NEW COMPLEX METHODOLOGY OF CHOOSING THE OPTIMAL RAILWAY TRACTION VEHICLES

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Summary: Today industry of railway traction vehicles can offer a lot of different vehicles and even that many variant of the same vehicle. Making the choice and purchasing one of them often isn't easy and depends from the level that could be done. This problem is particularly up-to-date for countries that are not economically strong and have not highly-developed manufacturing of railway traction vehicles. Bearing in mind this fact it has been very important to define universal, exact methodology for choosing the optimal railway traction vehicles.

Choosing the optimal railway traction vehicles is based on the group criteria that are defined as: the space and surrounding on which this vehicles will be operate with turn to ecology, maximum traction vehicle movement speed, the technical parameters of railway network, the use of technology of reducing the riding time, the traffic operation in respect of interoperability, the economical aspect for purchasing of vehicles and the period of introducing traction vehicle in the traffic.

Developed methodology is based on systematic approach by using the computer. It is divided in three chronological mutually connected parts: defining the basic criteria, selection of adequate traction vehicles from date basis of available traction vehicles and their multicriteria estimation-ranking. Every part is solved by application of particular tool-method: knowledge base, data base and multicriteria decision making. On this way defined procedure is united by package of programs.

1. INTRODUCTION

Industry of railway vehicles overcame new materials and new technologies in manufacturing of vehicles and than feasibility of vehicles new construction is no longer problem. Very often from this industry is heard message: "Tell us what do you need, we can produce it". According to that today, in modern world, the biggest problem is to define what type of railway traction vehicle is needed, especially if we take into account many specific requirements and parameters (criteria), such as economical, technical, technological requirements, environmental, traction parameters etc. Which of them are necessary which are of a primary or secondary importance? How should we combine them?

Depending on whether there is a need for purchase, modification or reconstruction and modification of traction vehicles, different amounts of financial funds are required, so that it is not all the same which type and what sort of traction vehicles are acquired, or what type of changes are made on them. The acquisition of traction vehicles represents an important financial venture for railway system. Today trains more and more frequently operate on a network of railway lines with several power supply systems, with different infrastructure characteristics,
namely the traffic is carried by various tractive vehicles owned by different railway administrations. In order to overcome such situation and to eliminate borders among railway administrations it is necessary for railway administrations to harmonize their fleets. Owing to a growing development of railway rolling stock production industry the rolling stock fleets of different administrations incorporate various types of vehicles, both with respect to their performance and maintenance, so that the operation and maintenance of traction vehicles have become more and more complex and expensive.

Clearly, experts from one field couldn’t harmonize and solve this problem. Every fields, even experts from one field, have not the same requirements and priorities and than it is necessary to provide exact, multidisciplinary solving of this problem.

2. APPROACH

In different periods of historical development of railway, the relevant requirements were different, which defined the required traction vehicle. At the very beginning the following was essential: the amount of installed power for steam locomotives and the maximum speed that could be achieved. Later on, additional requirements with respect to technical performances arose, such as a permitted load per axle, load per longitudinal meter, minimum curve radius, maximum upgrade to be surmounted by hauling a train of a specified weight etc. Today relevant requirements are defined in relation to a number of technical characteristics of the line in question, electrification system, technological parameters in traffic etc.

Obviously these requirements and their number are not strictly defined. They depend on the time period under consideration, conditions to be taken into account, defined space in which they are considered. Looking through the prism of decision-making, they differ from the level at which the decision-making takes place – strategic, tactical or operational, the approach and aspect of problem reviewing – structural or not structural, and the process of decision-making (single- or multi-dimensional).

The number of elements and requirements under consideration, in mutual inter-action can be found to be growing and in real situations their values often cannot be accurately determined and recognized. For such problems, therefore, semi-structured approaches and techniques for their solution are developed.

The basic elements of the procedure of choosing the railway traction vehicle and their relation to semi-structured approach can be represented through parts: definition of the needed traction vehicle in accordance with meeting the defined (relevant) requirements, selection of adequate traction vehicles from a group of possible vehicles, the choice of essential vehicle characteristics and their grouping up, the method of decision-making and choice of a traction vehicle in accordance with defined sets of criteria (Figure 1.).
3. RELEVANT REQUIREMENTS

In order to be able to properly classify the relevant requirements they must be specified and selected. Before the choice and classification of requirements, the vehicle kind and type has to be specified, as well as which relevant requirements it must meet.

Not all relevant requirements are equally important, nor have they the same impact on the choice of needed traction vehicles, and hence they are divided into two groups: primary and secondary. The primary requirements are those determining closer the space and surrounding in which the traction vehicles is to operate and the speed of its movement. The term `space and surrounding` in which the traction vehicle is to operate means the area covering: the network of railway lines of one, particular geographical area, a particular network of railway lines or a network of lines as an integral part of a corridor. This classification is based on magnitude and on the area on which the network of railway lines spreads.

Maximum traction vehicle movement speed. Not only the technical performance of traction vehicle, but also the required characteristics of infrastructure, the system of traction vehicle movement control, fixed installations etc. depend on this requirement. Also, after the introduction of high-speed traffic, a need arose to define traction vehicles for high speeds, that is, the division of vehicles into traction vehicles for high speeds and traction vehicles for `classical’ speeds.

The secondary requirements for the choice of needed traction vehicle comprise: technical requirements, which include the technical parameters of railway network (railway line, track, stations, signalling and telecommunication installations and information systems, power supply
system, overhead contact line, etc.), technological requirements comprising the traffic operations in respect of interoperability, the use of technology of reducing the riding time, time requirements, including the period of introducing traction vehicles in traffic, economic requirements including the amount of financial resources available.

All the requirements have their values and they are defined in three possible magnitudes to be able to be classified and used in choice of the needed traction vehicle.

4. METHODOLOGY

On the basis of the required vehicle as defined from the database prepared beforehand containing all possible vehicles, with all essential technical-technological characteristics, the selection of adequate traction vehicles is made and they then represent options that are further evaluated and ranked (Figure 2.).

Figure 2. Structural diagram of the methodology
In evaluation of the selected vehicles the essential characteristics of vehicles should be first selected and grouped up by criterion. At the strategic decision-making level from the aspect of supplier of services, the following groups of criteria are important: operational, technical, economic, environmental and the manufacturers’ references. The grouping up of characteristics is rather ‘global’, which means that there are fewer groups because at the strategic level of decision-making the problem of traction vehicle choice is considered more globally.

The elements of individual groups of characteristics are related to:

- **operational**
  - method of organization of operations,
  - reliability expressed through the number of kilometres passed till the first failure,
  - area where the traction vehicle operates,
  - techniques applied to reduce the travelling time;
- **technical**
  - vehicle capacity,
  - weight,
  - maximum traction power,
  - permitted axle load,
  - maximum speed,
  - continuous power of traction driving motors,
  - number of power supply systems;
- **economic**
  - vehicle price,
  - procurement costs,
  - maintenance costs;
- **environmental**
  - noise and vibration levels,
  - atmospheric air pollution,
  - energy utilization,
  - soil pollution and wastage waters coming from the process of operation and maintenance of traction vehicles;
- **the manufacturers’ references**
  - guarantees and method of payment,
  - number of vehicles manufactured,
  - ability of complying with the time schedule,
  - possibility for leasing.

To be able to determine the impact and importance of essential characteristics and their groups on the choice of vehicle, they are allocated the values of relative weight of criteria that can be made by the application of mathematical methods or on the basis of subjective evaluation by expert.

Furthermore, to establish relations between characteristics and alternatives when the choice of traction vehicle is to be made, the process of decision-making is to be defined. Due to the nature of the problem, the solution for defining the process of decision-making is a multiple-criterion decision-making and that a combination of several methods, namely the methods for individual and group decision-making.

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estimation - ranking. Every part is solved by application of particular tool-method: knowledge base, date base and multicriteria decision making. On this way defined procedure is united by package of programs.

For the knowledge-base it was necessary to form production rules (relations between individual requirements). To form the rules the selected relevant requirements and combinations of their values are taken into account. This part comprises the total of 243 theoretically possible variants of the rule. A specified software product from the class of tools for developing experts systems (shell) known as VP-Expert was used. This knowledge-base is so conceived and solved by programming that it can be continuously supplemented.

The database on traction vehicles contains information on characteristics of 305 traction vehicles. In creating the program this meant that for work with such database an adequate software program packet should be applied and it was decided to take Microsoft ACCESS.

After definition of traction vehicle and choice of the adequate traction vehicle (alternative) the evaluation of the selected criteria and alternatives, variants of the solution and choice of the traction vehicle takes place. For the application of multi-criteres decision-making, methods TOPSIS and AHP are used which are solved through separate programs. For the application of AHP method a ready-made special software packet Expert Choice is used, whereas for TOPSIS a program in the program language CLIPPER is made.

5. EXAMPLE - YUGOSLAV CASE

Until the 90’s the Yugoslav Railways in the field of railway vehicles followed up the trends of modern railways to a considerable extent. Unfortunately, the war and other happenings in the area of former FRY have for recent 10 years resulted in the impossiblity of acquiring the new generations vehicles. This means that by normalization of situation in the area of today’s Yugoslavia the problem of decision-making and choice of new vehicles will be extremely actual.

The application of the defined methodology to the choice of high-speed vehicles in Yugoslavia has shown that for the network of railway lines through Yugoslavia modified or new electric multiple units are required. By comparing this basis with requirements arising from the data on the required traction vehicle, four adequate vehicles have been selected, namely: the French TGV Atlantique, the Japaneze E3, the Italian ETR 500 and the Spanish AVE (Figure 3).
After allocation of preferences to criteria by experts 16 variants of the solutions have been defined by the application of programs TOPSIS and AHP.

By the analysis of obtained solutions by the application of TOPSIS program, depending on differently assessed weights of the criteria, shows that the ranking of trains in relation to the assessment of criteria weights, by the application of mathematical methods, according to the ranking of trains, taking into account also the subjective evaluations, the advantages of criteria, in 60% matches with the first best train, in 66% in the second best, in 53% the third best and in 58% of cases the train at the bottom of the ranking list.

Before the application of AHP method, as opposed to TOPSIS the decision-maker had to group up the criteria, namely to define the hierarchical structure of selection of traction vehicle. In most solutions the order was the same. However, it has shown that: the growth of importance of operational criteria by 105% mostly affects the order between trains that have been ranked at the bottom. The growth of criteria importance of the manufacturers references by about 282% affects the sequence of trains at the top of the priority list. By reducing the importance of environmental criteria by about 71% the priority among trains at the top and bottom of the priority list changes.
Figure 4. One of the variants of solutions obtained by the application of TOPSIS method

Figure 5. One of the variants of solutions obtained by the application of Expert Choice.
CONCLUSION

On the basis of the information set out in this paper, it is obvious that by the application of modern tools, methods and methodologies, it is possible to make a selection of traction vehicles in an exact way including a large number of criteria and requirements.

The methodology developed is one of the possible approaches to solving this type of problem.

The procedure defined is tested on an example of choice of high-speed vehicle. It is assumed that the developed methodology can be applied not only in the choice of high-speed vehicles, but also for other traction vehicles.

Obviously, the methodology as defined helps the decision-maker to take into account all essential characteristics in a systematic way, considering a number of vehicle types at the same time.

The test results indicate a sensitivity of the final choice to the values of preferences allocated to individual criteria. This is important because, as mentioned at the outset, as the time passes, the importance of requirements and characteristics changes.

Due to all this, the methodology and the procedure can be used as a suggestion and support for decision making. But the final decision is nevertheless on the decision-maker.

LITERATURE


Keywords: railway traction vehicles, definition of needed vehicles, definition of basic group of criteria, methodology, choice