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Integrated multi-criteria decision making model based on wisdom-of-crowds principle for selection of the group of elite security guards

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Abstract

Background & Study Aim: One of the most important topics for research revolves around the choice and selection of individuals for jobs that require exceptional morphofunctional abilities and my cause health impairments and even be life threatening. The study aims to design an algorithm for rating of security guards based on multi-criteria decision making methods and wisdom-of-crowds principle and use it to form a group of elite security guards.

Material & Methods: The research subject: 118 randomly selected security guards from the company *G4S Lietuva*. Twenty two leader managers (experts) from *G4S Lietuva* with not less than 10 years experience of service at private security structures involving the execution and organisation of security solutions have rated the competences chosen by authors of the article.

Selected security guards were tested and evaluated according to 41 criteria. The data received was classified into six groups of competences regarding the features analysed: theoretical and practical preparation; professional activity; mental qualities; physical development; motor abilities; and fighting efficiency. Staff selection method based on a single-expert evaluation and selection method based on wisdom-of-crowds principle, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Simple Additive Weighting (SWA) methods.

Results: The weights of criteria used for evaluation of security guards revealed the main selection and development tendencies. The following levels of criteria were defined: very important (*theoretical and practical preparing*; *mental qualities*; *motor abilities*), important (*fighting efficiency*) and moderately important (*professional activity*; *physical development*). Professional activities of security guards encompass observation, help and conflict resolution.

Conclusions: The staff selection algorithm recommended by authors of the article is more efficient by one-third in comparison to other currently used selection methods. Issues pertaining to contemporary selection and rating of security guards, just as any other staff of militarised structures, are considered to be especially relevant.

Key words: human factor • public safety • risk operations • specific tests

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Choice of the profession of a security guard – a system of examinations consisting of different tests for each major topic of different levels.

Selection of a group of elite security guards – a system of examinations consisting of different tests for each major topic dependent on difference of tests results.

Perceptual sentence – in methodological sense, it is a statement on the result of a certain observation (result of a measurement) [7, p. 60].

NIS – negative ideal solution.

PIS – positive ideal solution.

TOPSIS – Technique for Order Preference by Similarity to Ideal Solution.

SWA – Simple Additive Weighting.

Background

One of the most important topics for research revolves around the choice and selection of individuals for jobs that require exceptional morphofunctional abilities and my cause health impairments and even be life threatening. Such characteristic are also particular to the profession of security guards.

Companies that provide security services aim to protect rights and legal interests of their clients as well as ensure security and order. Private security service providers mainly focus on prevention of violations of law and possible damage to clients; threats could be both direct and indirect. Ninety percent of all activity in a security company should be aimed at reduction of possible damage to clients [1]. The variety of services provided by modern security companies has been recently increasing. The variety and quality of services offered do not only depend on the demand in the market but is also determined by staff competences [2].

In the field of security, human factor is considered to be the most important. Three thirds of losses in such companies occur due to inefficient staff work; 80% of secret information security depends on effective staff selection, teaching and management [3]. Effective staff selection procedures are very important in military services, which are responsible for safety of the public [4]. This is when appropriate human resources become very important in selecting or creating specific tests and their sets [5,6].

Security staff could be classified according to tasks they are responsible for: security staff of an object, administrative security staff of an object, armed security of an object, rapid response crew, armed security guard, cash and valuables transportation security guard and personal security guard. It is essential that employers focus on staff selection and take action to evaluate and rate candidates. This process requires defining key competences of a security guard and rating them depending on aims and possible threats at work. Stanisław Dadeło distinguished the main competences of security guards and rated them according to a single-expert evaluation thus defining principles for selection of a group of elite security guards responsible for increased risk operations [7]. However, evaluation and decisions taken by a single person are less correct than those made collectively with the difference between the two amounting to 26% [8].

To optimise the efficiency of the process for choice and selection of security staff, it is essential to search for methods based on collective evaluation. Decisions taken on the basis of wisdom-of-crowds theory will be efficient if strict selection and mathematical calculation methods are applied. If judgement of a crowd comprises signal-plus noise, averaging judgments will cancel out the noise and extract the signal [9,10]. This means that the members of the group should be highly competent in their field (have efficient knowledge and be motivated to develop the knowledge they have); their mistakes when taking decisions should not be systematic, i.e. there should be variability in their judgement (people making particular decisions should not be dependent on each other). Communication between group members or reliance on the same resources reduces the efficiency of decisions they make [11].

Decisions taken on the basis of wisdom-of-crowds require more complex mathematical methods for information processing. For this reason, multi-criteria decision making methods can be used. Multi-criteria decision making methods enable efficient selection of staff. Multi-criteria analysis is a set of techniques for comparative evaluation of alternative projects through an analysis of a set of criteria in a given complex context. Decision makers play a central role within this process, which takes into account the perspective of each party involved. Multi-criteria analysis synthesises opinions of those involved in order to establish priorities. Therefore, it proves useful in dealing with conflicts and providing recommendations. Assessing the efficiency of a staff selection method, it is essential to compare results of evaluation and selection processes that were defined by a single expert and a group of experts; as well as identify peculiarities of multi-criteria decision making methods.

The study aims to design an algorithm for rating of security guards based on multi-criteria decision making methods and wisdom-of-crowds principle. The specific task of the research is to use this method to form a group of elite guards and compare it with the group of elite guards formed on the basis of principles of a single expert evaluation.

It is due to the objective of this paper why the 'Results' part has been written in a different manner than in a standard original paper. In this paper, 'Results' comprises not only a set of observations and corresponding tables and figures but also contains assumptions and necessary – in our opinion - detailed methods, comments and information usually drafted in Discussion.

Material and Methods

Participants

One hundred and eighteen security guards were randomly selected from the company *G4S Lietuva*; twenty two leader managers (experts) of *G4S Lietuva* with not less than 10 years of service at private security structures

Table 1. The normalised professional competence rate average of security guards (*n=118*).

Security guards	Criteria (competitions)					
	Theoretical and practical preparing	Professional activity	Mental qualities	Physical developments	Motor abilities	Fighting efficiency
	χ_1	χ_2	χ_3	χ_4	χ_5	χ_6
α_{max} (highest values)	2.582	2.186	2.651	3.388	2.768	1.696
α_{min} (lowest values)	–1.606	–2.567	–2.518	–1.948	–2.596	–1.709
α_1	1.358	–1.503	0.607	0.520	1.381	1.696
α_2	0.259	–0.549	–0.424	–1.487	–0.645	0.068
α_3	–0.984	0.465	0.101	-0.479	0.690	–0.100
⋮	⋮	⋮	⋮	⋮	⋮	⋮
α_{116}	0.225	–0.500	–0.837	–0.599	0.749	0.795
α_{117}	0.561	–1.366	0.438	–0.017	0.013	–0.903
α_{118}	–1.512	–1.391	–2.180	–1.666	–1.520	–0.845

involving execution and organisation of security have rated the competences chosen by authors of the article.

Evaluation criteria

Selected security guards were tested and evaluated according to 41 criteria. The data received was classified into six groups of competences (variables) regarding the features analysed:

1. Theoretical and practical preparation (x_1): knowledge, skills, abilities, practical experience – acquired throughout life;
2. Professional activity (x_2): carrying out required tasks;
3. Mental qualities (x_3): individual psychical qualities vital for performance of professional activities;
4. Physical development (x_4): morphological indications of a body;
5. Motor abilities (x_5): personal physical conditions allowing to carry out physical tasks at work or home, during leisure, and reflecting the level of physical qualities;
6. Fighting efficiency (x_6): a set of physical and mental qualities influencing the ability to effectively carry out actions fighting an adversary in direct contact.

Selection method based on wisdom-of-crowds principle, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Simple Additive Weighting (SAW) methods.

Results

The data of the features analysed was normalised (Z_i) on the basis of standard deviation (S) and summarised. Each investigated security guard was rated depending on the scores of six features that were analysed (Table 1), which gave the basis to form a group of elite security guards.

Staff selection method based on a single-expert evaluation

Stanisław Dadeło aimed to select approx. 10% of security guards who were suitable for operations of increased importance or risk. The analysed competences were classified into two groups: more relevant and less relevant [7]. Among the more important ones were those that are relatively difficult to develop (*fighting efficiency, physical developments*, *mental qualities*); those competences that are easier to change fell into the category of less relevant ones (*theoretical and practical preparation*, *professional activity*, *motor abilities*). Data on each investigated security guard were grouped according to competence features and summarised: six ratios of determined competences were received in each case. The group of elite guards was formed classifying all of investigated security guards according to each competence criterion. The limit of highly relevant competences was defined when Z_i*>0, and the limit of lower relevance competences was defined when* Z_i>0.5 (Table 2). Staff selection is carried out prioritising particular qualities and eliminating the unsuitable candidates.

Staff selection method based on wisdom-of-crowds principle, TOPSIS and SAW methods

These methods take a different approach, depending on the amount of information available, the importance of

Table 2. The limits in the order and variability of competence criteria in the professional activity of security guards (*n=118*) when forming the group of elite security guards [7].

Criteria	Normalised rate (Z_i) selection limits
Mental qualities (χ_3)	>0
Physical developments (χ_4)	>0
Fighting efficiency (χ_6)	>0
Theoretical and practical preparation (χ_1)	>–0.5
Professional activity (χ_2)	>–0.5
Motor abilities (χ_5)	>–0.5

Note: $Z_i = \frac{\chi - \bar{\chi}}{S}$

criteria or the complexity of information (e.g. simple additive weighting method, TOPSIS and etc.).

The main reasons why TOPSIS and SAW methods are among the most widely used multiple criteria methods are as follow:

a. Ability to handle both tangible and intangible criteria.
b. An unlimited number of alternatives and performance criteria can be included.
c. A sound logic that represents the rationale of human choice.
d. A systematic procedure, which is relatively simple and fast.
e. Used after calculating the results, which have the closest distance to PIS (positive ideal solution) and farthest to NIS (negative ideal solution) – TOPSIS method.

The set of options to be analysed and the respective evaluation criteria are defined. The set of alternatives A={A_1, A_2,...., A_m} are assessed by a number of evaluation criteria X={X_1, X_2,...., X_n}.

The TOPSIS and SAW methods determine a decision matrix X, which contains m alternatives with n criteria:

$$X = [x_{ij}],\ i = \overline{1,m},\ j = \overline{1,n}\ , \qquad (1)$$

where χ_{ij}= the numerical outcome of the i^{th} alternative with respect to the j^{th} criterion, i=1,…, m and j=1,…, n.

When the considered criteria have a different significance for decision-makers, they receive weights, which form the vector w=(w_1, w_2,..., w_n).

In TOPSIS and SAW methods, criteria are usually grouped into "cost" and "benefit". The larger the attributes, the greater is preference for the "benefit" criteria and less – for the "cost" criteria. Further, any data which is expressed in a non-numerical way should be quantified through the appropriate scaling technique such as bipolar scale. Since all criteria cannot be assumed to be of equal importance, the method receives a set of weights from the decision maker. The weights could be obtained through different methods [12–19].

The TOPSIS algorithm

Multiple attributes decision aid provides several powerful solutions [20–29] for confronting sorting problems. TOPSIS is a multiple criteria method used to identify solutions from a finite set of alternatives based upon simultaneous minimisation of distance from an ideal point and maximisation of distance from a nadir point. TOPSIS can incorporate relative weights of importance of a criterion. The TOPSIS method was developed by Hwang and Yoon [20]. TOPSIS is attractive as it requires limited subjective input from decision makers. The only subjective input needed is weights. There are three different weight sources, reflected by equal weights, centroid weights, and weights obtained by regression (Olson [30]). TOPSIS has been applied to a number of applications (Hwang et al. [31]; Yoon [32]), although it is not nearly as widely applied as other multiattribute methods (Zanakis, et al. [33]).

In other manufacturing applications, it has been used in a case selecting a manufacturing process construction processes (Deng et al [34]), human resources management (Chen and Tzeng [35]), quality control (Yang and Chou [36]), and in an application selecting robotic processes (Parkan and Wu [37]). TOPSIS has also been used to compare company performance (Deng et al [34]) and financial ratio performance within a specific industry (Feng and Wang [38]).

TOPSIS method with grey related analysis was further developed using interval fuzzy numbers (Zhanga et al., [39]). Wang et al [40] use an evidential reasoning approach for solving multiple attribute decision analysis (MADA) problems under interval belief degrees. Yang et al. [41] explore multiple attribute decision making (MADM) method to solve a dynamic operator allocation problem. Quan et al. [42] approach ambiguous decision domain, the evaluation values of alternatives against attributes would be interval numbers because of the inherent, uncertain property of the problems. Lin et al. [43] offer appraisal TOPSIS method with grey number operations to deal with the problem of uncertain information. TOPSIS method with grey related analysis was also applied in hydroelectric generation scheduling (Liang [44]), building a thermal process (Wenbin et al.

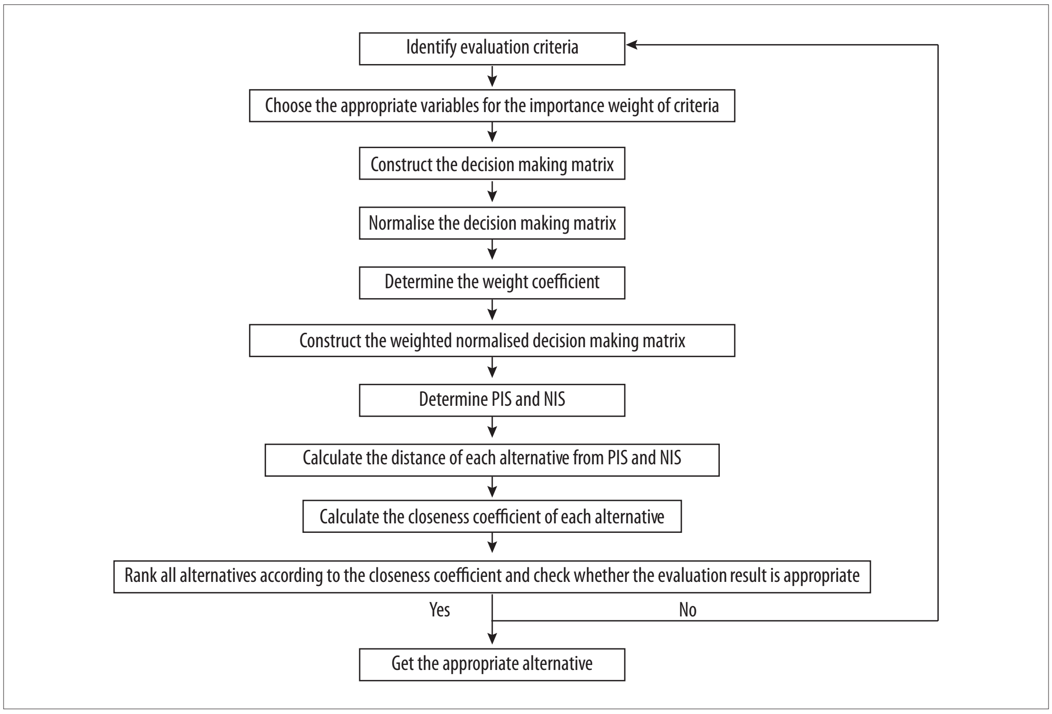

Figure 1. Process of evaluation and selection of alternatives using the TOPSIS algorithm [20].

[45]), decision making (Nwogugu [46]), and contractor selection (Zavadskas et al. [47]).

Based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative-ideal solution (NIS), TOPSIS was first developed by Hwang and Yoon [20] for solving a multiple criteria decision making problem. In brief the TOPSIS algorithm consists of the following basic six steps as shown in Figure 1:

First step. Construct the normalised decision matrix; the dimensions of different indices are usually different. Criteria of the evaluation object with different dimensions could not be directly compared. Thus, the original data must be normalised at first. This process transforms various dimensions into criteria with no dimensions. In literature, there is a number of different methods for normalisation including: Vector (the common one), Linear, Logarithmic and Nonlinear.

Second step. Construct the weighted normalised decision matrix.

Third step. Determination of the ideal solution and negative-ideal solution.

Fourth step. Calculate the separation measure.

Fifth step. Calculate the relative closeness to the ideal solution.

Sixth step. Rank the preference order.

Vector Normalisation (the most common for TOPSIS method) is used. An element $\bar{\chi}_{ij}$ of the normalised decision making matrix $\bar{X}$ is calculated as follows:

$$\bar{x}_{ij} = \frac{x_{ij}}{\left(\sum_{i=1}^{m} x_{ij}^{2}\right)^{0.5}}, \; i = \overline{1,m}; \; j = \overline{1,n}. \tag{2}$$

Consequently, each attribute has the same unit length of vector.

Construction of the weighted normalised decision making matrix

$\hat{x}_{ij} = \bar{x}_{ij} \cdot w_j$; where w_j is the weight of the *j-th* attribute, and $\sum_{j=1}^{n} w_j = 1$.

The weights can be specified either by a user or calculated using different techniques.

Determination of the ideal and negative ideal solutions. Let $J=\{1,2,\ldots,n\}$ and $J_1=\{j={}_{j1},{}_{j2},\ldots,j_k\}$ represent benefit criteria and $J_2=\{j={}_{k+1},j_{k+1},\ldots,j_n\}$ is associated with cost criteria. Then, the two created alternatives A^+ and A^- indicate the most preferable alternative (ideal solution) and the least ideal solution.

The two artificial alternatives A^+ and A^- are defined as follows:

$$A^{+} = \{[(\max_{i} \hat{x}_{ij} \mid j \in J), (\min_{i} \hat{x}_{ij} \mid j \in J^{*})] \mid i = \overline{1,m}\} = \{\hat{x}_1^{-}, \hat{x}_2^{-}, ..., \hat{x}_n^{-}\} \quad (3)$$

$$A^{-} = \{[(\min_{i} \hat{x}_{ij} \mid j \in J), (\max_{i} \hat{x}_{ij} \mid j \in J^{*})] \mid i = \overline{1,m}\} = \{\hat{x}_1^{-}, \hat{x}_2^{-}, ..., \hat{x}_n^{-}\} \quad (4)$$

Calculating the separation measure. The separation between each alternative can be measured by the Euclidean distance. The separation of each alternative from the ideal solution is then given by:

$$L_i^{+} = \left(\sum_{j=1}^{n} \left(\hat{x}_{ij} - x_j^{+} \right)^2 \right)^{0.5}, \ i = \overline{1,m} \quad (5)$$

Similarly, the separation from the negative-ideal solution is given by

$$L_i^{-} = \left(\sum_{j=1}^{n} \left(\hat{x}_{ij} - x_j^{-} \right)^2 \right)^{0.5}, \ i = \overline{1,m} \quad (6)$$

Calculating the relative closeness to ideal solution. The alternative closeness of A_i with respect to A^+ is defined as:

$$C_i^{*} = \frac{L_i^{-}}{L_i^{+} + L_i^{-}}, \quad i = 1,2,..., m, \ 1 \geq C_i^{*} \geq 0 \quad (7)$$

It is clear that $C_i^* = 1, \text{ if } A_i = A^+ \text{ and } C_i^* = 0, \text{ if } A_i = A^-$. A greater value of C_i^* indicates a higher priority of the alternative. So, alternatives can be ranked based on the value C_i^*.

Simple Additive Weighting (SAW) method algorithm [48] (Figure 2).

Simple additive weighting, which is also known as weighted linear combination or scoring methods is a simple and the most often used multiple criteria decision making technique. Firstly, the SAW method was utilised to cope with the portfolio selection problem. The procedure of SAW can be summarised as follows:

First step. Calculating the relative weight w_j of the j-th attribute;

Second step. Obtaining the decision making matrix whose elements composed χ_{ij} for the j attribute with respect to the i alternative. If the raw decision making matrix comprised by χ_{ij} for the j attribute with respect to the i alternative, in order to reduce the influence of the dimension, it is applying normalisation according to the following principle:

If the criteria are defined as benefit criteria (the larger χ_j, the greater preference); then the normalised outcome is:

$$\bar{x}_{ij} = \frac{x_{ij}}{\max_{i} x_{ij}}, \ i = \overline{1,m}; \ j = \overline{1,n} \quad (8)$$

If the criteria are defined as cost criteria (the smaller is χ_j, the greater is the preference); then the normalised outcome is:

$$\bar{x}_{ij} = \frac{\min_{i} x_{ij}}{x_{ij}}, \ i = \overline{1,m}; \ j = \overline{1,n} \quad (9)$$

Third step. Synthesising the value C for the i alternative:

$$C_i = \sum_{j=1}^{n} \bar{x}_{ij} w_j, \ i = \overline{1,m}; \ j = \overline{1,n} \quad (10)$$

Fourth step. Selecting the best alternative defined in this:

$$A^{*} = \left\{ C_i \,\middle|\, \max_{i} C_i \right\}, \ i = \overline{1,m} \quad (11)$$

The bigger SAW rating means a better performance value [20,49].

Determination of criteria weights by experts

During the second step, the expert (n=22) judgment method was used to determine criteria weights. This expert judgment method was implemented during the following stages [29]:

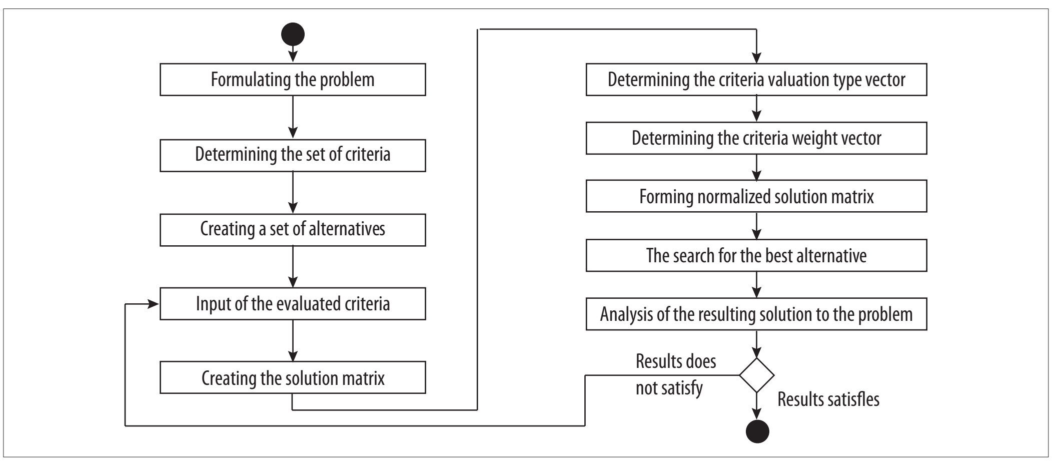

Figure 2. The solution algorithm using the SAW method [48].

Table 3. Criteria weights determined by the experts (*n=22*).

Expert k=1,…22	Efficiency criteria ranks values, t_{jk}; $_{j=1,\ldots n}$; $_{n=6}$					
	χ_1	χ_2	χ_3	χ_4	χ_5	χ_6
1	6	1	5	3	2	4
2	5	2	3	1	6	4
3	5	1	3	2	6	4
4	6	1	5	3	4	2
5	6	1	5	2	3	4
6	5	1	4	2	6	3
7	4	2	3	1	6	5
8	6	2	5	3	4	1
9	5	4	6	3	2	1
10	5	4	6	1	2	3
11	4	1	3	2	6	5
12	6	2	4	1	5	3
13	6	4	5	1	3	2
14	6	3	5	1	4	2
15	4	1	3	2	6	5
16	4	1	3	2	6	5
17	6	1	4	2	3	5
18	6	3	4	1	5	2
19	4	1	5	2	6	3
20	6	2	4	1	5	3
21	5	2	6	3	4	1
22	4	1	6	3	2	5
Σ	114	41	97	42	96	72
$\bar{\chi}$	5.111	2.000	4.500	1.833	4.333	3.222
Attribute rank	1	5	2	6	3	4
Attribute weight	0.247	0.089	0.210	0.091	0.208	0.156

- Calculation of values t_{jk}; Calculation of weights w_j; Calculation of values s;
- Calculation of values T_k; Calculation of values w; Calculation of values $\chi^2_{\alpha,v}$;
- Testing the statement $\chi^2_{\alpha,v} > \chi^2_{tbl}$.

The values t_{jk} for statistical processing were obtained by interviewing 22 leader managers of *G4S Lietuva* (Table 3).

The algorithm of criteria weight establishment and process of calculation [29] is presented in Table 4. Once calculations were performed, criteria weights were established.

Kendall [49] has shown that, when $n>7$, the value $\chi^2=Wr(n–1)$ has a distribution with degrees of freedom $v=n–1$, where n is the number of criteria considered and r is the number of experts. It has been proved that if the calculated value χ^2 is larger than the critical tabular value χ^2_{tbl}, the pre-selected level of significance is $\alpha=0.01$; therefore, the above mentioned conditions should be satisfied. If the $\chi^2_{a,v}>\chi^2_{tbl}$ is obtained, opinions of respondents are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted. The concordance coefficient based on the criteria weights is $W=0.66$. In this case, the tabular value was taken from Fisher and Yates [50] statistical tables. When the degrees of freedom is $v=n–1=6–1=5$ and pre-selected level of significance is $\alpha=0.01$ (or error probability $P=1\%$), in the value $\chi^2_{tbl}=15.09$. Since $\chi^2_{a,v}>\chi^2_{tbl}$, the assumption is made that the coefficient of concordance is significant and expert rankings are in concordance with 99% probability.

Table 4. Algorithm for establishing criteria weights [30].

Process of calculation	Efficiency criteria χ_j; $j=1,\ldots n$; $n=6$					
	χ_1	χ_2	χ_3	χ_4	χ_5	χ_6
Sum of ranks $\bar{t}_j = \sum_{k=1}^{r=22} t_{jk}$	114	41	97	42	96	72
The average rank value of a criterion $\bar{t}_j = \frac{\sum_{k=1}^{r=22} t_{jk}}{r}$	5.111	2.000	4.500	1.833	4.333	3.222
Rank of a criterion	1	5	2	6	3	4
Weight of a criterion $q_j = \frac{\bar{t}_j}{\sum_{j=1}^{n=6} t_j}$	0.247	0.089	0.210	0.091	0.208	0.156
$\sum_{k=1}^{r=22} (t_{jk} - \bar{t}_j)^2$	15.38	25.00	25.50	13.94	51.11	42.42
Dispersion of expert ranking values $\sigma^2 = \frac{1}{r-1} \sum_{k=1}^{r=22} (t_{jk} - \bar{t}_j)^2$	0.73	1.19	1.21	0.66	2.43	2.02
Variation $\beta_j = \frac{\sigma}{\bar{t}_j}$	0.167	0.546	0.245	0.444	0.360	0.441
Ranking sum average	$V = \frac{1}{r} \sum_{j=1}^{n=6} \sum_{k=1}^{r=22} t_{jk} = 114 + 41 + 97 + 42 + 96 + 72 = 77$					
The total square ranking deviation	$S = \sum_{j=1}^{n=6} \left(\sum_{k=1}^{r=22} t_{jk} - V \right)^2 = (114-77)^2 + (41-77)^2 + (97-77)^2 + (42-77)^2 + (96-77)^2 + (72-77)^2 = 4676$					
The coefficient of concordance	$W = \frac{12S}{r^2(n^3 - n)} = \frac{12 \cdot 4676}{22^2(6^3 - 6)} = 0.552$					
The significance of the concordance coefficient (no related ranks)	$\chi^2_{\alpha,v} = \frac{12S}{rn(n+1) - \frac{1}{n-1} \sum_{k=1}^{r} T_k} = \frac{12 \cdot 4676}{22 \cdot 6(6+1)} = 60.73$, where $\frac{1}{n-1} \sum_{k=1}^{r} T_k = 0$					
Rank of table concordance when the importance equal to 1%.	The freedom degrees value of a solved problem; $v = n - 1 = 6 - 1 = 5$; $\chi^2_{tbl} = 15.09$					
Compatibility of expert judgement (Kendall [49])	$\chi^2_{\alpha,v} = 60.73 \succ \chi^2_{tbl} = 15.09$ The hypothesis about the consent of experts in rankings is accepted					

The weights of criteria determined by expert methods show how much one of the criteria is more significant than another one. It is obvious, that a criterion according to the significance of criteria rank is as follows: $w_1 \triangleright w_2 \triangleright w_5 \triangleright w_6 \triangleright w_4 \triangleright w_2$. It is obvious that 3 criteria are very important, 2 criteria are of moderate importance and one criterion is important (Figure 3).

Selection of the group of elite security guards and results using TOPSIS and SAW methods

Solution of the problem using SAW method

First step. First o all, a changed decision making matrix was prepared, where the worst value of all possible attributes values equals to 1. This is made by subtraction of the worst value and adding 1:

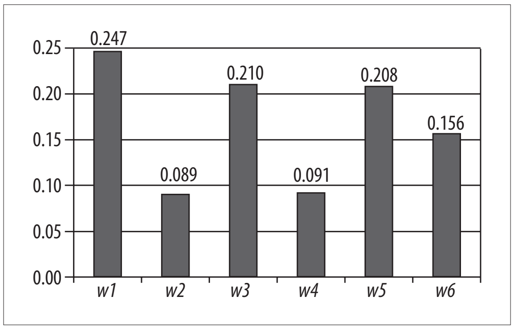

Figure 3. Criteria weights of elite security guards (w_1 – theoretical and practical preparation; w_2 – professional activity; w_3 – mental qualities; w_4 – physical developments; w_5 – motor abilities; w_6 – fighting efficiency).

Changed decision making matrix								
Alternative		χ_1	χ_2	χ_3	χ_4	χ_5	χ_6	
Optimum direction		*max*	*max*	*max*	*max*	*max*	*max*	Average
Criteria weights		0.247	0.089	0.21	0.091	0.208	0.155	
1	A_1	3.96	2.06	4.12	3.47	4.98	4.40	3.20
2	A_2	2.87	3.02	3.09	1.46	2.95	2.78	2.06
3	A_3	1.62	4.03	3.62	2.47	2.91	2.61	2.24
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
116	A_{116}	2.83	3.07	2.68	2.35	4.34	3.50	2.49
117	A_{117}	3.17	2.20	3.96	2.93	3.61	1.81	2.31
118	A_{118}	1.09	2.18	1.34	1.28	2.08	1.86	1.00
Σ		307.53	420.88	415.07	347.84	424.28	319.63	297.24
Optimal		5.19	5.75	6.17	6.34	6.36	4.40	4.17

Second step. Then, a normalized decision making matrix was prepared:

Normalised decision making matrix								
Alternative		χ_1	χ_2	χ_3	χ_4	χ_5	χ_6	Average
Criteria weights		0.247	0.089	0.21	0.091	0.208	0.155	
1	A_1	0.764	0.359	0.669	0.547	0.782	1.000	0.766
2	A_2	0.552	0.525	0.501	0.231	0.464	0.630	0.493
3	A_3	0.313	0.701	0.587	0.390	0.457	0.592	0.537
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
116	A_{116}	0.546	0.533	0.434	0.371	0.683	0.795	0.597
117	A_{117}	0.611	0.382	0.641	0.463	0.567	0.410	0.553
118	A_{118}	0.211	0.378	0.217	0.202	0.326	0.423	0.240

Third step. Next, a normalised-weighted decision making matrix was prepared:

Normalised-weighted decision making matrix									
No.	Alternative	χ_1	χ_2	χ_3	χ_4	χ_5	χ_6	K	RANK
1	A_1	0.189	0.032	0.140	0.050	0.163	0.155	0.729	8
2	A_2	0.136	0.047	0.105	0.021	0.096	0.098	0.504	76
3	A_3	0.077	0.062	0.123	0.035	0.095	0.092	0.485	87
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
116	A_{116}	0.135	0.047	0.091	0.034	0.142	0.123	0.573	53
117	A_{117}	0.151	0.034	0.135	0.042	0.118	0.064	0.543	57
118	A_{118}	0.052	0.034	0.046	0.018	0.068	0.066	0.283	118

Fourth step. Solution according to TOPSIS method. According to the changed decision making matrix, square means for all criteria values were calculated:

Criteria	χ_1	χ_2	χ_3	χ_4	χ_5	χ_6
Square mean	2.7900	3.7031	3.6557	3.1114	3.7309	2.8860

Fifth step. Then, a normalised decision making matrix was prepared:

Normalised decision making matrix								
Alternative		χ_1	χ_2	χ_3	χ_4	χ_5	χ_6	Average
Criteria weights		0.247	0.089	0.21	0.091	0.208	0.155	
1	A_1	1.4208	0.5574	1.1282	1.1144	1.3338	1.5263	1.4208
2	A_2	1.0270	0.8151	0.8461	0.4696	0.7908	0.9623	1.0270
3	A_3	0.5816	1.0887	0.9897	0.7936	0.7789	0.9041	0.5816
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
116	A_{116}	1.0148	0.8281	0.7331	0.7550	1.1646	1.2140	1.0148
117	A_{117}	1.1352	0.5942	1.0821	0.9418	0.9672	0.6259	1.1352
118	A_{118}	0.3924	0.5877	0.3658	0.4120	0.5562	0.6457	0.3924

Sixth step. Next, weighted-normalised decision making matrix was prepared and ideally positive (PIS) and ideally negative solutions were determined (NIS):

Weighted-normalised decision making matrix											
No.	Alt.	χ_1	χ_2	χ_3	χ_4	χ_5	χ_6	L(NIS)	L(PIS)	K	RANK
1	A_1	0.3509	0.0496	0.2369	0.1014	0.2774	0.2366	0.4353	0.2154	0.6690	5
2	A_2	0.2537	0.0725	0.1777	0.0427	0.1645	0.1492	0.2553	0.3768	0.4039	69
3	A_3	0.1436	0.0969	0.2078	0.0722	0.1620	0.1401	0.2271	0.4267	0.3474	97
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
116	A_{116}	0.2507	0.0737	0.1540	0.0687	0.2422	0.1882	0.3041	0.3413	0.4712	52
117	A_{117}	0.2804	0.0529	0.2272	0.0857	0.2012	0.0970	0.3045	0.3293	0.4804	48
118	A_{118}	0.0969	0.0523	0.0768	0.0375	0.1157	0.1001	0.0840	0.5598	0.1305	118
PIS		0.4593	0.1383	0.3544	0.1853	0.3548	0.2366				
NIS		0.1083	0.0887	0.1174	0.0839	0.0774	0.0000				

Seventh step. Then, distances in Euclidean space from PIS (L(PIS))and NIS (L(NIS) were determined for each alternative (see the table above). Comparison of solution results:

Comparison of solution results							
No.	Alt.	SAW		TOPSIS			
		K	RANK	L(NIS)	L(PIS)	K	RANK
56	A_{56}	0.842	1	0.4950	0.1657	0.7492	1
6	A_6	0.768	2	0.4786	0.2047	0.7004	2
34	A_{34}	0.729	9	0.4727	0.2199	0.6825	3
76	A_{76}	0.751	3	0.4558	0.2144	0.6801	4
1	A_1	0.729	8	0.4353	0.2154	0.6690	5
47	A_{47}	0.740	4	0.4208	0.2096	0.6675	6
46	A_{46}	0.731	6	0.4253	0.2169	0.6622	7
84	A_{84}	0.738	5	0.4375	0.2527	0.6339	8
96	A_{96}	0.717	10	0.4486	0.2629	0.6305	9
81	A_{81}	0.730	7	0.4025	0.2375	0.6289	10
33	A_{33}	0.674	15	0.4016	0.2387	0.6272	11

Having applied Dadelo [7] method for the selection of the group of elite security guards, which is based on a single-expert judgement, and having made calculations, elite security guards were selected into *A group* (Table 5). Having applied TOPSIS and SAW methods based on expert group estimation and having made calculations, elite security guards were selected into *B group* (Table 5).

Group A (n=11) was selected according to professional competence weight given by a single expert and measuring the distance between the features that reflect defined criteria and arithmetic average and also the weight given by a single expert. Group B (n=11) was selected by independent experts (n=22) criteria rating by giving different weights. Selection of group B was carried out by adapting multi-criteria decision making TOPSIS and SAW methods and creating special algorithms. Groups A and B have differences and similarities in their quantitative and qualitative features. Five people fell into both groups (45% group match). Both groups had six different people (Table 3).

Estimating the qualitative differences between the groups it was defined that group B has theoretical and practical training (x_1) criteria advantage ($p<0.05$). No essential differences between the criteria were defined. To emphasise and evaluate the differences between group A and B, the security workers that got into both groups were eliminated ($a_{46,}$ $a_{47,}$ $a_{56,}$ $a_{76,}$ a_{81}). Then, groups A and B had seven different persons. Calculation and comparison of the average rate in both groups revealed essential differences ($p<0.05$) among half of the criteria: *theoretical and practical preparing* (x_1), *physical developments* (x_4); *motor abilities* (x_5) (Figure 4).

During A group section procedure *fighting efficiency* (x_6), *physical developments* (x_4,), *mental qualities* (x_3) were emphasised as most important, and in group B: *theoretical and practical preparing* (x_1), *mental qualities* (x_3), *motor abilities* (x_5); *fighting efficiency* (x_6) criterion was considered of moderate importance.

Discussion

During the process of investigation, the algorithm was formed using multi-criteria decision making TOPSIS and SAW methods. Evaluation criteria weights were defined on the basis of Wisdom-of-crowds principle [11,51–55]. Authors of the article aimed at forming a group of experts who would correspond to the following principles: be professional in the field they estimate, be motivated (knowing the aims, objectives and methods of the investigation), not to be influenced by outside factors or each other, and evaluation should be featured by average rates.

The experts involved in the research were selected following all of the following structural requirements. The weights of criteria of security guards revealed the main selection and development tendencies. security guards revealed the main selection and development tendencies. The following levels of criteria were defined: very important (*theoretical and practical preparing*; *mental qualities*; *motor abilities*), important (*fighting efficiency*) and moderate importance (*professional activity*; *physical developments*). Professional activities of security guards encompass

Table 5. Elite guards selected following Dadelo [7] method (group A), and those selected according to the algorithm based on TOPSIS and SAW methods; normalised (Z_i) data average of professional competences.

Elite group persons		Criteria: Theoretical and practical preparation χ_1	Professional activity χ_2	Mental qualities χ_3	Physical developments χ_4	Motor abilities χ_5	Fighting efficiency χ_6	Average
Group A (n=11)	α_{56}	**1.251**	**2.186**	**0.956**	**1.219**	**2.768**	**1.527**	**1.651**
	α_{81}	**0.408**	**1.518**	**1.154**	**2.067**	**1.271**	**0.632**	**1.175**
	α_{47}	**0.954**	**0.836**	**1.659**	**1.550**	**0.698**	**0.738**	**1.073**
	α_{76}	**2.127**	**−0.489**	**0.403**	**2.095**	**0.104**	**1.583**	**0.971**
	α_{106}	−0.478	2.175	0.716	1.135	0.524	1.583	0.942
	α_{46}	**1.619**	**0.577**	**0.573**	**0.512**	**0.449**	**1.414**	**0.857**
	α_{8}	−0.116	2.050	0.442	0.647	−0.180	0.688	0.588
	α_{36}	0.835	−0.126	0.714	1.153	−0.248	1.189	0.586
	α_{73}	0.242	0.516	1.145	0.862	−0.320	0.387	0.472
	α_{52}	0.314	−0.166	0.101	2.122	−0.430	0.676	0.436
	α_{38}	0.186	0.168	1.044	0.137	0.839	0.137	0.418
	$\bar{\chi}$	0.667	0.840	0.810	1.227	0.498	0.960	0.834
	$S\bar{\chi}$	0.776	0.993	0.437	0.674	0.928	0.517	0.382
Group B (n=11)	α_{56}	**1.251**	**2.186**	**0.956**	**1.219**	**2.768**	**1.527**	**1.651**
	α_{81}	**0.408**	**1.518**	**1.154**	**2.067**	**1.271**	**0.632**	**1.175**
	α_{47}	**0.954**	**0.836**	**1.659**	**1.550**	**0.698**	**0.738**	**1.073**
	α_{76}	**2.127**	**−0.489**	**0.403**	**2.095**	**0.104**	**1.583**	**0.971**
	α_{84}	0.394	0.441	0.852	−0.597	2.745	1.358	0.865
	α_{6}	1.055	−0.500	2.651	−0.819	1.895	0.870	0.859
	α_{46}	**1.619**	**0.577**	**0.573**	**0.512**	**0.449**	**1.414**	**0.857**
	α_{34}	2.577	0.799	1.057	−0.350	0.433	−0.163	0.725
	α_{1}	1.358	−1.503	0.607	0.520	1.381	1.696	0.676
	α_{96}	2.375	0.652	−0.652	−0.246	0.223	1.640	0.665
	α_{33}	1.452	−0.562	1.099	−0.359	0.359	0.432	0.403
	$\bar{\chi}$	1.415	0.360	0.942	0.508	1.121	1.066	0.902
	$S\bar{\chi}$	0.725	1.050	0.813	1.076	0.978	0.605	0.326
Differences between group A-B and their efficiency	*d*	*0.748*	*0.481*	*0.132*	*0.719*	*0.623*	*0.107*	*0.068*
	t	*2.337*	*1.104*	*0.475*	*1.877*	*1.532*	*0.444*	*0.452*
	p	*<0.05*	–	–	–	–	–	–

observation, help and conflict resolution. The possibility of threats faced may depend on the value of the objects protected. Actions can be classified into the following stages: threat and offence identification, analysis of the situation, prediction of the possible consequences and solution methods, choice of a solution and the solution itself. Resolved situations, including conflicts, may differ in intensity, level of danger and dynamics; all this depends on the influence of a security guard. In conflict situations with offenders, a security guard must be capable of influencing the opponent psychically, using physical force, special means and weapons.

A security guard must be aware of his/her personal responsibility when making decisions especially in cases where physical contact cannot be avoided and fighting efficiency is necessary. Fighting efficiency, depending on the intensity of resistance and the level of danger, can be classified as follows [56]: 1) minor offence – verbal communication (giving information on responsibility,

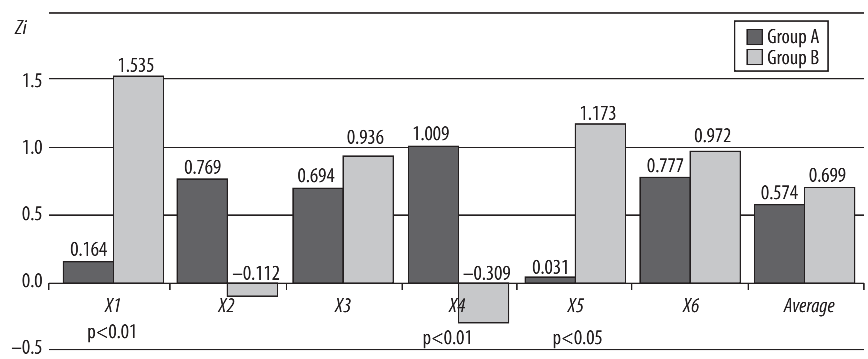

Figure 4. A (*n*=6) and B (*n*=6) professional competences of the group of elite security guards (x_1 – theoretical and practical preparation; x_2 – professional activity; x_3 – mental qualities; x_4 – physical developments; w_5 – motor abilities; w_6 – fighting efficiency).

consequences and requirements); 2) passive resistance (ignoring requirements) – handling the situation (giving orders, non-verbal warning acts, arrest); 3) active resistance (avoiding physical contact, active resistance) – restriction technique application (act of strangling or attempts to cause pain); 4) active attack with an aim to causing physical damage (strikes, attempts to cause pain when striking or strangling) – self-defence techniques and adequate use of special means (strikes, attempts to cause pain when striking or strangling); 5) active attack actions aimed at serious physical damage – self-defence techniques, the use of special means and adequate use of a weapon.

Conclusions

The staff selection algorithm recommended by authors of the article is more efficient by one-third in comparison to other currently used selection methods. Issues pertaining to contemporary selection and rating of security guards, just as any other staff of militarised structures, are considered to be especially relevant. The current situation in the world is unstable; therefore, there is always a high possibility of danger that can be successfully prevented in our society with the help of militarised security systems, including private security staff.

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