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Evaluation of vehicle fleet maintenance management indicators by application of DEMATEL and ANP

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ABSTRACT

The paper refers to the importance of maintenance management to increase the vehicle fleet energy efficiency. The fleet maintenance management influences as the vehicle maintenance process itself as well as the primary transport process but also their environment. In order to increase fleet energy efficiency by means of a more efficient maintenance management, it is indispensable to observe maintenance process, transport process and the environment. Since the implementation effects of such measures can be measured by different indicators, this paper analyses the influence of indicators in all three mentioned areas on management decision-making. In this sense, appropriate indicators have been defined and subsequently used in fleet maintenance management. To determine levels and intensities of interdependence as well as relative weight of selected indicators two methods have been combined: Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP). A model was proposed with indicators' interdependence whose relative weights were calculated. The proposed model has been implemented in several companies with road vehicle fleets. Collected results show the perceived evaluation by company managers in view of maintenance management process influence onto their fleet energy efficiency. Besides, by proposed model implementation we have obtained equally managers' evaluation upon effectiveness and efficiency of the maintenance management within studied companies.

1. Introduction

Companies with own road vehicle fleets attain profit by performing transport services. The amount of profit is significantly influenced among other things, by the costs incurred by transport and vehicle maintenance processes. Considered companies seek to accomplish all the planned transport tasks while minimising transport and maintenance costs.

More efficient fleet maintenance management could affect rational transport process realisation, i.e. reduction in incurred costs. Efficient maintenance management facilitates vehicles of best suited construction–operation (CO) groups in a state "ready for operation" for transport tasks realisation during the required time periods. This certainly influences the increase in energy efficiency of the fleet and transport and maintenance costs reduction, meanwhile company's core performance is not jeopardised i.e. all planned transport tasks are to be accomplished.

In order to attain an efficient maintenance management, it is necessary to coordinate the primary (core) process with maintenance, which has been researched mostly in the field of industrial production (Ashayeri, Teelen, & Selen, 1996; Nikolopoulos, Metaxiotis, Lekatis, & Assimakopoulos, 2003; Waeyenbergh & Pintelon, 2002). In these papers different models and systems have been proposed, all with the objective of increasing efficiency and productivity of industrial machines.

However, vehicle operation and maintenance processes differ from those related to industrial machines. The fact that vehicles are mobile assets, further affected by a large number of external environmental factors imposes the need for a different approach in their maintenance management, compared to other static machines.

In this sense, for an efficient fleet maintenance management it is necessary to observe jointly: (1) the transport process as a primary (core) process that brings profit to the company; (2) the vehicle maintenance, as logistical support to the core transport process, which by means of maintenance interventions transforms vehicle condition from the state of "unready for operation" to the state "ready for operation"; (3) the environment, associated to safety and environmental protection from the maintenance impact, which is monitored via technical inspections. For an integrated approach to maintenance management an important concept is the "Process based maintenance" (Zhu, Gelders, & Pintelon, 2002) and (Zhu & Pintelon, 2001). This concept, among other things, involves the definition of necessary indicators which allow measuring the implementation effects of specific measures during maintenance

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management, monitoring the value of indicators in relation to the adopted thresholds and management decision making in the event of unauthorized indicator values deviation from threshold values.

However, in case of several indicators for measuring the implemented measures effects and for management decision making, it is necessary to determine which of the indicators is more significant for achieving a defined objective. Moreover, large number of observed indicators have interdependent impact. Implementing certain measures within management, could improve an indicator value, but impact differently a number of other indicators' values. The considered issue represents a classic example of Multiple Criteria Decision Making (MCDM).

Therefore, the problem under consideration in this paper is to determine the level of interdependences of indicators and determine their significance and their relative weight in the maintenance management causing an increase in the fleet energy efficiency, provided that planned transport tasks are realised. As a solution, a model with ranked indicators upon their impact onto the fleet energy efficiency is obtained. The resulting model should point out to managers which indicators should be given more attention in measuring the implemented measures effects and in maintenance management decision-making. The proposed model can be used to evaluate the managers' perception of the importance of maintenance management to increase the fleet energy efficiency. Also, managers can be evaluated by means of the model upon their effectiveness and efficiency in the fleet maintenance management.

To calculate the level of interdependences and determine the level of significance of indicators in relation to the accomplishment of a defined objective, a combination of two methods DEMATEL and ANP will be used as tools for Multiple Criteria Decision Making (MCDM).

DEMATEL method has been developed by "Science and Human Affairs Program of the Battelle Memorial Institute of Geneva" between 1972 and 1976 and used for research and solving several groups of complicated and interdependent problems (Fontela & Gabus, 1974) and (Fontela & Gabus, 1976). This method has been applied in various fields most recently (Li & Tzeng, 2009; Lin, Chen, & Tzeng, 2009; Lin, Yang, Kang, & Yu, 2011; Tzeng, Chiang, & Li, 2007). As a result, total direct and indirect influences of each factor (indicator) are obtained as each factor's (indicator) influence given to other factors, but as well influence received from other factors. This interdependence is visually depicted by a Network Relation Map (NRM).

ANP method represents a more developed version of Analytic Hierarchy Process (AHP) method. Proposed by Saaty in (Saaty, 1996) and (Saaty & Vargas, 1998), in order to avoid hierarchical constraints that exist in the AHP method (Saaty, 1980). It is a relatively new MCDM method used to calculate the interdependences of factors and determine their relative weights. This method has been applied in many areas (Chung, Lee, & Pearn, 2005).

However, treatment of factors' interdependences in ANP method is not objectively addressed in relation to the actual system. This lack is covered by using the DEMATEL method, where interdependences between groups (sets) of factors are determined more objectively and based on the NRM form a structure of the observed system is created, which is subsequently used to calculate the relative weight of factors by using the ANP method (Yang et al., 2008). Combined use of these two methods has been recently implemented for solving MCDM problems in different fields (Yang & Tzeng, 2011; Wu, 2008; Lin, Hsieh, & Tzeng, 2010). In the paper (Lee, Huang, Chang, & Cheng, 2011), the authors go a step further and propose a new hybrid method, which is a developed version of the method compared to the paper by (Ou Yang et al., 2008). According to (Lee et al., 2011), DEMATEL method is used not only as a more objective view of interdependences of groups (sets) of factors, but its total-influence matrix – T is normalised and incorporated into an unweighted supermatrix by the AHP method.

A combination of DEMATEL and ANP methods has been used in this research with same approach as in the paper by (Lee et al., 2011). By literature review and based on authors' personal experience, appropriate indicators were defined in the fleet maintenance management. A model which contains three interdependent groups or fields: transport and maintenance processes and their environment has been developed. In each field there are interdependent factors (indicators). Based on a conducted research of perceptions of field-related professors and other relevant experts from the Faculty of Transport and Traffic engineering in Belgrade, the interdependences among indicators, as well as interdependences between observed fields have been established. Afterwards, the relative weights of indicators and of each observed field are calculated within the developed model using the above mentioned methods. By surveys of managers in several transport companies and by the proposed model implementation, an evaluation of perception on maintenance management impact on the enhancement of the fleet energy efficiency was made, as well as evaluation of managers' efficiency in the maintenance management within each studied company.

In the following Section 2, the concept of fleet maintenance management has been presented in detail, together with a description of selected indicators. Section 3 describes the DEMATEL and ANP methods. Based on survey results, relative weights of indicators and observed fields were obtained in the developed model. In the Section 4 the results of proposed model implementation in several companies with road fleets were addressed. In Section 5 the results were thoroughly analysed, while in the last section the main conclusions and future research topics were drawn up.

2. Fleet maintenance management

2.1. Interdependence of transport and maintenance processes and their environment

Studied transport companies most often own heterogeneous fleets composed of different construction–operation (CO) vehicle groups, especially from the point of view of their available cargo capacity. The set of all planned transport tasks that vehicles have to accomplish in certain time period is defined by the Operation Plan (OP) (Milosavljević, Teodorović, Papić, & Pavković, 1996) and (Momčilović, Papić, & Vujanović, 2007). In this sense, it can be assumed that fleets in observed transport companies operate according to the predefined OP.

During transport task realisation, i.e. during the transport process, vehicles are undergoing more or less important deterioration of their technical condition (Fig. 1). As a consequence of such deterioration, vehicles are initiating maintenance requests. During realisation of maintenance interventions vehicles are in a state "unready for operation" and such vehicles therefore will not be available for transport tasks realisation according to OP requirements. The moments and durations of those periods depend mainly on fleet maintenance management effectiveness and efficiency. After completion of required maintenance interventions, vehicles turn into the state "ready for operation" and become available for further transport tasks realisation.

In this sense, vehicle maintenance process represents a logistic support for the transport process, which on the other hand should provide for the transport service in order to satisfy client requests. The objective of vehicle maintenance process is to allow the accomplishment of Transport Company's objective through ensuring the required number of vehicles in the state "ready for operation" in the exact moment when and the entire period during