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# Applying a mathematical approach to improve the tire retreading process

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ABSTRACT

Problem of waste treatment is very important for environment and the share of tires in this scope is high. The aim of this paper is to analyse retreading as one very interesting way of tires' treatment. In practice, firms involved with commercial vehicles exploitation have to decide whether to retread used tires or not, depending on the number of retreadings of used tires and travelled distances after each retreading. An approach based on Bayesian networks is proposed as a tool for decision making support in tire retreading process. Analysis is performed on database of tires' exploitation from a company of public passenger transportation and the statistical results are used as inputs to the proposed model. The results obtained according to the proposed model provide a good basis when it comes to making a decision whether to retread or not a used tire.



## 1. Introduction

It has long been widely considered that road traffic, as well as the increasing concentration of world capital in automobile industry, has a negative impact on the environment. At the end of the last millennium, there was more than half a billion vehicles in the world (Dabic et al., 2012), and according to the forecasts, this number will increase to more than a billion in next few decades. At the moment, from the total number/mass of vehicles, 25% finish their working life on landfills (Suterland, 2000). The actual level of science, technical and technological development, indicates that the figure of one billion vehicles on world roads is outdated, meaning that there are significantly more of them.

Vehicle itself is a complex product, made of different materials, a large number of components and parts. One of these components with significant economical, as well as ecological influence during and after the exploitation on vehicles are tires. When the tires reach the end of their working life, they are recycled (obtaining raw materials and other components for certain manufacturing processes) or burned (obtaining energy). During the exploitation, a tire with worn tread can be processed in a certain way to allow its reuse. In the past few decades, the emphasis has been on its further use. If during the exploitation, a tire suffers the damages which can be fixed, it is planned for retreading.

In order to be retreaded a tire must undergo a control realized in two basic steps before being accepted for further treatment. The first step consists of a visual control of tire treads or other damages. The second step consists of an X-ray of the interior of the tire. After retreading, within a final control, each retreaded tire is once again subject of a detailed visual check, before being returned in service.

Two technologies of retreading – setting up a new tread on a prepared tire – are being applied, cold cure and hot cure retreading. Cold cure retreading is the process used for tires of commercial vehicles. This process can be repeated several times, since it does not influence on the structure of a tire. It is done by applying a new tread on a tire in the form of ring (Fig. 1a) or strip (Fig. 1b), and then such a tire is placed in special chambers where the pasting procedure of a new tread is done. Hot cure retreading is the process applied on tires for passenger vehicles. It is done only once, by applying a new tread to the processed surfaces of a used tire, after which the tire is placed in a press and heated to a temperature of 140 °C.

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**Fig. 1.** Types of treads.

In practice, if the tire treads are worn out, the tire user shall decide either to retread the tire or to discard it. This procedure is shown in Fig. 2.

The decision to retread, if the basic structure of the tire is not damaged, depends also on the "history" of the tire. It includes the data on number of retreadings performed before the decision to retread or not was made and on the travelled distance of the new tire and after each of the retreadings. These values are incidental. Therefore, the decision on retreading requires *an appropriate mathematical model* to be applied.

The model for solving this kind of problem uses conditional probability for, per example, the case: "...tire retreading process is done twice; as new tire, the distance passed was $x_0$ km, after the first retreading process $x_1$ km, and after the second $x_2$ km; what is mathematic expectation of the travelled distance km after the third retreading...". This problem can be solved by simulation, where a certain degree of stochastic in analyzed process must be involved. This method contains a risk that the obtained results could be hardly used in practice. Bayesian approach belongs to a class of analytical modelling tools which have a number of benefits respect to simulation models. They provide a perfectly clear relationship between inputs and outputs. On the other hand, simulation results need to be statistically interpreted. Furthermore, there are several issues that any simulation needs to cope with: data independence, random number generation, representative outputs, removing transient periods, etc.

The problem in this paper is analytically tractable so it is preferred to be optimized by analytical methods. Also, the performance measure is explicitly known (Fu, 1994). Therefore, this paper presents an attempt to solve the problem by the Bayesian networks.

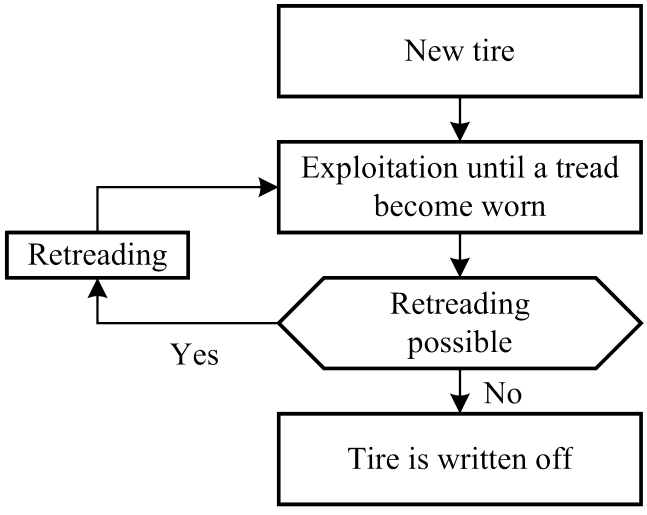


**Fig. 2.** Lifetime of a tire.

The paper is organized in five sections including Section 1 for introducing the problem. Section 2 gives a brief summary of literature related to tires reusing process Section 3 gives a description of the considered problem. Conditions and needs for solving this problem are also presented, as well as the previous research results used as a background. Besides that, it presents the basic structure of the model proposed for the solution of the above mentioned problem. Section 4 consists of four parts. The first part gives a short general description of the BN approach. The second part presents a new BN approach to be applied within the described problem solving methodology related to the decision making regarding the retreading of tires. The third part gives a detailed presentation of the step number 5 of the proposed model which suggests how to solve the problem and make a decision whether to retread a tire or buy a new one. The fourth part of this chapter includes a result discussion. Finally, in Section 5, we conclude this paper with some perspectives on further developments.

## 2. Literature review

This section has two parts. In the first subsection, the review of literature related to the *research of ELV* (E*nd of Life Vehicle*) and researches for used tires and their treatment are presented. The second subsection gives a review of various application fields of Bayesian Belief Networks, as well as the appliance of this and/or other approaches for solving the problem of tire retreading process.

Literature related to research in the field of *treatment of ELVs and/or their parts*, as well as the tires themselves is becoming more actual but that is still not enough to make certain decisions regarding the manufacture and exploitation of vehicles. There are two classes of problems which are directly connected to the treatment of ELVs and their components. The first class of problems is related to all the activities performed on vehicles which have finished their working life and cannot be reused (or at least some of their parts, among which are the tires). This class concerns problems related to the influence of used vehicles on the environment, issues concerning the industry of disassembling of used vehicles, including those concerning technical-technological treatment of almost each part of a disassembled vehicle, as well as the problems related to the further exploitation of such parts. This research gives a concise description of papers suggesting models and/or solutions for this problem, which has become more and more actual. The conclusion is that (according the analysis of research in similar fields) the accent is on ecological and economic effects.

Froelich et al. (2007) points out the importance of choosing the highest possible quality materials for manufacture of different parts of vehicles, which is also important from the aspect of ELV treatment. When speaking about retreading tires, this could be the basis for making their return into re-usage simpler. The so-called Mexican model by Cruz-Rivera and Ertel (2009) deals with the problem of collecting used parts of ELV and increasing the percentage of