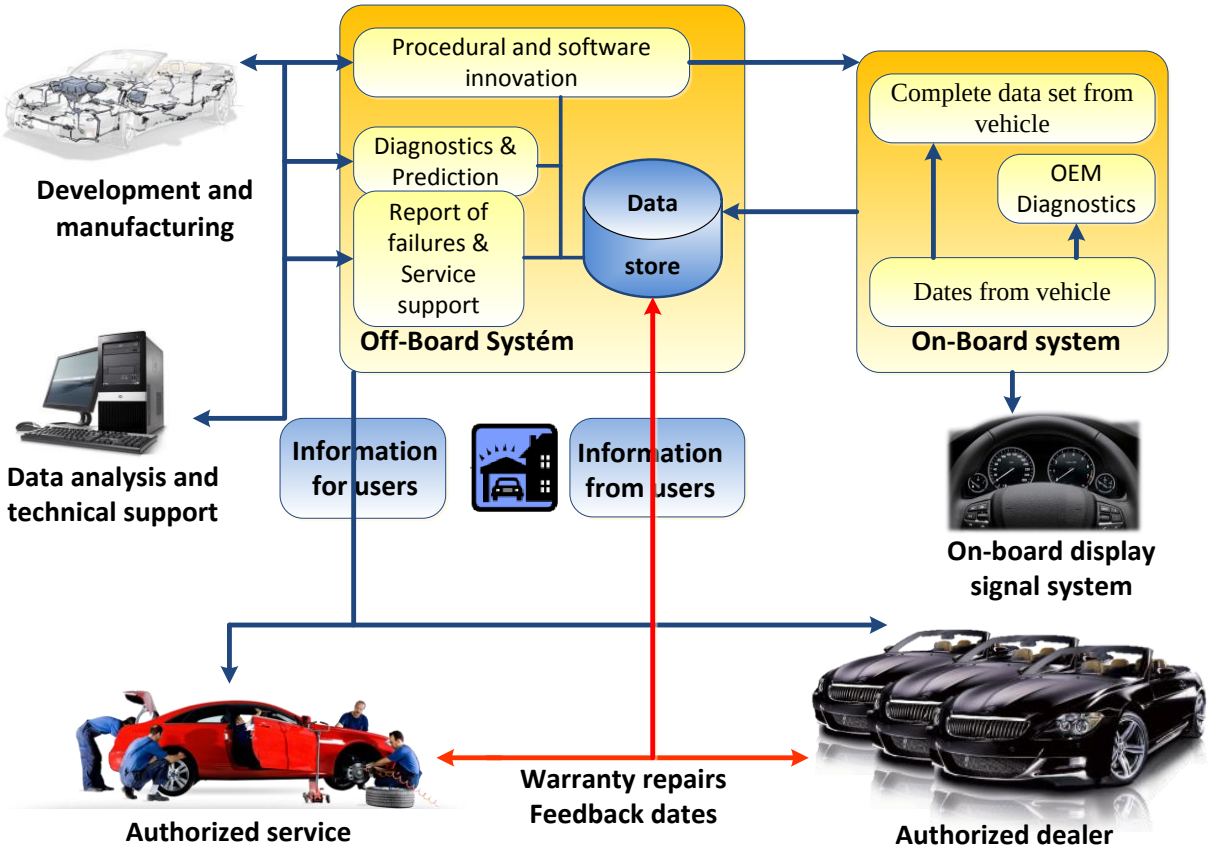

Fig. 2. Design of predictive maintenance

3. *Results and discussion - Proactive maintenance system*

One of the latest trends in maintenance systems is proactive maintenance completed with so called "telemaintenance". The proactivity is manifested also in the fact that new vehicles are designed with respect to an easy access to their integral diagnostics. Possible connection of diagnostic systems, location of sensors and measuring spots for monitoring vibrations, temperatures, lubricant sampling and detection of other selected parameters should be considered during the vehicle design.

Proactive maintenance arose from the predictive maintenance type as a reaction especially to long-term findings that a certain group of failures repeats periodically upon clear causes. Known causes include mainly the following:

- Incorrectly organised maintenance work.
- Incorrectly performed maintenance (technical operation in the vehicle).
- Unqualified operators and maintenance personnel [3].

The proactive maintenance type is aimed at keeping inherent reliability of the vehicle on an acceptable level. As a source of information technical diagnostics is utilized. The main objective of proactive maintenance is:

- Further reduction of maintenance and operational costs.
- Prevention of failure occurrence and thus extension of an interval to preventive maintenance, meaning extension of the vehicle durability.
- Statistic control of accidental and systematic influences affecting the vehicle operability [3].

Proactive approach means not only monitoring and evaluating the vehicle condition, but especially performing such actions that prevent or at least postpone damage occurrence.

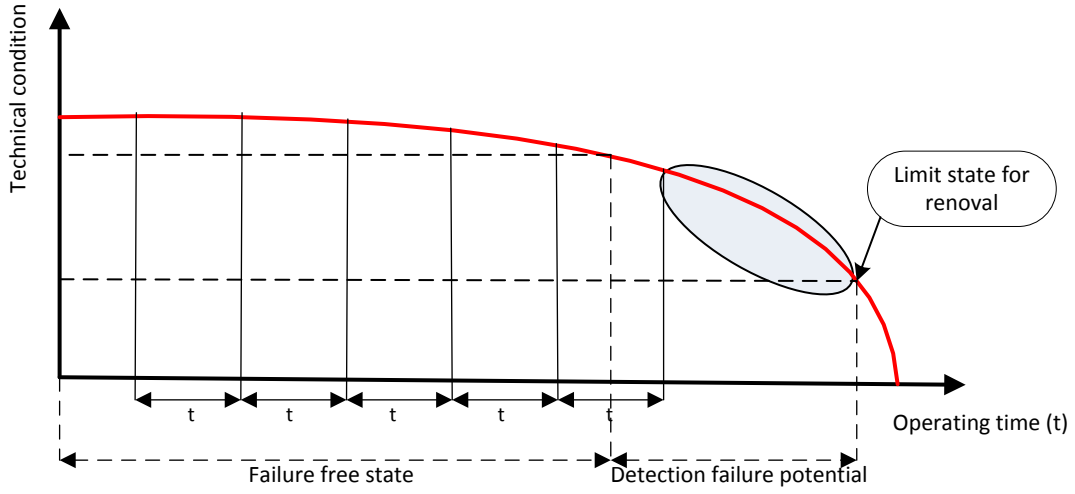

Fig. 3. Machine components technical condition of dependence on operating time

On-board diagnostics OBD is a label for diagnostic system installed in the vehicle system to ensure the control of exhaust emissions, which must be able to indicate failure and probable causes using the fault codes stored in the control unit memory. The aim is to ensure OBD standards throughout the life of your vehicle minimal amount of exhaust emissions [7].

The OBD II is characterized by monitoring these parameters to emissions:

a) monitoring the lambda sensors,
b) monitoring the fuel system and the air supply,
   - fuel injection pressure,
   - ignition advance,
   - intake air temperature,
   - intake air quantity,
   - absolute pressure in the intake pipe,
c) monitoring the effectiveness of the catalyst,
d) monitoring the exhaust gas recirculation,

Other parameters monitored:

e) standardized output operational data,
   - vehicle speed,
   - engine speed,
   - coolant temperature and oil etc.,
   - engine oil pressure,
f) monitoring of braking systems (ABS, ASR, ESP, etc.),
g) monitoring of safety systems - airbags and anti-theft,
h) monitoring of transmission (mostly automatic),
i) condition of brake pads,
j) condition of brake fluid,
k) condition of the spark plugs,
l) monitoring of active chassis - control wheels, suspension settings etc.,
m) condition of accumulator battery and wiring,
n) monitoring of engine oil quality.

The OBD system must be equipped with control lamp errors - MIL (Malfunction Indicator Light).

Detecting the state and quality of the engine oil is one of the newest ways using internal sensors. These are mounted directly on the engine. The measured data are transmitted using the CAN bus of the vehicle and then evaluated using the OBD II [9].

Sensors detect oil quality:

- amount of oil,
- temperature of oil,
- index TBN (Total Base Number) - measuring ability to neutralize acids - affects the oxidation and corrosion, oiliness and viscosity,
- dynamic viscosity of oil - η,
- specific density of oil - ρ,
- for diesel engines soot content in oil,
- water content in the oil,
- electrolytic conductivity - G, measures the concentration of salts and acids,
- permittivity – ε_r.

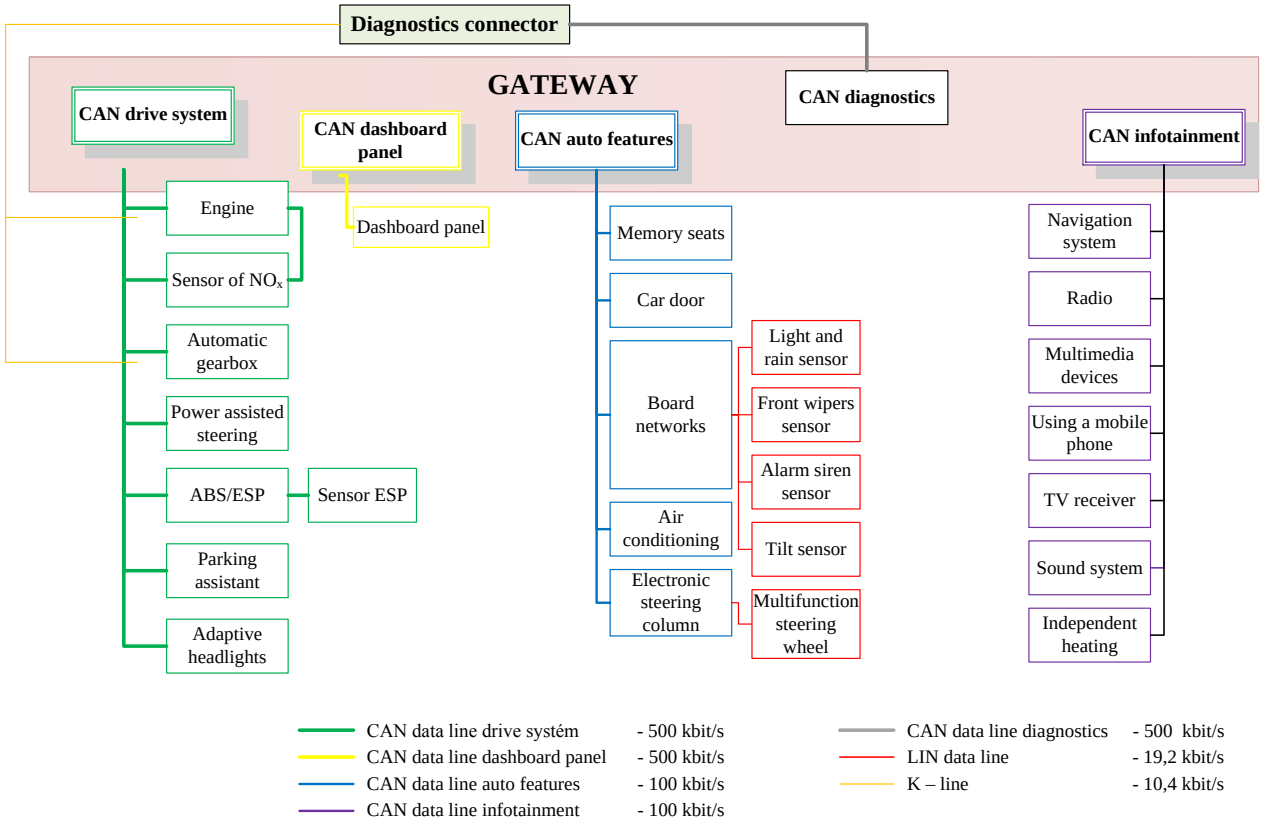

Fig. 4. Electric scheme for OBD vehicle

Predictive and proactive maintanance systems are based on information obtained from vehicle sensoric networks, which are inherently instaled in vehicle. Therefore emphasis is putted on instalation of sensors in vehicles subsystems and also on their connection in backbone network with the intention to obtain efficiency of whole electronical vehicle diagnostics. CAN, LIN and other buses are already used for these purposes. One of the biggest requirement on OBD (on board diagnostics) is the creation of Gateway with single output diagnostics connector (Fig. 4).

The latest trend in the maintenance area is so called "telemaintenance", which may be explained as remote-controlled maintenance employing the proactive maintenance principle. In some publications, the term "Remote Diagnostics & Maintenance (RD&M)" is used [5]. It is based on wireless transmission of technical data about the vehicle. The main field of its utilization is in companies specializing in long-distance transportation and also in military environment. This method enables on-line monitoring of parameters upon sensors integrated in the vehicle and wireless transmissin of the information to a remote computer. This is utilized especially for securing missions in a foreign territory.

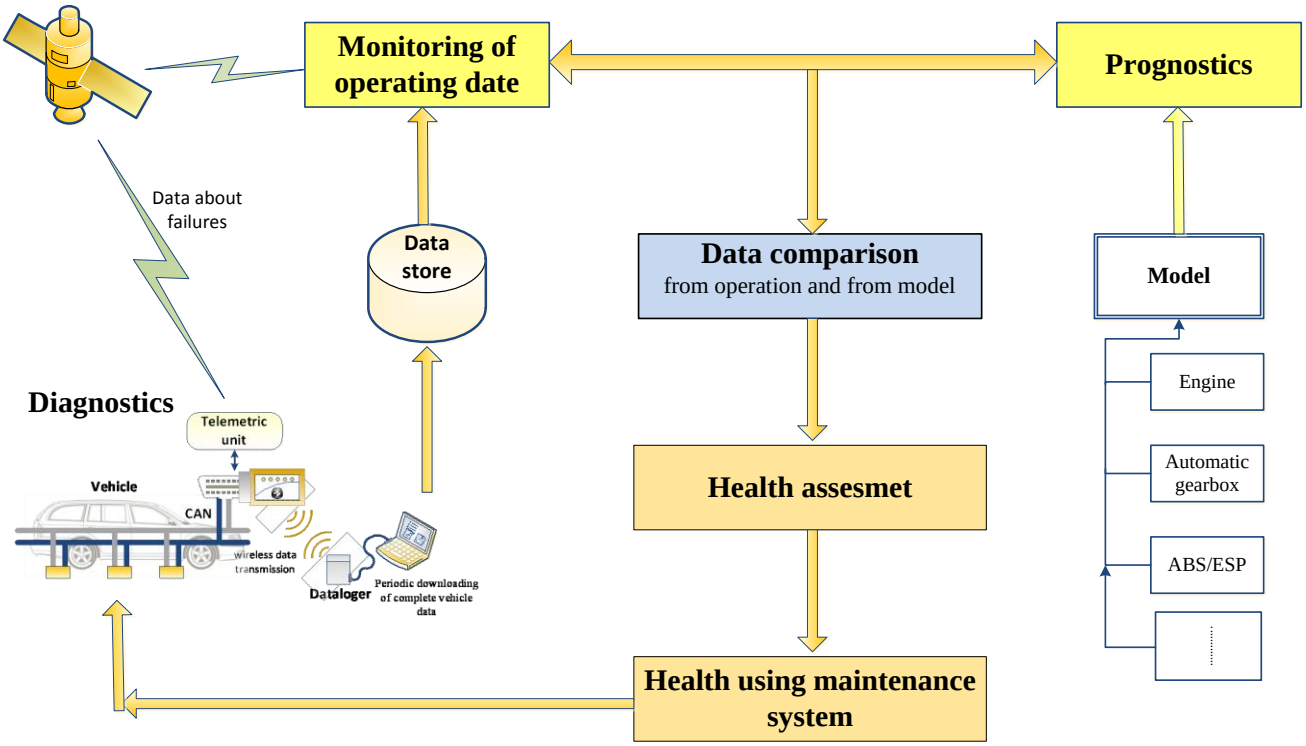

Fig. 5. Design of proactive maintenance with telemetry

Complete output data obtained from vehicle bus can not be transmited using wireless monitoring. This is caused mainly by limited capacity of wireless connection on long distances. Therefore it is recommended to transmit just selected important data, mainly failure reports. Another data obtained from vehicle bus should be recorded from vehicle datalogger into computer memory and subsequently used to create analysis and prediction modeling.

Telemaintenance may be divided to the four following levels:

1. Diagnosed vehicle with a driver.
2. Support logistics centre where a computer processing the diagnostic information is located.
3. Experts performing the maintenance on the vehicle.
4. Vehicle manufacturer who supplies a technical database including drawings and technological procedures for maintenance [3].

Proactive systems are characterised by complete OBD and also by subsequent vehicle data transmition. Transmition of data can be executed by loading complete datalist in periodic intervals or by on-line data transmition. One of the most modern way is the usage of long distance transmition of selected data. These systems are applied in big transport companies and also in army conditions. Except of these requirements there is also an effort to create individual prediction models of single machine parts. Possible proposal could be seen in figure 5. These models are based on monitored data obtained from vehicle buses. Data are taken during vehicle operation. Afterwards there is a possibility to compare obtained data with true values and define real TS (technical state) of vehicle subsystems subsequently. Apart from defining the real TS, we should be capable to predict time period to service control, TTL (total technical life of vehicle) part alternatively. This could cause reduction of maintanance costs, operation and costs caused by vehicle temporary shutdown. The costs for acquisition are higher contrarily. Decisive criterion should be total LCC (life cycle costs).

4. Conclusion

The purpose of this article is to introduce to the reader the development of particular maintenance approaches since the beginning of the 20th century to the present. It includes advantages and disadvantages of performing maintenance after use, preventive maintenance with predetermined interval, predictive maintenance and proactive maintenance. The final part brings a new approach to maintenance based on on-board diagnostics, which is on-line testing of diagnostic signals and their wireless transmission to the telemaintenance logistics centre.

The unified diagnostic systems for reasonable application of telemetry have to be introduced. It is also necessary to use unified CAN BUS. These issues should be already solved in acquisition phase. With regard to previous experiences, I would consider to unify all those components and systems into common control unit including single OBD connector for data transmission for subsequent analysis.

Using telemetry, which can be described as the wireless data transmission into logistic centres, with which is possible to analyse obtained data about technical state of vehicles in real time. The vehicle maintenance can be executed on the basis of comparison of obtained data and data recommended. These workshops should have possibility to contact crew of vehicle in order to give them advice about solution of the problem

Implementation of maintenance system based on telemetry enables cost reduction of proper realization of maintenance, on the other hand their purchase cause higher acquisition costs of vehicles and related portable wireless devices. Except the lower maintenance expenses, this access bring also the complete overview of general operation of all in this way equipped vehicles.

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