GLOBAL NONLINEAR MODEL FOR EFFICACY EVALUATION IN TEAM SPORTS

Slavko Trninić[1], Igor Jelaska[1] and Vladan Papić[2]

[1] *Faculty of Kinesiology, University of Split*
[2] *Faculty of Electric, Mechanical Engineering and Naval Architecture, University of Split*

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Abstract
There is probably no efficiency model within team sports games that represents kinesiological reality in whole. This is so because in sport kinesiology or sports science it is impossible to explicitly form theories and models without fault, since they are tested on a limited assembly of instances. This is particularly true for theories and models applying to the situational approach because the experts are aware of the fact that kinesiological theories and models constantly modify based on the feedback generated in the process of scientific-exploratory work. The linear model, which is dominantly present in explaining the factors of sports efficacy, does not explain the interaction between inner and outer factors of competition efficacy. The reason is that it doesn't describe the bothways' effect of mentioned variables, but shows an assembly of known and unknown factors that influence the team or athlete efficacy, that is, it shows a pondered sum of their influences. Unlike the linear, the suggested nonlinear model enables a more appropriate insight and understanding of multiple influences of inner and outer efficacy factors in sports. The goal is to use the basis of the suggested nonlinear model to construct an exact, expert-scientific interaction approach that would enable an appropriate efficacy formula in team sports games based on which appropriate diagnostics, selection and development of potential top-level athletes and/or teams could be conducted.

Keywords: *sport, teams, efficacy, nonlinear model*

Introduction

From a historical genesis point of view, regarding kinesiology of sport or sports science, already in the last century '60-es Konstantin Momirović (1966, 1969, 1972), as a protagonist of the newly founded quantitatively exclusive science of kinesiology, was the first to point to the necessity of introducing simplified linear models in explaining efficacy factors in sport. He also claimed that the linear model shows an assembly of known and unknown factors that affect athlete or team efficacy, that is, that it shows a pondered sum of their influences.

Therefore, the mentioned educational pattern doesn't exclude multiple reciprocal connections between the variables, nor does it specify the effect of internal and external variables applicable to sports efficacy. Such a simplified linear combination of anthropological factors had neglected the influence of external factors onto athlete's performance and sports accomplishment. However, Momirović (1966) thought even back then, that such a pattern of comprehension of sport factor structure doesn't meet the criteria of ''hard'' science, especially regarding poly-structural and complex sports activities, (Matvejev, 1977, 1981, 1999) because they have far more complex demands on an individual player then do monostructural cyclical and acyclical sports activities.

Quite expectedly, the monostuctural sports activities (cyclical and acyclical) are simple motor activities, whose success formula is made up of a relatively minor number of relevant dimensions. However, complex sports activities, as are the team sports games and the poly-structural ones (martial arts) are determined by a large number of inner and outer influences in multiple interactions. Team sports games are of multi-causal nature and as such cannot be reduced simply to athlete's potential and/or his actual quality and team structure (athlete selection). Therefore, athlete's performance and competition efficacy are based on multi-causal mechanisms, where the basic idea is that internal and external variables are in a reciprocal deterministic relationship (Philips and Orton, 1983). For this reason the explorations in sports science must be unconditionally interdisciplinary (Trninić et al, 2008). Athletes in team sports games are indirect carriers of sports activity and competition results in the context of the tactics model and coach's leadership behaviour. This is why it is mandatory in the efficacy model for team sports games to include, besides internal factors like athlete's potential (basic and specific anthropological dimensions), team structure, adequacy of the tactics model, coach's athlete and team leadership, organization system, expert policy and sports institution logistics, emotional and functional inter-athlete relations (cooperation quality)relations within the club, interplay level, ''internal chemistry'' of the team (Silva and Stevens, 2002) and micro social conditions in the team, as well as external determinants: quality of the opposing coach, quality and readiness of the opponents (individual players and/or team), objective factors: wider environment, judging criteria, spectators, competition conditions, conditions when organizing the sport preparation process, as well as specifics of the particular sport, unknown factors and certain dimension and measurement importance assessment errors.

Ways of evaluating and predicting efficacy in sport

Horga (1993), states that there are two basic ways to evaluate and predict sports efficacy. The first refers to a comparison of athletes of different actual quality in features for which we are trying to establish how much they attribute to efficacy predictions. This presuming that the more and the less successful will differ from each other in these relevant features for the explored sports activity. This differentiation of the more and the less successful athletes within the same sport refers to the level of development of relevant anthropological features, and to the structure of the characteristics of the whole assembly of the athlete efficacy features. The second basic way to evaluate and predict sports efficacy consists of connecting efficacy in sport to an assembly of athlete's relevant features. Accordingly, it is assumed that the features that have a high relative influence onto efficacy will show connectivity with some of the measures of competition efficacy. Horga (1993) states that this way of analyzing demands defining criteria of efficacy in sport. He additionally states that defining efficacy in sport is a complex issue, because not in every sport can the results be objectively determined (for example: artistic gymnastics, rhythmic gymnastics, water jumping and figure skating). This enlightens the fact that determining features of efficacy in sport isn't a simple issue. Horga (1993) directs that it is impossible to solve this problem instantly in general for all sports, but separately for each sporting activity, and that before any attempt to determine the formula of sports efficacy specification, it is crucial to define several basic parameters: the way to determine efficacy in sport, potential predictors (athlete features) of sports efficacy, and the sports efficacy of the participants, that is, the quality of the sport group getting tested. Therefore, it is necessary to answer two basic questions. One refers to the level of development of particular anthropological features that would show relevant for the investigated sport. The other one refers to the specific features that might be of relevance for that one sport exclusively, not any other sport. This is important because sports differentiate based on different demands that this activity makes on the athlete's potential. In the process, each activity enforces development of a specific structure of athlete's features. From the scientific-investigatory blueprint point of view, it is most appropriate to define all relevant anthropologic features based on top-level athletes in the chosen sport. It is assumed, of course, that successful athletes posses relevant feature, and/or that combination of developed features ideal for the particular sport. In example, Morgan (1979) states that physiological or psychological data can never on its own be an appropriate predictor of efficacy. Accordingly, only when an athlete is investigated as a complex psycho-biological system is it possible to approach the ideal level of prediction. Likewise, Deshaies et al (1979) state that sports behaviour should be examined in the light of interaction of numerous physiological, as well as psychological variables, and that such an approach is more appropriate then solely physiological or psychological predictive models of sports efficacy.

Determining an efficacy model in sports for team sports games

Because of the complexity, that is, the impotence to set a mathematic model that would completely describe the factors that affect sports efficacy and their mutual influence, a solution emerged in expert systems. A reason for application of expert systems in the field of kinesiology can be explained by their gratification of the principles of simplicity and coverage. It is also important to mention that modularity and possibility of expansion of expert systems have encouraged an array of new scientific researches which enabled further progress of sports science (Dežman, 1988, 1992, 1995; Jošt et al, 1992; Dežman and Leskošek, 1993; Filipčić, 1996; Dežman and Erčulj, 1995; Dežman et al, 2001a, 2001b; Trninić et al, 2002a, 2002b). Therefore, it is important to point out that expert systems provide acceptable solutions, but without a mathematically structured equation that would precisely define the whole model of efficacy and its behaviour in dependence of variability of internal and external parameters.

Expert systems are based on the knowledge acquired from expert people and a set of rules that are formed through their filled questionnaires, and the emulation of human contemplation is expanded further through an application of the so-called fuzzy logic (Zadeh, 1965, Siler and Buckley, 2005, Papić et al, 2009, Rogulj et al, 2009.).

New scientific blueprints directed at research of efficacy factors in complex and poly-structural sports as in complex dynamic systems marked by variant processes of integration, and functional mutual dependence of players who play different positions in a particular team sports game (Trninić, 1995; Lebed, 2006, 2007; Trninić et al, 2008). In accordance with this is also the assumption that the best player in team sports games is the one who in interaction with other co-players achieves maximal individual and team performance. This demonstrates that for team sports games it isn't all about how much a certain player can play, but how much he participates in assistance systems in al phases of the course of the game (Trninić et al, 2009). In sports practice, expert coaches believe that an appropriate determination of the efficacy equation is the basis for a rational management of the process of sports preparation, a starting point for adequate guidance, selection and specialization of a particular player for particular roles in the game (Dežman, 1988; Trninić, 1995). Jacob and Carron (1997) have come to a conclusion that the most important factors that have contributed to the status of sports teams are performance ability and roles of the players in the team, as well as competition experience. Player roles enable development of a dynamic game system of a particular team (Lebed, 2006, 2007; McGarry and Franks, 2007). The traditional approach to understanding sports factor structure was directed mainly on the assembly of athlete's abilities, treats, knowledge, skills and habits that influence sports performance and competition efficacy in an individual branch of sport. Accordingly, research was dominantly directed on the influence of anthropologic dimensions on efficiency in sports activities and vice versa. However, except for numerous internal factors, external and general social factors influence efficacy of players and of team, and are multiply interacting (Filipčić, 1996; Dežman, 1988, 1997; Trninić et al, 2008). Because of the complexity of the sports efficacy model, solving the sports factor structure is commonly just partial and therefore provides with incomplete answers to the basic question- what makes a successful player and/or team (Horga, 1993). Dežman (1992, 1995, 1997) and Erčulj (1998) state that ascertaining an efficacy model for an individual player and/or team is possible to conduct in two ways:

1. through measuring or evaluating all factors with the biggest influence on performance quality of an individual player and/or team. This approach evaluates player's potential (the level of development of relevant basic and specific anthropologic dimensions that affect player's efficacy) or his potential efficacy. The tests that measure potential efficacy must have high correlation with the criterion of situation efficacy and/or total actual player quality. Based on acquired results in such a type of selected tests, it is possible, with the help of multiple regression analysis, to calculate beta ponders, which in different ways ponder particular tests in total points count. So it is necessary, within the theory of efficacy, to distinguish total (e.g. total potential or psychosomatic player status) and partial potential efficacy (e. g. motor area of player's psychosomatic status). In recent researches, several multi-criteria models for determining partial potential have been formed and checked (Dežman and Leskošek, 1993; Dežman, 1992; Jošt et al, 1992; Dežman and Erčulj, 1995; Dežman, 1996; Leskošek, 1996; Erčulj, 1998). Schilling (1975) says that the total of athlete's personality (individual set of behaviour, thought, and emotions that identify athlete's adjustment) is labelled by his potential abilities (fitness, muscle force, extended performance ability, quality of total nervous system function, technique and sports activity tactics adoption), readiness for accomplishment (treats of personality and motivation, emotions and athlete's intentions). He also believes that the category of potential sports accomplishment (what the athlete is capable of) and readiness for accomplishment (what the athlete wants and how much he assists), especially in complex sports activities, are in constant multiple interaction. From the methodical aspect, the manner of defining potential accomplishment and readiness for accomplishment is different from one researcher to another. This is, of course, determined mainly through technical possibilities of research performance, and specifics of demands for some sports activity.

2. through evaluation of total and partial efficacy. Total game efficacy (total athlete quality) includes all relevant factors of actual player quality, which are assesses by experts by using a certain criteria system (Trninić, 1996; Trninić et al, 1999a; Trninić, Dizdar, 2000; Trninić et al, 2000, Dežman et al, 2001a, 2001b, Trninić et al, 2002a, 2002b, Hraste et al, Trninić, 2008). Also, concerning the football game, Ćorluka (2008) founded a criteria system for evaluation of total efficacy in a football game, while in water polo Hraste et al (2008) set a criteria system for evaluation of actual quality of top-level water polo players. Ćorluka (2008) and Hraste (2008) have affirmed characteristics of the measurement instrument for evaluation of total efficacy in football and water polo games, and concluded that for most criteria metric characteristics (objectivity and sensitivity) are in coherence with their coefficients of relevance for a certain position. In these mentioned scientific researches, there is a defined relative contribution of individual criterion to total quality of players on particular positions in the game, and accordingly there was a suggested structure of relevant criteria for each position.

Empirical findings show evident differences in importance of individual criterion for evaluation of player quality in afore-mentioned team sports games considering the position that the player plays primarily. It is important to mention that in team sports games the efficacy of each player is evaluated by the level of achievement of set common and special tasks. Unlike total efficacy, partial efficacy obtains only those factors that are gathered by a statistic record of final actions of players in the competition (indicators of situation efficiency), also known as player efficiency (Jošt et al, 1992; Swalgin, 1994, 1998; Erčulj, 1998; Dizdar et al, 1997, Trninić et al, 1997, Trninić et al, 1999b).

The assessment of total situation efficacy should be based on valuation of players according to position and time spent in the game. So, for example, Dizdar (2002) states that with the help of 13 indicators of situation efficacy, it is possible to assess around 77% of the criterion variable ''total basketball player quality'', even 85% if together with the 13 indicators of situation efficacy we also include variables for assessment of player consistency in situation efficacy (evaluated by standard deviations). Such a result may be considered the threshold of prognostic validity of mentioned variables. It is important to note that the findings of this study have shown that the biggest contribution to prediction of criteria variable ''total basketball player quality'' was made by the variables defence jump, successful two-point shoot, free throws and assistances, while the others didn't show statistic relevance.

Therefore, single player quality can be evaluated in three ways:

- through subjective evaluation of expert coaches (Trninić, 1995, 1996; Dežman, 1988; Swalgin, 1998),
- through objective evaluation of the situation efficacy (Gréhaigne and Godbout, 1995; Swalgin, 1994, 1998; Trninić et al, 1995; Dizdar et al, 1997, Dežman, 1998)
- through combining both approaches - the model includes professional subjective assessment based on a criteria system and an objectively measurable situation effect (Trninić et al, 2000; Dežman et al, 2001a, 2001b)

Thus, a player can be evaluated by an assessment of the condition of the development of his/her anthropologic feature and/or evaluation of total game efficacy. Because of high complexity of sports games and diversity of roles of athletes in game, their potential as well as actual quality can be differently structured (Trninić et al, 2002a, 2002b). This means that athletes manage to achieve equal total evaluation of potential and/or total game efficacy in different ways.

The specific structure of factors of athlete's potential conditions also a specific structure of factors that determine game efficacy. This is why not only the final value of potential evaluation or total game efficacy are said to be relevant, but also the profile of their individual factors (Dežman et al, 2001a, 2001b). From the point of view of the expert systems model, potential efficacy of athletes encompasses all important internal and external factors that govern the efficacy in team sports games, but also a set of factors that encompasses some general social factors which can be only approximately defined. Erčulj (1998) points out the fact that expert systems are more and more adequately applied for sports efficacy research. Also states that computer-assisted expert system enables us to accept relations between individual factors of efficacy within a particular sport discipline or sports branch and a different level of development of these factors which make the basic source of information when choosing. This is particularly relevant for identifying differences between potential efficacy and actual athlete quality. Further on, Erčulj (1998) claims that the reliability and quality of a decision depends upon the quantity and quality of information (expert knowledge) possessed by an expert (most important and irreplaceable instrumentation in the development of sports expertise and science), that is, an expert group in the interdisciplinary, multidisciplinary and trans-disciplinary approach. Within the mentioned scientific study, what was also investigated was the relationship between the variables of potential efficacy (predictor variables) and the variables which helped conclude player efficacy and situation efficacy (criteria variable). This showed that all connections between the variables of potential efficacy (predictor variables) and the variables which helped conclude efficacy and situation efficacy (criteria variable) are linear. Accordingly, the hypothesis that potential efficacy of all three basic types of players in basketball (guards, wings and centres) is directly shown in their player efficacy and efficiency has been substantiated. However, this research has encompassed only some of the internal factors (morphologic and motor potential) that directly affect athlete potential, and that probably have a bigger meaning in younger age categories then in senior categories where the psychosocial status differentiates more the level of actual player and team quality. Independently, what is achieved is a high prognostic value expressed mostly in anticipating actual player efficacy and efficiency of athletes and the team. Erčulj (1998) believes that the model of potential basketball player efficacy shown in the study isn't something formal, and should be changed in accordance with knowledge databases.

As well as with results of sciences and practical knowledge of expert coaches. These are all preconditions that enable experts to improve their knowledge and cognition.

Proposition of a nonlinear efficacy factors model in sports

Malacko and Popović (2001) state that during efficacy factors analysis in sports activities, the information on how many factors F_1, F_n influence an individual activity presents the main task of researchers in the field of applied kinesiology. Further on, they point out that the generating of the hierarchy structure of anthropologic characteristic of athletes is done through application of mathematical statistics methods (factor, regression or canonical analysis), and that the most common form of the specification equation is:

$$Y = \sum_{i=1}^{n} a_i F_i + ex, \quad \text{where}$$

Y- stands for efficacy in a particular sports activity

F_i - stands for factors which sports activity efficacy depends on, i=1,...,n

a_i - stands for coefficients of influence of particular factors (contributions of efficacy), i=1,...,n

ex - stands for error factor

In accordance to the mentioned, it is assumed that by means of the system of differential equations we could more appropriately describe the high complexity of internal and external determinants of athlete's performance and competition efficacy, and their interaction in poly-structural and complex sports activities. It is relevant to note that the systems described by differential equations must as variables have objects described functionally, by continuous objects. This is a problem, since kinesiology as an applied science gets variables through measurements, as a finite discrete set of normally distributed data. In that context, it is possible to use continuous approximation.

Further more, the presented efficacy specification equation can be understood as a linear part of Taylor's series expansion of the efficacy function

$$Y = f(x_1, x_2, ..., x_n)$$

which is obtained through solving the nonlinear system of (differential) equations that in itself integrates dynamic relations between system's variables? It is, however, possible to solve the system by a numeric scheme and get a discrete solution (Smith, 1978), and generalize it by usage of interpolation techniques into continuous (Fröberg, 1966; Kvasov, 2003; Jelaska, 2005).

In the context of multi-index notation, the Taylor's series expansion of function consisted of d variables, about d-dimensional point $a = (a_1, ..., a_d)$ would be as follows (Bermant and Abramanovich, 1975; Atkinson, 1988; Bajpai et al, 1973):

$$f(x) = \sum_{|\alpha|=0}^{n} \frac{1}{\alpha!} \frac{\partial^\alpha f(a)}{\partial x^\alpha}(x-a)^\alpha + \sum_{|\alpha|=n+1} R_\alpha(x)(x-a)^\alpha$$

Demonstrated as standard, upper formula can be written in following form:

$$f(x_1, x_2, ..., x_d) = \sum_{\alpha_1=0}^{\infty} \cdots \sum_{\alpha_d=0}^{\infty} \frac{(x_1-a_1)^{\alpha_1} \cdots (x_d-a_d)^{\alpha_d}}{\alpha_1! \cdots \alpha_d!} \left(\frac{\partial^{\alpha_1+...+\alpha_d} f}{\partial x_1^{\alpha_1} \cdots \partial x_d^{\alpha_d}} \right)(a_1, ..., a_d)$$

For example, if we were to say that d=2, meaning the function is dependant of only two variables, X and Y, then Taylor's series expansion, including quadratic terms, about the point (*a*, *b*) would be:

$$f(x,y) \approx f(a,b) + (x-a) f_x(a,b) + (y-b) f_y(a,b) +$$
$$+ \frac{1}{2!}\left[(x-a)^2 f_{xx}(a,b) + 2(x-a)(y-b) f_{xy}(a,b) + (y-b)^2 f_{yy}(a,b)\right]$$

Where we used standard symbols for partial derivations:

$$\frac{\partial^2 f}{\partial x^2} = f_{xx}, \frac{\partial^2 f}{\partial x \partial y} = f_{xy} = f_{yx}$$

Here we can see that with a different notation:

$$f(x,y) \approx x f_x(a,b) + y f_y(a,b) + f(a,b) - a f_x(a,b) - b f_x(a,b)$$
$$+ \frac{1}{2!}\left[(x-a)^2 f_{xx}(a,b) + 2(x-a)(y-b) f_{xy}(a,b) + (y-b)^2 f_{yy}(a,b)\right]$$

we get the linear part separated from the nonlinear, so the first two members of the above expression would correspond with some two-factor model of efficacy

$$Y = a_1 F_1 + a_2 F_2 + ex$$

with ponders $a_1 = f_x(a,b)$ and $a_2 = f_y(a,b)$, while the rest would enter error factor ex. Quite analog to this, we read out coefficients for an efficacy model with n factors.

It is important to accentuate that Taylor's series expansion can be more compactly written down in a matrix form (Bermant and Abramanovich, 1975):

$$T(x) = f(a) + (x-a)^T Df(a) + \frac{1}{2!}(x-a)^T \{D^2 f(a)\}(x-a) + ...$$

Where Df(a) is the gradient of function f calculated in point x=a and $D^2f(a)$ is Hessian matrix. It is important to note that by changing the degree of approximation, we also vary its precision. Also, a nonlinear and reciprocal functional relation of variables X and Y can be integrated into the part of Taylor polynomial that includes the exponents of variable X, and all its multiple products with variable Y.

Conclusion

From the sports kinesiology or sports science point of view, the formation of the process of sports preparation depends on an appropriate factor sport structure, since without its proper defining it is impossible to rationally manage the processes of growth of athlete's potential and/or the whole team. Modern kinesiology is theoretically directed to inter-relation and interaction of inner, outer and general social factors that determine efficacy in a sport. This is because the processes of interaction are dynamic and chaotic in a sports surrounding. Through explicit defining and construction of multiple connections amongst variables within a hypothetical nonlinear model, we enter the frames of usage of the mathematical functional symbolic instrument which generates higher order interactions. Therefore, the linear model of sports efficacy factors cannot be the appropriate pattern that depicts the complexity of sports activities of a poly-structural and variable type. On the other hand, the factors of efficacy of a particular team sports game cannot be presented as a single direction, since the processes occurring in dependence of the time variable in the system of sports preparation do not move single-dimensionally but oscillate. Therefore, the linear model is not only inappropriate, but also limited in explaining and understanding the determinants of competition efficacy, because it clearly does not explain the interaction of the inner and outer factors that determine efficacy. These reduction patterns do not describe mutual influences of mentioned variables that refer to sports efficacy. The athlete, the team and also the sports activity is impossible to properly interpret by one-way relations or as static occurrences, but as nonlinear dynamic systems which inside carry implemented two-way paths between particular inner and outer factors of competition efficacy. In order for the factor structure of efficacy in sport to be defined and properly guide the process of sports preparation, it is important to be familiar with not only the development level of basic and sport-specific anthropologic dimensions of top-level athletes, but it is also necessary to know the coefficients of importance of criteria for particular positions in the team sports game (actual athlete quality).

However, factor structures of sports for mono-structural, poly-structural and complex sports activities shouldn't be compatible in the mathematical formal description, since the demands of each sports activity different, and also the factor combination that structures the equation of efficacy in sports. In so, the model characteristics of top-level athletes in sports activities demand prediction of development of a particular team sports game, and accordingly, an anticipation of model features of top-level athletes and teams, and an explicit analysis of actual and future model demands.

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GLOBALNI NELINEARNI MODEL ZA PROCJENU UČINKOVITOSTI U MOMČADSKIM SPORTOVIMA

Sažetak

Vjerojatno nijedan model uspješnosti unutar momčadskih sportskih igara ne predstavlja u potpunosti kineziološku realnost. To zato što u kineziologiji sporta ili sportskoj znanosti nije moguće eksplicitno formirati teorije i modele koji ne bi imali nikakvu grešku jer se testiraju na ograničenom skupu pojava. To osobito vrijedi za teorije i modele koji se odnose na situacijski pristup jer su eksperti svjesni činjenice da se kineziološke teorije i modeli neprestano modificiraju na temelju povratnih informacija generiranih u procesu znanstveno-istraživačkog rada. Linearni model koji je dominantno prisutan u objašnjavanju čimbenika uspješnosti u sportu ne objašnjava interakciju unutarnjih i vanjskih čimbenika natjecateljske uspješnosti. To stoga jer ne opisuje obostrane utjecaje navedenih varijabli već prikazuje skup poznatih i nepoznatih faktora koji utječu na uspješnost sportaša ili momčadi tj. prikazuje diferencijalno ponderiranu sumu njihovih utjecaja. Za razliku od linearnog, predloženi nelinearni model omogućava primjereniji uvid i razumijevanje višestrukih interakcija između unutarnjih i vanjskih čimbenika uspješnosti u sportu. Cilj je na predloženom nelinearnom modelu zasnovati egzaktni, znanstveno-stručni interakcijski pristup koji bi omogućio prikladnu jednadžbu uspješnosti u momčadskim sportskim igrama na temelju koje bi se provela primjerena dijagnostika, selekcija i razvoj potencijalnih vrhunskih sportaša i/ili momčadi.

Ključne riječi*: sport, momčadi, učinkovitost, nelinearni model*

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Correspondence to:
Assoc. Prof. Vladan Papić, Ph.D.
University of Split
Faculty of Electric, Mech. Engineering and Naval Architecture
Ruđera Boškovića b.b. 21000 Split, Croatia
Phone: +385 (0)21 305 777
E-mail: vpapic@fesb.hr

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