TOMISLAV JOSIP MLINARIĆ, Ph.D.
E-mail: mlinaric@fpz.hr
MLADEN NIKŠIĆ, M.Sc.
E-mail: mladen.niksic@fpz.hr
University of Zagreb,
Faculty of Transport and Traffic Sciences
Vukelićeva 4, HR-10000 Zagreb, Republic of Croatia
MILAN BRKIĆ, B.Eng.
E-mail: milan.brkic@hznet.hr
HŽ Passenger Transport
Antuna Mihanovića 12, HR-10000 Zagreb,
Republic of Croatia

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IMPLEMENTATION OF FLEET MANAGEMENT IN TRAIN TRACTION

ABSTRACT:

The implementation of fleet management in the train traction activity is a must in the conditions of market operation of the railway sector, since good management of traction units has not alternative. The crucial issue of implementing such sophisticated tools is in real environment, and therefore SWOT analysis of the most important technological indicators has been carried out, in order to determine the most efficient method of its implementation. The defined technological indicators and the respective criteria have been used to evaluate the possible implementation of the total fleet management system in the HŽ Vuča vlakova (HŽ – Train Traction) company. The pilot project carried out in the activities of the HŽ – Train Traction has resulted in great savings at the annual level in fuel consumption, creating also the preconditions for the savings in fleet maintenance and work force recruitment. Based on the results of the pilot project the methodology for efficient implementation of fleet management was defined. The defined methodology was tested in real conditions and can be implemented at any company which provides services of train traction or manoeuvring of locomotives.

KEY WORDS

liberalization, train traction, technological criteria, total-fleet management, SWOT analysis

1. INTRODUCTION

The *fleet management* system is more implemented in road traffic than in railways. However, liberalization of railway transport market and the necessary restructuring of the railways system requires its introduction precisely in the train traction activity. Therefore, the subject of this paper is to present the results of research carried out in the HŽ Train Traction. The objective of the research was to raise the level of efficiency of traction at HŽ, in order to allow adequate usage of the tools to realize this objective. The main problem observed, and the solution of which has been proposed, is the introduction and implementation of the fleet management system as efficiently as possible into a real environment, characteristic for individual activity of train traction, as performed at HŽ. Consequently, the paper presents the methodology that should be applied in every concrete environment so that the fleet management implementation would give very soon good results. Therefore, it was tested at HŽ which has justified its systemic application. The methodology is based on determining the key technical and technological parameters at Train Traction for its efficient realization. Without proper evaluation of the determined parameters the use of the fleet management system can be in the beginning focused on the wrong priorities. Therefore, the proposed methodology determines the hierarchy of the priorities to which the introduction of fleet management should be primarily oriented in order to maximize the results in the real environment. In order to verify such approach the proposed methodology was implemented in the system of HŽ recognizing all its specific characteristics. This fact shows that this would not hold in case of other railway administrations, which makes the methodology itself universal.

In railway transport system the Train Traction represents a unique technological unit of extreme significance for regularity and quality of the transport service. Train Traction represents a significant expenditure item in the price of transport due to continuous rise in the fuel prices, high life cycle costs (LCC) of the tractive units and expensive, and at the same time inefficient labour (operative staff). The tendency towards optimization of Train Traction is understandable, which means LCC reduction, rationalization of fuel consumption and maximal usage of labour in the given legal frames. Such objectives cannot be realized without a good system of managing the fleet of tractive units and accompanying human resources. The specific circumstances in which individual train traction service provider is working need to be taken into consideration (condition and structure of the fleet, condition of infrastructure, organizational structure, valid regulations, etc.).

Besides, the definitive orientation of the EU member countries for liberalized approach to railway infrastructure needs to be taken into consideration. The consequence is that the railway network lines of these countries are available, under certain conditions, not only to national state railway companies, but rather to all other railway carriers, both national and foreign. In the organizational structure of HŽ which had existed until 29 December 2006, the Train Traction had operated as part of a special operating area of the railway transport ŽP (Figure 1). Such organizational structure of HŽ had resulted in numerous problems:

- lack of harmonization between actual needs for rolling capacities and their availability;
- lack of harmonization between investing into the fleet with real forecasts regarding volume structure of traffic flows;
- difficult planning and establishment of the system of strategic and current purchase;
- unclear limitation between costs and absence of a common strategy within the business area of ŽP.

The Law on Railways, which contains the elements of railway infrastructure liberalization has been implemented in the Republic of Croatia since 1 January 2006. On 29 December 2006 HŽ was separated into HŽ Infrastructure and three transport companies. HŽ Train Traction started to operate as a company providing train traction services to HŽ Passenger Transport and HŽ Cargo, its own tractive units and staff. The three newly established transport companies have regulated the complex interrelations by contracts. Such model of Train Traction functioning as separate operator is not implemented at other railways that have also passed through the transformation process into new companies (organized in holdings [1], i. e. concerns [2]). Usually the traction activity is owned by the newly created passenger and cargo operators. Consequently, the tractive units are classified accord-

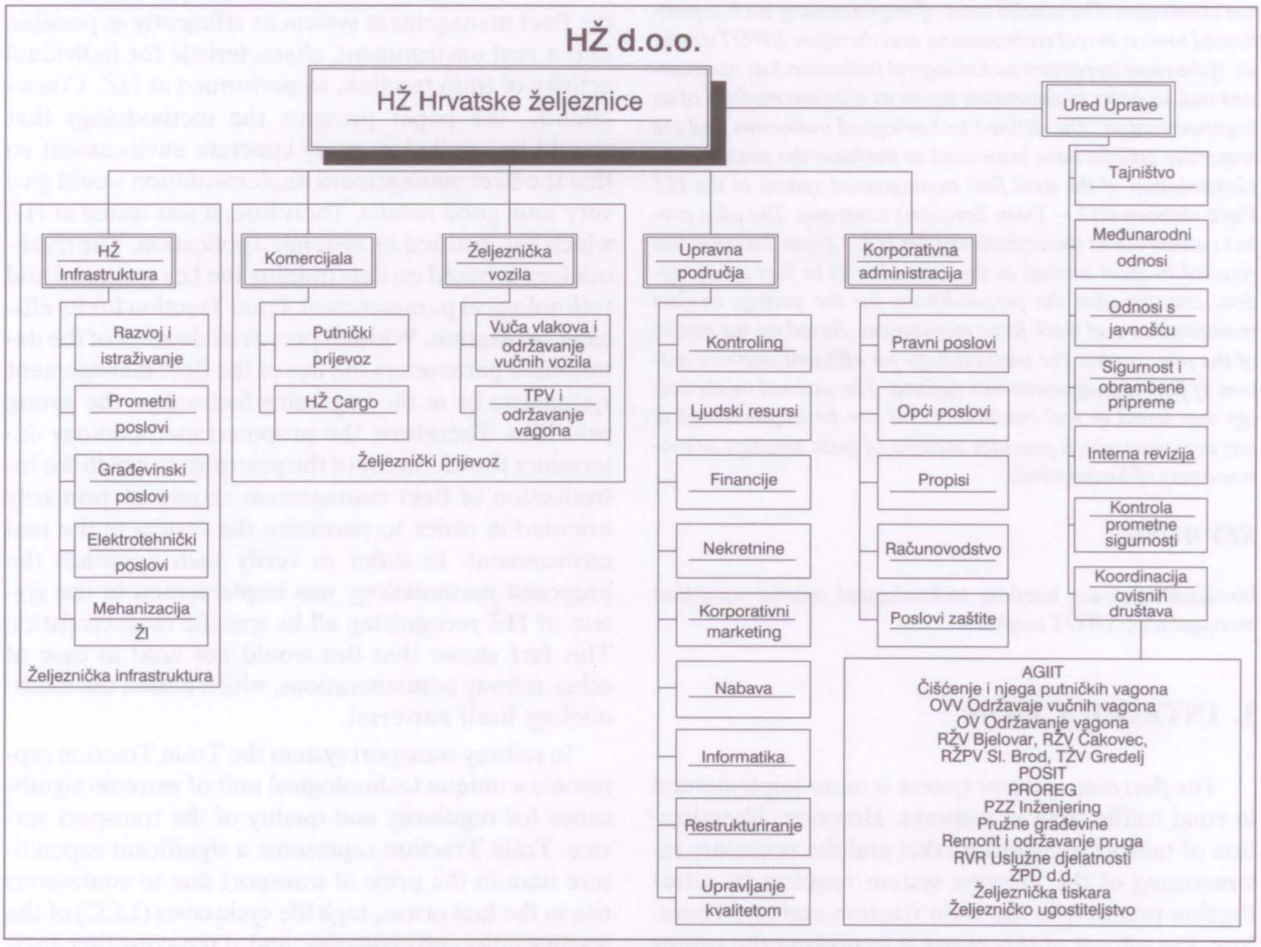

Figure 1 - Organizational scheme of HŽ until 29 Dec. 2006

ing to the purpose so that locomotives belong to the enterprises performing cargo transport (e.g. DB Railion, SBB Cargo, PKP Cargo, etc.). Motor trains and locomotives intended exclusively for the traction of regional and local trains belong to the enterprises that perform passenger transport at local or state level (e.g. DB Regio, DB Fernverkehr, BKV, BVB, etc.). Such organizational structure has proven as very successful and has additionally enabled for newly established operators easier and better making of strategic decisions regarding investments and positioning on the transport market and, on the other hand, good and efficient control of the traction costs share in the total operation costs. Thus, much greater competitiveness is achieved, as well as the possibility of adaptation to the increasingly demanding conditions of modern transport and economy. According to the aforementioned, the model of functioning of HŽ Train Traction Holding Company as independent enterprise, in relation to the environment, is not a good model. This is obviously a compromise solution due to the existing internal divisions per professions and the impossibility of finding a better solution of the piled-up problems within the HŽ system.

2. TECHNICAL AND TECHNOLOGICAL INDICATORS OF TRAIN TRACTION ACTIVITY

At the end of 2006 (Figure 2), the Croatian Railways had in their inventory fleet 85 electric locomotives for system 25kV 50Hz and 22 locomotives for system 3kV, out of which 11 are available for operation, which does not meet the timetable requirements under the conditions of increased cargo transport from the Rijeka basin. Therefore, apart from the locomotives of series 1 061 on network 3kV also two leased multi-unit electric locomotives of series 1 241 are used. Out of a total of 108 operating diesel-electric locomotives, on the average 64 are required daily for operation. The availability of operating diesel locomotives satisfies the requirements in order to realize the schedule except under the conditions of intensive overhauls when additional diesel locomotives for material trains are required. The operating diesel locomotives are also used for heavier shunting operations, and due to occasional difficulties regarding the availability of electric locomotives, to help in the traction of cargo trains on electrified lines as well. The shunting locomotives, although their number is sufficient, are not satisfactory either regarding their traction capabilities or their driving reliability.

The structure of the rolling stock of tractive units of HŽ Train Traction is on the average unsatisfactory for several reasons. First, it should be noted that the rolling stock of tractive units is obsolete. The diversity of types in relation to a relatively small total number of tractive units makes the maintenance more difficult and more expensive. The ratio of the number of breakdowns in operation to the travelled kilometres is significantly less favourable compared to the railways in West Europe. The last purchases of new tractive units were realised in 1990 through the delivery of electric locomotives of the series 1 142 (thyristor) and diesel-motor tilting trains delivered in 2004. The biggest number of diesel locomotives are the locomotives manufactured in the USA, which feature high specific fuel consumption because of two-stroke diesel engines, and because of the axle arrangement Co-Co

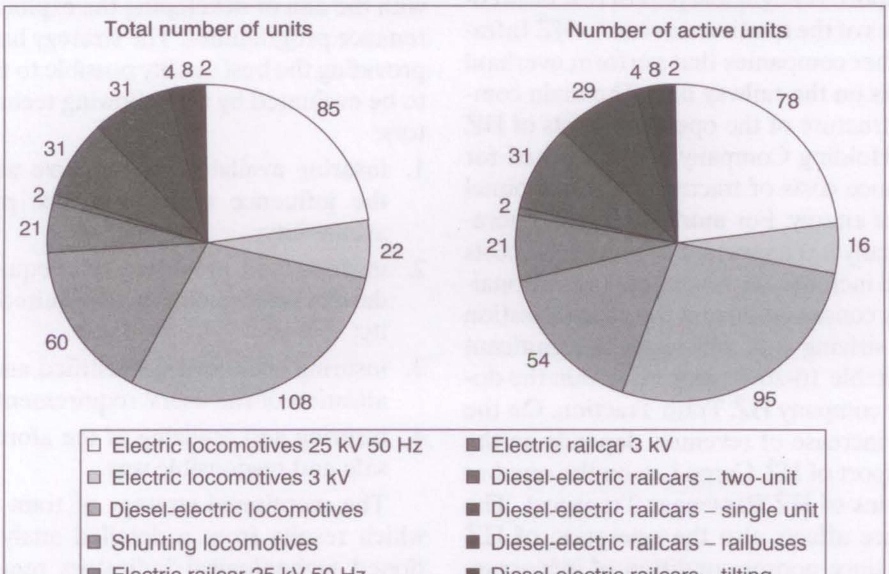

Figure 2 - Structure of total and active rolling stock of tractive units owned by HŽ Vuča vlakova d. o. o. (state as of 29 Dec. 2006)

they have poor influence on the existing infrastructure (high lateral forces).

In regional passenger traffic 30 electric and 20 diesel locomotives are used daily for the traction of passenger trains due to insufficient number of motor trains. The electric railcars of series 6 111, which represent the backbone of the suburban traffic in Zagreb, were delivered in 1978, and due to continuous increase in the number of passengers these trains are becoming less and less suitable for suburban traffic. Evidently, modernization of traction unit rolling stock is necessary and therefore the purchase of new tractive units has been planned at the level of HŽ within the period between 2007 and 2011. This refers to the purchase of 18 electric railcars for urban – suburban traffic in Zagreb, 33 electric railcars for regional traffic and 20 diesel railcars for regional traffic. Also, a purchase of 15 multi-system electric locomotives and 15 shunting locomotives has been planned. The purchase of new electric locomotives of HŽ Train Traction creates the assumptions for interoperability i. e. provision of traction services also outside Croatia, and could thus become competitive to other railway operators.

Because of the liberalized approach to railway infrastructure, it is extremely important to set a sustainable model of the operation of train traction at the strategic level, i. e. in operative sense to design a systemic approach to everyday realization of requirements which are set by newly established railway operators to the train traction. The HŽ Train Traction Holding Company in the newly created conditions of operation realizes almost the entire revenues from selling the train traction services to HŽ Cargo and HŽ Passenger Transport. A negligible part of revenues comes from the sales of the traction services to HŽ Infrastructure and other companies that perform overhaul and similar works on the railway line. The main components in the structure of the operation costs of HŽ Train Traction Holding Company are accounted for by the maintenance costs of tractive units, personnel costs and costs of energy. For more successful operation of this company it is important to reduce the costs of operation and increase the revenues. The rationalization of energy consumption and the rationalization of engaging the driving staff will result in significant savings, a predictable 10-20%, which is within the domain of the very company HŽ Train Traction. On the other hand, the increase of revenues depends on the contracted transport of HŽ Cargo i. e. on the number of passenger trains of HŽ Passenger Transport. The HŽ Infrastructure affects also the operation of HŽ Train Traction, since poorer condition of infrastructure means reduction in the train running speed, which leads to longer engagement of the driving staff while total quality of transport services is falling [3].

The analysis of technological indicators is crucial for enabling precise study of the method of managing the traction sector in the HŽ system, and can be divided into two groups. The technological indicators that refer to the strategy of train traction activity are related to all the management improvements over exploitation and maintenance of tractive units and technologies included in this process based on the already in-advance defined tasks. Acting precisely on these technological indicators will result in a positive influence on the realized revenues. Along with direct savings realized in the process of exploitation and maintenance of tractive units and indirect savings resulting from the increase in usage of capacities and reduction of traffic congestions, result in significant improvement of reliability and productivity. The introduction of the selected system has to insure the availability of tractive units at the required level with the necessary planning and control for its implementation. Since such a system greatly depends on the exploitation conditions on the network, collecting and analysis of large amounts of information becomes a very important task. The success of the system depends on the method of obtaining information, clarity of information and methodology used to analyze the information. At the operative level it is necessary to define the minimally acceptable quality standards, insure optimal allocation of resources (driving staff, propulsion material, tractive units), financial means and maintenance terms. Collection and analysis of data about the exploitation of the tractive units rolling stock over a longer period of time makes it possible to predict the effects of wear and maintenance activities necessary to repair this wear. Forecasts, based on statistical models, are used by the models of economic evaluation with the aim of developing the exploitation and maintenance programmes. The strategy has to be based on providing the best quality possible to the users and has to be evaluated by the following technological indicators:

1. insuring availability of tractive units by reducing the influence of maintenance process on their availability;
2. insuring and providing of adequate quality standard of tractive units with required level of reliability;
3. insuring economically justified and productive realization of the users' requirements;
4. insuring and realizing of the aforementioned in a safe and responsible way.

The mentioned strategy of train traction activity which results from a detailed analysis of the mentioned technological indicators requires a new approach and design. Such approach in theory is called dynamic distribution of effective (Winner, 1995) and can result in unnecessary delay of trains. This can be preventively avoided by planning the available capacities of tractive units and planning of action in random unexpected events. In operative and tactical sense, a precise overview of material elements for the insurance of the train timetable (of stable and mobile means) is required. Based on the passenger and goods transport plan, the necessary number of tractive units is defined, i. e. the volume of inventory, operating and exploitation fleet of the available tractive units have to be known. The determined size of the required wagon fleet will be compared with the actual number of locomotives that are available for the current timetable. It is also necessary to know the available number of passenger wagons, electric railcars and diesel railcars. Regarding the differentiated demand, it is necessary to insure also the structure of demand according to the journey segments.

Based on the planned operation in the transport of passengers and cargo, on the one hand, and the available material and technical elements on the other hand, all the other design elements of the timetable are analyzed and prepared. For the adopted plan of transport and wagon flows, the traction for all the railway lines and trains is determined according to the available number of locomotives. In principle, according to the organizational structure (usually territorial) the traction of passenger and cargo trains is organized, determining also the traction sectors. Based on this, also the tractive units turn-round is planned. The mass and number of trains that transport passengers are determined in the function of passenger flows. The flows are used to plan the number of wagons for regular train compositions. In cargo transport, for each railway line, the train masses are determined according to the useful lengths of the main transit and adjacent tracks at railway stations, type and series of locomotives, types of trains, braking parameters, and all this according to adequate regulations and instructions. Based on the technological qualitative and quantitative indicators of exploiting tractive units, at the completion of the timetable, a clear picture of the success in managing the exploitation and maintenance of the available tractive unit fleet is obtained (Table 1). Basically, the locomotive is let into the production cycle by being "let" by the authorized traction unit into exploitation from the main locomotive depot. After the production task or several of these tasks, including also the stay at the turn-round unit of traction are completed, the locomotive is returned to the main unit. Full locomotive turn-round with servicing can be expressed as:

$$\Theta = \frac{2L}{V_k} + t_{mat} + t_{ob} + t_{pr} \quad \text{(hours)}$$

where:

$2L$ – two lengths (two directions of traction sector) in km,

V_k – commercial locomotive running speed in km/h,

t_{mat} – keeping locomotive at the main unit of traction or at the main railway station in hours,

t_{ob} – stay of the locomotive at the turn-round unit of traction or at turn-round railway station,

t_{pr} – stay of the locomotive at the service (maintenance).

Thus, the application of all those tools or methods that tend to shorten the running time, or time spent at the home unit of traction or at the turn-round unit of traction and at service, results in shortening the total time of turn-round duration and allows greater availability of tractive units rolling stock. On the other hand, it is precisely on the basis of the here presented indicators, whose values result from the success of the traction management, that it is possible to decide on the implementation of different optimisation methods, e. g. rostering tasks. These methods aim at rostering *N* locomotives to *n* types of tasks, under the condition that the productivity of each single locomotive is known in order to achieve the maximum volume of work.

In order to achieve best results possible in the traction activity it is important to take into consideration also the interrelations of certain indicators, such as

Table 1 - Overview of quantitative and qualitative indicators of train traction

Quantitative indicators as consequence of action of train traction on transport	Qualitative indicators as consequence of action of train traction on transport
1. Realized running kilometres	1. Average load of tractive unit
2. Realized gross-tonne kilometres	2. Average length of the tractive sector
3. Kilometres of secondary operation	3. Average speed (commercial and technical)
4. Travel time	4. Tractive unit turn-round
5. Locomotive days	5. Average daily running and tractive unit operation during day, and coefficient of secondary operation
6. Number of let units	6. Tractive unit productivity
7. Total fuel consumption	7. Specific fuel consumption
	8. Driving staff efforts (effective hours)

e.g. relation between the length of the traction sector and commercial speed per necessary number of locomotives per day. The potentially feasible results should be considered in the context of strategic goals of traction regarding availability, reliability, safety and life cycle costs (LCC) of the tractive units.

The implementation of the *total-fleet management* system enables: real-time monitoring of each single tractive unit (GPS and GSM); control in the operation of tractive vehicles per routes in real time; control of the running speed from the dispatcher's place; prompt calculation of the realized operation of the tractive unit; efficient control of traction vehicle energy consumption; communication between the dispatcher's place and the tractive unit (voice and data); authorization of driving staff and other staff members working on the tractive unit; planning of the exploitation and maintenance of tractive units according to real criteria (travelled kilometres, realized running hours of certain assemblies or exploitation time); creation of a database for keeping track of maintenance ("tractive unit passport"); optimization of the timetable. The introduction and implementation of such a system have to lead to the realization of the following concrete objectives: increase in the availability of diesel tractive units; improved quality of the diesel tractive unit life cycle; substitution of the current administrative practice by new organization of collecting and processing data; efficient management of the tractive units rolling stock.

3. ANALYSIS OF TECHNOLOGICAL CRITERIA RELEVANT FOR THE TRAIN TRACTION ACTIVITY OF THE CROATIAN RAILWAYS

For the decision-making process, related to the entire activity of the train traction unit, a detailed transport-logistics analysis has been made. The results obtained and processed and, finally presented in the form of the previously described technological indicators have to be compared and evaluated according to the pre-determined reference values. The result of this analysis is a methodology additionally tested on the results obtained on the base of a pilot project of introducing the *fleet management* system at the traction units of Varaždin and Zagreb. The most important advantage of this methodology lies in the fact that the results, achieved at the train traction units of Varaždin and Zagreb, taking into consideration their significance and specific characteristics in the train traction activity at the level of HŽ, enables its equally good implementation to other units of train traction. The methodology is based on the SWOT analysis. For the pre-determined group of technological indicators, different criteria have been defined as well as the respective indicators. Real problems usually have no criteria of the same level of significance and the decision-maker should define the factors of significance of single criteria by using adequate weight coefficients (weights – w_j) or the so-called criteria ponders. Classification of criteria in order to evaluate the existing technological indicators of train traction has to be done in relation to the previously planned strategic goals such as: increase in reliability and availability of tractive units, improvement of the quality of unit life cycle; substitution of the current administrative practice by new organization of real-time collecting and processing of data; improvement of rolling stock management; lower life cycle costs (LCC) of the units.

Based on this, a procedure of evaluating criteria has been designed, and the indicators have been assigned the characteristics and measurement values. The values of indicators range between 1 and 5, and the criteria were evaluated so that their total value was 100% for each observed indicator. The indicators were evaluated in the same way as the criteria. In order to implement the methodology, the following steps in the evaluation procedure have been undertaken:

1. determining the evaluation system of indicators and criteria;
2. specification of evaluation of each single indicator;
3. evaluation of each single criterion;
4. calculation of the general (overall) implementation index.

The overview of the external and internal environment in which the described methodology for train traction activity has been carried out, is presented in Table 2.

The strength of technological criteria in train traction activity is primarily reflected in the possibility of meeting the train traction requirements of all operators on the railway lines in the Republic of Croatia. Besides, the excess in the free available tractive units or driving staff can be offered for the provision of traction services in border traffic and in the area of adjacent railway administrations. The additional strength lies in fulfilling of all the regulated conditions that have to be met by the tractive units for safe traffic flow.

The greatest weaknesses of the mentioned technological criteria lie in inadequate structure of the tractive units rolling stock and the absence of regularity in cargo traffic (every day a large number of cancelled and introduced trains). The direct consequence thereof is the irrational usage of tractive units and the driving staff and the realization of the timetable. Due to inadequate maintenance the level of reliability of the tractive units in operation is low which results in disturbances in traffic and great immobilization of the active rolling stock. The condition and the quality of

Table 2 - External and internal criteria for the needs of analysing HŽ Train Traction Ltd.

STRENGTHS	WEAKNESSES
1. although in difficult conditions meeting the needs for the traction of all operators in RH; 2. provision of traction services in border traffic; 3. insurance of all the necessary conditions that have to be satisfied by the tractive units for safe traffic flow; 4. possibility of insuring necessary human resources; 5. possibility of providing traction services in the area of adjacent railway administrations; 6. proven possibility of using the fleet management system of the tractive means.	1. unsatisfactory structure of rolling stock; 2. excessive share of diesel traction; 3. irrational usage of tractive units and personnel; 4. high immobilization of active rolling stock; 5. low level of reliability of tractive units in operation; 6. inadequate maintenance; 7. maintenance in the function of technologically unnecessary traction outdoor administrative unit; 8. poor functioning of the dispatcher traction service; 9. irregular cargo transport; 10. inadequate standardization of technological processes in traction; 11. limitations of the usage of tractive units due to the infrastructure condition; 12. questionable sustainability of timetable due to the total infrastructure condition; 13. unnecessary restrictions due to the existing regulations; 14. difficult business decision-making due to the influence of the unions at all decision-making levels.
OPPORTUNITIES	THREATS
1. different possibilities of changing the rolling stock structure; 2. reorganization of traction sector in order to increase the capability of fast response to the change in market conditions; 3. reduction of specific consumption of energy per unit of work; 4. modernization of the maintenance system; 5. insurance of operative reserve of tractive units; 6. improvement of staff based on e-learning; 7. reduction in the share of diesel traction operation; 8. rationalization of the technological process in traction; 9. harmonization of the regulations with the new legislation; 10. realization of NPRŽI [3] according to the profession criteria; 11. clear distinction between the decision-making process and union action; 12. introduction of the long-term purchase planning system of spare parts.	1. inadequate maintenance quality; 2. occurrence of mass defects due to inadequate maintenance; 3. falls in availability percentage of tractive units; 4. unfair competition; 5. strict implementation of EU standards; 6. implementation of EU regulations; 7. difficult purchase of spare parts due to orientation to import; 8. impossibility to insure strategic reserves of materials.

infrastructure are a limiting factor from the aspect of optimal usage of tractive units, and the keeping of timetable becomes questionable. The additional loads are reflected in a large share of expensive diesel train traction and in the organizationally and technologically inadequate processes at the train traction outdoor administrative units.

Numerous possibilities of the technological criteria in the train traction activity result primarily from the reorganization of the traction activities with the aim of increasing the flexibility i. e. capability for fast adaptation to the changed market conditions. Further possibilities and development prospects are opened by the change in the structure of the traction units rolling stock and modernization of the maintenance system as well as of the entire logistics support (purchase, spare parts, and consumable material, information technology system technical documentation, modern staff training working in exploitation and maintenance of traction units, driving means). Finally, there are significant possibilities in rationalization of the specific consumption of energy of electric and diesel traction units and in optimizing the technological processes in exploitation and maintenance of traction units.

The basic threat for the train traction activity is hidden in the fact that foreign competition of the more developed railway operators (with advanced and good traction vehicles, lower costs i. e. greater productivity and lower prices for the traction service) will take advantage of the existing drawbacks: mass defects due to inadequate and poor maintenance, significantly reduced availability of traction units, difficult realization of the timetable, high costs of the traction service. Additional barrier may be presented in the form of requirements to fulfil the EU standards and regulations, and there are permanent problems with the regularity of supply and purchase of spare parts i.e. strategic material.

The result of this analysis and the proposed methodology has confirmed the need to introduce the fleet management as tools that can significantly help in realizing the planned business objectives in the current practice of train traction. Fleet management represents the system of managing the fleet of vehicles of any company involved in public transport or that has a fleet for its own needs. Such a system includes, for the requirements of traction activity, an entire series of functions such as: purchase of new traction units, maintenance of traction units, monitoring and diagnostics of traction units, managing the shifts of the driving staff, management of fuel consumption, management of health-safety system, analysis of work and efficiency of personnel and vehicles. Generally, it allows companies that in their operation rely strongly on transport, to eliminate or minimize the risks related to the investments into new vehicles, improvement of efficiency and productivity, and, at the same time, reduction of total transport costs and 100% harmonization with the valid legislation.

The biggest European railways (German, French, Italian, etc.) have developed programmes for monitoring their own fleets regarding exploitation and maintenance before restructuring the railway administrations. By separating the railways, the programmes have been adapted to the newly formed companies i. e. the fleet ownership. Besides, the vehicles are equipped with GPS devices so that their position and working status may be momentarily tracked. The pre-condition for this procedure is not only the installation of the equipment on the traction units, but rather the making of a digitized network of railway lines with GPS locators. At the Austrian Railways, the daughter companies ÖBB Traction and ÖBB Technical services (owned by ÖBB Passenger transport and ÖBB Cargo), have made a programme for monitoring exploitation and maintenance of their own rolling stock and they are offering it to other carriers with the necessary modifications and adjustments. The Slovenian railways plan the development of a similar programme for monitoring the entire fleet, and they are currently using their own, rather obsolete, programme for controlling the wagon fleet as part of the Technical – Wagon activity. In train traction region, the Slovenian railways have made a completely automated and computerized system of diesel fuel supply, and the electric traction vehicles are equipped with electricity consumption gauges, so that bills towards suppliers are paid on the basis of the actual consumption of electricity. For HŽ Train Traction there was the need to make a proposal of automation and computerization of the fuel supply system based on the experiences of other railways. The automated system allows real-time monitoring of fuel distribution per fuel reservoirs, vehicle series and the vehicles themselves thus reducing the possibility of illegal fuel manipulation. The system is networked and the data are simultaneously sent to the railway administration, fuel distributer and the authorized territorial unit of train traction. Rationalization of the number of fuel reservoirs is also needed, since the justification of their usage at 19 locations is questionable. The installation of electricity consumption measuring gauge is planned on electric traction units in order to pay only for the actually spent energy.

4. CASE STUDY - (INTRODUCTION OF *FLEET MANAGEMENT* IN TRACTION UNITS IN VARAŽDIN AND ZAGREB)

The share of diesel traction in the HŽ system is relatively high. In 2005, out of the total operation of traction units expressed in KBRTKM, diesel traction accounted for 34.47%, and in 2006 this share amounted to 34.66%. It is well known that diesel traction units are more demanding regarding maintenance and that during the exploitation cycle their traction properties deteriorate due to driving wear of the diesel engine. Therefore, it is a very complex task to plan the maintenance and to maintain diesel traction units in good condition without exceeding the planned costs and with constant availability in realizing the timetable. In order to increase the availability of diesel traction units, if necessary, the following activities need to be carried out: improve the organization and the technologies of maintenance and the overall logistic support; shorten the time the unit spends on regular overhauls; modernize the existing traction units or purchase new ones with high level of reliability in operation.

The existing exploitation practice of diesel traction units in the HŽ system are characterized by the following problems: it is obsolete and complex and led at several hierarchical levels; there is no possibility of on-line verification of the traction unit and crew status; administrative delays; official data do not match the actual condition. Regarding the complexity of the previously mentioned issues, it is understood by itself that it cannot be solved at once nor in a short period of time. Therefore, an attempt has been made to carry out a pilot project in one organizational unit of traction, of using a fuel additive (conditioner) in order to reduce the fuel consumption and maintenance costs. The realization of such effects results from the quality of the respective conditioner as indicated by the manufacturer offering the product for testing. The decision to start the pilot project of applying the conditioner was made at the technical services of the business area of traction at HŽ due to the high share of fuel purchase costs in the total costs of train traction activity. The daily consumption of diesel fuel for train traction in the HŽ system amounts to about 90t. Consequently, it may be concluded that the application of efficient measures of fuel consumption rationalization can bring great financial savings at the annual level.

The quarterly exploitation testing of the fuel conditioner (DFT 1500) was carried out during the year 2005 on a locomotive of series 2 044 of the Train Traction Unit Varaždin. Based on the monitoring of the fuel consumption, travelled kilometres and gross-ton kilometres, a saving of 2% of fuel was realized. Monitoring the fuel consumption was done by GPS device installed in the locomotive so that the fuel volume in the tank was permanently measured by a pressure probe connected to the GPS device. Thus, it was possible at the same time to control on-line the current position of the locomotive, its running speed and the volume of fuel in the tank. For the selected period of exploitation using the applied software it was possible to reproduce the movement of the locomotive, its staying at single locations, refuelling quantities, fuel consumption in dependence with the travelled route and the operation of the diesel engine (operation hours, driving position). In accordance with the positive results of the previously described testing the implementation of the pilot project followed, controlling the fuel consumption of diesel engine of three locomotives in the Train Traction Unit Zagreb. There is, namely, suspicion that a certain quantity of diesel fuel is spent for wrong purposes (misappropriated), which additionally increases the costs of energy supply. The GPS devices were installed on the locomotives, and the data were transferred via Vipnet and T-Com networks. At the beginning of December 2005 the devices for controlling the diesel engine fuel consumption were installed on three locomotives (2062-001, -010 and 2063-001 which operate within Train Traction Unit Zagreb). During six months the following parameters were controlled: quantity of fuel in the tank; loading and unloading of; fuel consumption; locomotive speed; travelled kilometres; locomotive acceleration; time that the locomotive spends standing with engine on or off; locomotive location (digital road map).

The comparison of the registered data and the data obtained by the new method of monitoring results in the following conclusion: approximately 12% more travelled locomotive kilometres were determined than the officially registered, which is to be expected since the travelled kilometres are registered according to the running schedules, rather than the actually travelled kilometres; according to records 4% more fuel was spent than measured by the installed probes. The presented diagrams show the fuel consumption of locomotives 2 062 001 and 2 062 010, during 2005 before the installation of GPS device (Figures 3 and 5), and Figures 4 and 6 show the fuel consumption in the first four months of 2006 when the GPS device on the respective locomotives was functioning.

Obviously, this method of monitoring fuel consumption should be systemically applied. Taking into consideration the systemic and random errors and the carried out approximations, one may conclude that such control of fuel consumption could result in savings of 5 – 7%. Expressed in money units, this is a respectable value in reducing the costs of driving power for train traction. Besides, a proposal has been made for the automation of the fuel supply system based on the experiences of other railways. The automated system enables real-time monitoring of fuel delivery per fuel reservoirs, analysis of the fuel consumption per fuel reservoirs, series of vehicle and vehicles themselves, and reduces the possibility of illegal fuel ma-

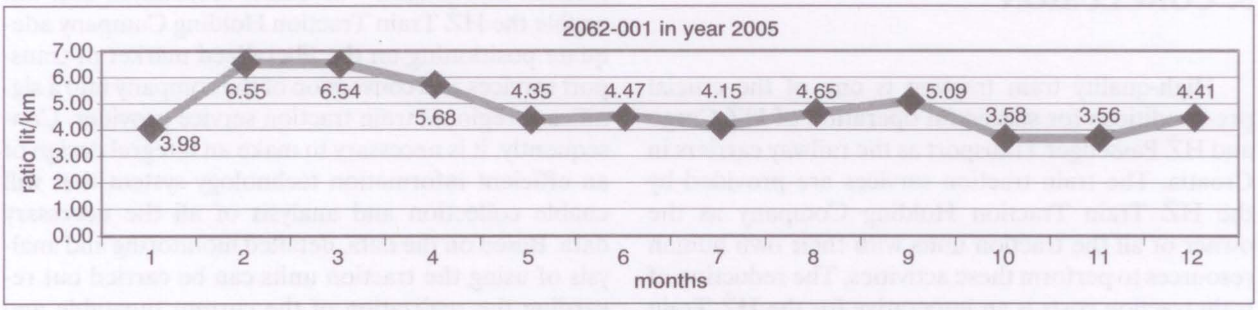

Figure 3 - Fuel consumption of locomotive 2 062-001 in 2005

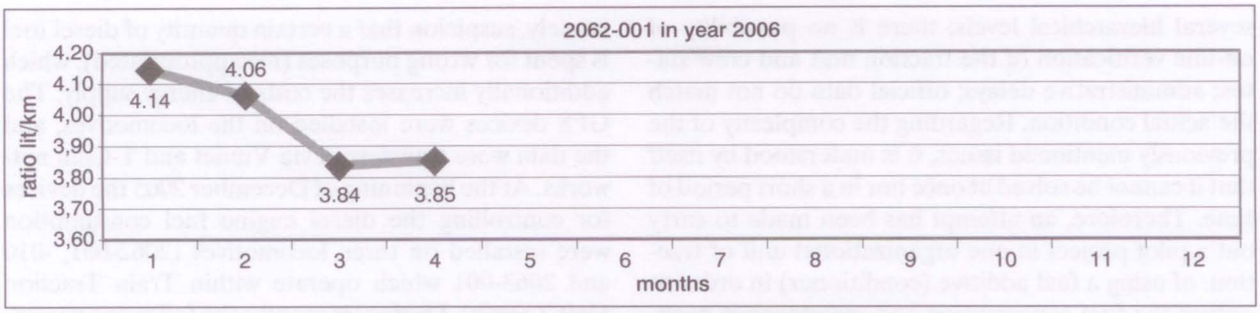

Figure 4 - Fuel consumption of locomotive 2 062-001 in 2006

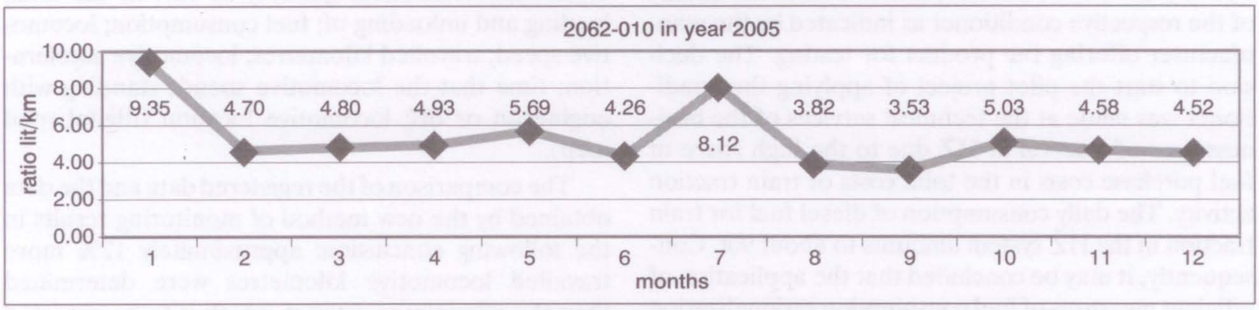

Figure 5 - Fuel consumption of locomotive 2 062-010 in 2005

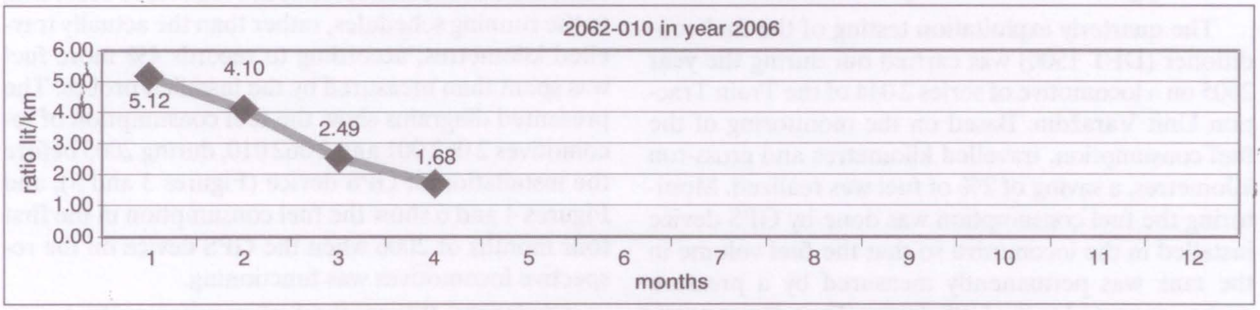

Figure 6 - Fuel consumption of locomotive 2 062-010 in 2006

nipulation. The system is networked and the data are sent at the same time to the railway administration, fuel distributer and authorized territorial train traction unit. If it is assumed that the annual saving in fuel consumption was only 5%, this would mean lower consumption of approximately 1600t diesel fuel. Assuming that the price of fuel today is about 6kn/kg the financial effect of fuel saving would be 9.8 million kuna per year.

5. CONCLUSION

High-quality train traction is one of the crucial pre-conditions for successful operation of HŽ Cargo and HŽ Passenger Transport as the railway carriers in Croatia. The train traction services are provided by the HŽ Train Traction Holding Company as the owner of all the traction units with their own human resources to perform these activities. The reduction of train traction costs is an imperative for the HŽ Train Traction Holding Company if they are to be well positioned on the liberalized market of railway transport services.

By implementing the integral *total-fleet management* system, the HŽ Train Traction Holding Company can evidently realize large savings at an annual level in the consumption of fuel alone. Substantial savings are also possible in maintenance and labour engagement, which is to be realistically assessed after having introduced the *total-fleet management* system.

The basic aim of implementing this system, in strategic sense, is the optimisation of the relation train traction exploitation – timetable realization. This will enable the HŽ Train Traction Holding Company adequate positioning on the liberalized market of transport services and conversion of the company into a significant regional train traction service provider. Consequently, it is necessary to make an integral design of an efficient information technology system that will enable collection and analysis of all the necessary data. Based on the data, detailed monitoring and analysis of using the traction units can be carried out regarding the realization of the current timetable and possible provision of services outside.

The final objective is to establish *total fleet management* of traction units and *fuel management* of diesel traction units and testing of the possibilities of its partial "outsourcing". The introduction of *total fleet management* is a project whose introduction may be funded from the fuel savings, and which can be realized already by equipping the locomotives with GPS system for the control of fuel status in the tank which is in fact the first phase of the project.

Dr. sc. **TOMISLAV JOSIP MLINARIĆ**
E-mail: mlinaric@fpz.hr
Mr. sc. **MLADEN NIKŠIĆ**
E-mail: mladen.niksic@fpz.hr
Sveučilište u Zagrebu, Fakultet prometnih znanosti
Vukelićeva 4, 10000 Zagreb, Republika Hrvatska
MILAN BRKIĆ, dipl. ing.
E-mail: milan.brkic@hznet.hr
HŽ Putnički prijevoz
Mihanovićeva 12, 10000 Zagreb, Republika Hrvatska

SAŽETAK

PRIMJENA "FLEET MANAGEMENTA" U VUČI VLAKOVA

Primjena fleet managementa u djelatnosti vuče vlakova neupitna je u uvjetima tržišnog poslovanja željezničkog sektora, jer dobro gospodarenje vučnim vozilima nema alternative. Ključno je pitanje primjene takvoga sofisticiranog alata u realnom okruženju, zbog čega je provedena SWOT analiza najvažnijih tehnoloških pokazatelja, kako bi se utvrdio najefikasniji način njegove primjene. Utvrđeni tehnološki pokazatelji i njima pripadajući kriteriji, poslužili su za evaluaciju eventualne primjene sustava total-fleet managementa u društvu HŽ Vuča vlakova. Pilot projektom, provedenim u djelatnosti vuče vlakova Hrvatskih željeznica (HŽ), ostvarene su velike uštede na godišnjoj razini u potrošnji pogonskog goriva, a stvoreni su preduvjeti i za uštede u održavanju voznog parka te angažiranju radne snage. Na temelju rezultata pilot projekta utvrđena je metodologija za učinkovitu primjenu fleet managementa. Definirana metodologija testirana je u stvarnim uvjetima te može biti primijenjena u bilo kojoj tvrtki koja pruža usluge vuče vlakova ili manevriranja lokomotivama.

KLJUČNE RIJEČI

liberalizacija, vuča vlakova, tehnološki kriteriji, total-fleet management, SWOT analiza

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1. Holding (Lexicon of economics) – a company that has in its assets only shares of other companies or at which the majority of assets are shares of other companies. A holding company performs financial operations that are of interest for the companies which control and manage or control production and commercial activities of these companies.
2. Concern (Lexicon of economics) – the highest level of monopolistic merging. In a concern the enterprises completely lose their independence. The difference between a trust and a concern is that the trust merges enterprises of the same branch whereas concern merges enterprises of different production branches.
3. NPRŽI - Nacionalni program razvitka željezničke infrastructure (National Railway Infrastructure Development Programme)

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