STUDY OF DOMINANT QUALITY INDICATORS OF MATERIALS AND DESIGNS OF RAILROAD CONDUCTORS' UNIFORMS

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Abstract: *The article is devoted to the study on determining the basic requirements for the design of conductors' uniforms of passenger rail transport. To solve the problems associated with highlighting the most significant indices for the materials and design features of individual products, the use of expert evaluation method has been proposed. A group of experts has been identified, consisting of clothing design experts, managers and representatives of Ukrzaliznytsia. The most essential indicators for materials, constructions and manufacturing technologies, using the method of ranking with normalized coefficients, have been determined on the example of men's and women's uniform suits. To verify the results, the degree of concordance of experts' opinions on the coefficient of concordance has been determined. The calculated values of the coefficients of concordance for all the considered problems are in the range W=0.69÷0.78, that indicates a high level of experts' agreement. Ranking identifies the sixteen most significant requirements for materials, structures, technologies and cost. Advanced models of women's and men's uniform suits with improved ergonomic and aesthetic performance have been proposed.*

Keywords*: uniform, expert estimation method, material quality indicators, design uniforms, rank correlation of indicators, coefficient of concordance.*

1 INTRODUCTION

Ukrzaliznytsia employs more than 308,000 people, some categories use uniforms. In 2017, the company spent 1.4 million UAH on the purchase of uniforms. All train drivers of locomotives and conductors of rolling stock of passenger trains were provided with uniforms. Their work is related to the influence of a number of harmful production factors: working at night shifts, dusty air, poor microclimate due to the presence of draughts, fluctuations in temperature and humidity, low-frequency vibrations, infrasound and noise. The high risk of injuries is due to a busy schedule, which is three-shifted with most conductors or there may happen extended working hours up to 12 hours. Accordingly, conductors' uniform is a complex multifunctional item that must meet the requirements for protective clothing and provide indicators of ergonomics, reliability, aesthetics and economy [1]. When developing the nomenclature of quality indicators of uniforms and materials for its manufacture, it is necessary to take into account the changing parameters of the environment, harmful production factors and topographies of their impact, the nature of work activity and materials characteristics [2]. The efficiency and duration of the uniform depend on the correct and reasonable choice of materials, design and technological solutions [3-5].

The main task of designing uniforms is the development of structural and harmonious solutions according to the strict classical style. The solution to this problem is related to a comprehensive approach that covers information on the properties and characteristics of textile materials, terms of use and available structural and technological solutions of the uniforms for Ukrzaliznytsia conductors [4, 6].

The preliminary analysis of the working conditions and the available uniforms of the conductors made it possible to establish that its assortment is quite large and consists of coats, cloaks, overcoats, jackets, camisoles, vests, blouses, shirts, trousers, skirts. Depending on the terms of usage, the use of products is possible separately and in kits. Such an analysis has become a prerequisite for the development of a nomenclature of mandatory and recommended indicators of uniforms. The conductors' uniforms should be seasonal, complete and consist of a sufficient and necessary number of items, each of which has an ergonomic, aesthetic and constructive technological solution.

There is a whole range of design requirements for railway workers' uniforms. A number of standardized

(mandatory) indicators is related to materials that can be used for the production of certain uniforms. Another category of requirements is directly related to the design and technological development of products, which, along with the standardized list, should take into account the recommended (additional) indicators of reliability, ergonomics, aesthetics and economical ones [1, 7, 8].

The seasonal uniform kit consists of five to seven products. Considering it as a complex system has allowed us to determine that there is a sufficient number of external and internal factors that influence the course of its operation. Such factors are of different origin and are usually incommensurate, that is, it is difficult to distinguish a common benchmark of comparison. At the initial stage of designing, the designer does not have information about the importance of each factor, so it is difficult to assess the degree of their impact on the response function, which for this statement of the task is a ready-made uniform with a guaranteed term of usage [3, 6, 9].

Separate characteristics (physico-mechanical, hygienic, protective) of the materials have different units of measurement and their values are characterized by interval estimates. That is why the establishment of functional links between them and regulated indicators of uniforms is a very difficult task. Experts' opinions can overcome such complexity, and it also can be done by taking into account the designer's ability to make sound decisions in the event of impossibility of their complete formalization. In this regard, at the initial stage of the study, a task arises which is connected to the choice of the most important and the exception of the least significant factors, which allows to further reduce the number of experimental tests in laboratory and industrial conditions. The generally accepted procedure for screening factors [8, 10] because of a large number of indicators is quite cumbersome, time-consuming and requires considerable time to take the necessary measures.

According to the experience, in a number of cases, the results obtained at intermediate stages may have ambiguous, and sometimes contradictory, meanings. Such difficulties can be overcome by using the specialists' opinions, as well as taking into account the designer's ability to make rational decisions in the event that their full formalization is impossible. Therefore, it has been suggested to use the method of expert estimation to solve the problems related to the identification of the most relevant indicators for the materials and designs of individual products.

The purpose of the article is to determine the dominant indicators for materials, construction and manufacturing technologies of conductors' uniforms of passenger rail transport.

The following tasks have been solved in the article:

1. Requirements for women's and men's uniform suits concerning material, construction, manufacturing technologies and economic indicators have been analyzed and systematized;
2. It has been proposed to use the method of expert estimation in determining the dominant indicators, which allows to formalize the initial information into separate components of the process of uniform creation;
3. The qualification of the expert group has been determined and the level of consistency of their opinions has been checked;
4. The results obtained during refinement of models of uniform suits have been implemented.

2 RESEARCH MATTER AND RESULTS

Designing products you have to take into account a large number of requirements put forward by designers, customers and users of uniforms. Uniforms are purchased at the enterprise expense at annual tenders. Uniforms should meet the indicators of reliability, ergonomics, aesthetics, and to improve the competitiveness of products it is advisable to evaluate the economic indicators.

While designing uniforms, problems may arise due to a great number of requirements [1-4, 11, 12]. The main requirements include:

- the item dynamic conformity, which does not restrict movement, working position or sensory perception; does not cause movements that could be dangerous for the conductor or passengers;
- the item static conformity, which ensures the correct product fit on the body and does not change its correct position throughout the term of usage regardless of the environment, movements and working position of the conductor;
- ease of products usage that does not create complications in the performance of the conductors' duties, allow them to dress quickly and properly, provide the highest possible comfort level, provide information about the position and have elements of corporate identity;
- the comfortable microclimate under clothing. It does not allow the person to cool in the cold season and overheat in conditions of high temperatures, prevents wetting and perspiration;
- maintenance, cleaning and replacement of individual parts.

2.1 Input data

The uniforms effectiveness depends on the properties of the set of materials, which determine its ability to meet the requirements for protective, physical, mechanical and hygienic characteristics, and acceptable structural and technological solutions.

Let us consider the basic requirements with the example of designing uniforms for women and men, which are the most used and all-season clothing conductors. On the basis of the conducted analysis, the list of requirements for indicators of men's and women's uniform clothing of conductors for shoulder (jacket and ladies' jacket) and waist (skirt and trousers) products has been singled out. The basic requirements for materials and ready-made products are given in Table 1.

2.2 Model description

There are a lot of requirements and constraints while designing uniforms. The information availability, its reliability and correct usage largely determine the rationality of the chosen solution. However, in the design of garments, in addition to numerical and statistical data, information covers indicators that are not mathematical. In addition, the decision-making process involves focusing not only on quantitative values, but on aesthetic acceptance and convenience, taking into account the professional characteristics and fashion trends.

Most creative project tasks cannot be solved without human involvement. Choosing a rational solution involves human participation at the stages of formation of initial parameters in order that the final product meets the basic requirements. The peculiarity of designing clothes is the impossibility of formalizing the computing procedures. It is difficult to create formal models and methods that fully reflect the qualitative and quantitative relationships between materials, structures, manufacturing technologies and cost. These difficulties can be overcome by using the method of expert estimation. This method makes it possible to use the knowledge and opinions of experts to determine the dominant indicators in case of impossible complete formalization of the source information [7-10].

An expert estimation to determine the dominant quality indicators of the uniforms involves forming a group of experts, their interviewing, processing expert estimation and analysing the results. The reliability of the group expert estimation depends on the level of coherence of experts` opinion that participates in the survey.

At the first stage, twelve respondents were selected, including specialists from enterprises manufacturing uniforms, conductors, management of the railway, and specialists of research centers and laboratories of the textile industry. They were asked to rank the quality indicators of individual products according to their impact on the forecasted properties of the uniforms.

The method of direct estimating the ranking of initial requirements is difficult to use because of a large number of factors and their indicators (Table 1).

The indicators analyzed are diverse in both quantitative and qualitative characteristics. Therefore, the use of standard methods of expert estimation is not effective and requires adaptation to the specific tasks. A method of determining the rank of a group of indicators on the basis of normalized weight coefficients has been proposed [8].

Table 1 Requirements for material and products (men's and women's suit)

Requirements for material	**Requirements for products**		
	Construction	***Manufacturing technology***	***Economic indicators***
The content of natural fibers in the raw composition [%]	Dynamic conformity [grade]	Tensile loading of seams [H]	The cost of the product [UAH]
Color fastness to chemical influences, wet treatments, ultraviolet radiation, sweat [grade]	Static conformity [grade]	Air permeability of seams [$dm^3/(m^2.s)$]	Guaranteed lifetime [hours]
Crease-resistance [grade]	Ease of usage [grade]	Water permeability coefficient of the seam [$dm^3/(m^2.s)$]	Repair costs [UAH]
Breaking loading [N]	Lining availability	Technological processing of fasteners, vents, pockets, straps, collar	Cleaning costs [UAH]
Elongation at break [%]	Constructive form articulation	Technological processing of the lining	
Resistance to abrasion [cycles]	Direction and location of membership lines	Elasticity of the middle back seam, elbow seam of the jacket/ladies' jacket	
Thickness ratio [%]	Form stability	Individual items duplicate	
Air permeability [$dm^3/(m^2.s)$]	Internal pockets availability	Maintainability	
Water resistance [grade]	Availability of elements for clear belt fixation	The level of technical performance of the product, all available structural elements to the external perception	
Coefficient of thermal diffusivity [m^2/s]	Availability of distinction signs (corporate logo and position)	Level of finishing and ready-making of the product	
Coefficient of thermal conductivity [W/(m.°C)]	Artistic and color design		
Hygroscopicity [%]	Number of cleaning cycles		
Changing linear dimensions after wet treatments [%]			
Number of piles			

2.3 Ranking of task-demand for material and ready-made garment

The first stage identifies four groups of factors that determine the requirements for the material, construction, manufacturing technology and economic performance of the product. For each group, the normalized indicators are defined in the following order:

1. During ranking, *m* experts have been asked to place *n* requirements in the sequence that they consider to be the most reasonable and to assign to each requirement *X* ranks from 1 to *N*. For this rank 1 receives the most preferred indicator and rank *N* – the least important;
2. The normalized coefficient *K* for each of the *q* group of requirements is defined by the formula:

$$K_q = \frac{\sum_{j=1}^{m} X_q^j}{\sum_{q=1}^{n}\sum_{j=1}^{m} X_q^j}, \quad (1)$$

where X_q^j is the rank of the q^{th} group of the requirement provided by the j^{th} expert; q = 1…n; j = 1…m;

3. After the normalization the results have been obtained, which are given in Table 2.

In the second stage, the experts are asked to rank the indicators in each group of requirements. According to the algorithm, normalized coefficients of K_q up to 12 material indices and 24 product indices have been determined. The total normalized ranking coefficient *K* of alternative solutions has been calculated by the formula:

$$K=K_q.K_i \quad (2)$$

where K_i is the normalized coefficient for each i^{th} group of indices.

The ranking results highlight the eight most significant material requirements (Table 3) and the eight product indicators (Table 4).

2.4 Concordance testing of expert judgments

The coherence of expert opinions with a large number of indicators is determined by the level of consistency of opinions of a heterogeneous group of experts. The obtained ranking estimates can be taken as random variables, so generalized statistical characteristics are used to estimate consistency [7-9].

Table 2 Ranking of requirements for material and product

Factor	Requirements for material	Requirements for constructions	Requirements for manufacturing technology	Economic requirements
Normalized coefficient K_q	0.12	0.20	0.31	0.37
Rank	1	2	3	4

Table 3 Ranking of material indicators

№	Indicator	Normalized coefficients			Rank
		Ki	*Kq*	*K*	
1	Crease-resistance	0.04	0.12	0.004	1
2	Breaking loading	0.08	0.12	0.0093	2
3	Air permeability	0.09	0.12	0.0105	3
4	Water resistance	0.12	0.12	0.0140	4
5	The content of natural fibers in the raw material composition	0.13	0.12	0.0152	5
6	Resistance to abrasion, cycles	0.15	0.12	0.0176	6
7	Color fastness to chemical influences, wet treatments, ultraviolet radiation, sweat	0.16	0.12	0.0187	7
8	Elongation at break	0.23	0.12	0.0269	8

Table 4 Ranking of product indicators

№	Indicator	Normalized coefficients			Rank
		Ki	*Kq*	*K*	
1	Dynamic conformity	0.03	0.20	0.006	1
2	Tensile loading of seams	0.05	0.31	0.0155	3
3	Static conformity	0.07	0.20	0.014	2
4	Cost of the product	0.11	0.37	0.04125	6
5	The level of technical performance of the product, all available structural elements to the external perception	0.13	0.31	0.0403	5
6	Ease of usage	0.16	0.20	0.032	4
7	Guaranteed lifetime	0.21	0.37	0.07875	8
8	Lining availability	0.24	0.20	0.048	7

The coherence of expert opinions is estimated through the coefficient of concordance *W* [3], which

is defined as a generalized correlation coefficient for a group of *m* experts. The algorithm for calculating the coefficient of concordance has the following sequence:

Determine the variance of *DR* estimates, the value of which is characterized by the variation between rank estimates in individual professionals:

$$DR = \sum_{i=1}^{i=n} \left\{ \sum_{j=1}^{j=m} x_{ij} - \frac{1}{2} m(n+1) \right\}^2 \quad (3)$$

where $\sum_{j=1}^{j=m} X_{ij}$ *is* the sum of the rankings for each i^{th} factor received from all j^{th} experts; $\frac{1}{2} m(n+1)$ is the average sum of ranks.

The *DR* value is maximal if all the experts ranked the same and is determined by the formula:

$$(DR)_{max} = \frac{1}{12} \cdot n \cdot m^2 \cdot (n^2 - 1) \quad (4)$$

We define the concordance coefficient *W* as the ratio of the actual value obtained to its maximum value:

$$W = \frac{DR}{(DR)_{max}} \quad (5)$$

Estimate the significance of the concordance coefficient using the table values of Pearson criterion χ^2. Based on the calculations, calculate the criterion:

$$\chi_c^2 = m \cdot W \cdot (n-1) \quad (6)$$

It is necessary that the found value $\chi^2_{\ p}$ exceeds the table value, which is determined by the number of freedom degrees f and the probability level *α*:

$$\chi_c^2 \geq \chi_{tabl}^2 \qquad f = (n-1) \quad (7)$$

The results of the calculation of the concordance coefficient for each of the three stages of ranking are given in Table 5. Table 5 shows the definition of the conformation coefficient for the three calculations:

variant 1 - calculation results in Table 2;

variant 2 - expert assessment of requirements to the material;

variant 3 - expert assessment of product requirements.

Table 5 Concordance coefficient

Estimated parameters	Variant 1	Variant 2	Variant 3
Experts *m*	12	12	12
Factors *n*	4	14	26
Estimated dispersion *DR*	566	24 570	145 314
Maximum dispersion DR_{max}	720	32 760	210 600
Concordance coefficient *W*	0.78	0.75	0.69
Pearson criterion χ^2	**28**	**117**	**207**

As it can be seen from Table 5, the values of the calculated concordance coefficients are in the range *W=0.69÷0.78* for ranking tasks of three groups of factors. Such values indicate a high level of coherence of experts' opinions. The calculated values of Pearson criterion χ^2_c exceed the table values of χ^2_{tabl}=6.25…37.65 at the significance level *α*=0.1 [9].

2.5 The new models of railroad conductors' uniforms

According to the rating results, the specialists of different directions in further development of uniform suits have selected a sufficient number of indicators (8 for materials and 8 for products) that meet the requirements of reliability, ergonomics and economy.

Based on the ranking results, the choice of materials has been justified. When choosing fabrics for outerwear and lining, their physical-mechanical (breaking loading) and hygienic (breath ability) are determined. It has been determined that it is advisable to use the fabric of article I1013-045 for manufacturing men's and women's suits. Raw material composition is 90% wool and 10% elastin; surface density 212 g/m^2; kind of weave - satin. All products include a lining of material 434 (Bosfor Nextile) with a surface density of 75 g/m^2, containing 50% viscose, 47% acrylic and 3% elastin.

The dominant quality indicators of material I1013-045 are: crease-resistance 0.53 grade; breaking loading - warp 524 N, weft 397 N; air permeability 368 dm^3/(m^2.s); the content of natural fibers in the raw material composition 90%, abrasion resistance 1100 cycles, colors resistance to chemical treatments, wet treatments, ultraviolet radiation, sweat action as 4 grades; water permeability 30 g/(m^2.s); relative elongation - warp and weft 1.5%.

New design and technological solutions of conductors' uniforms have been proposed, which take into account definite dominant indicators (Figure 1).

Static and dynamic conformities are ensured by further determining the increments of static and dynamic dimensional features. During the design, incremental dimensions have been calculated taking into account the basic working positions and movements of the conductors. Estimates of the dynamic increments of the corresponding static dimensional features have made it possible to establish that additional increments should be introduced in the increments for back to waist, back width, arm length to wrist, thigh measuring. Tolerances that take into account ergonomic requirements are taken as the basis when constructing a conductor uniform.

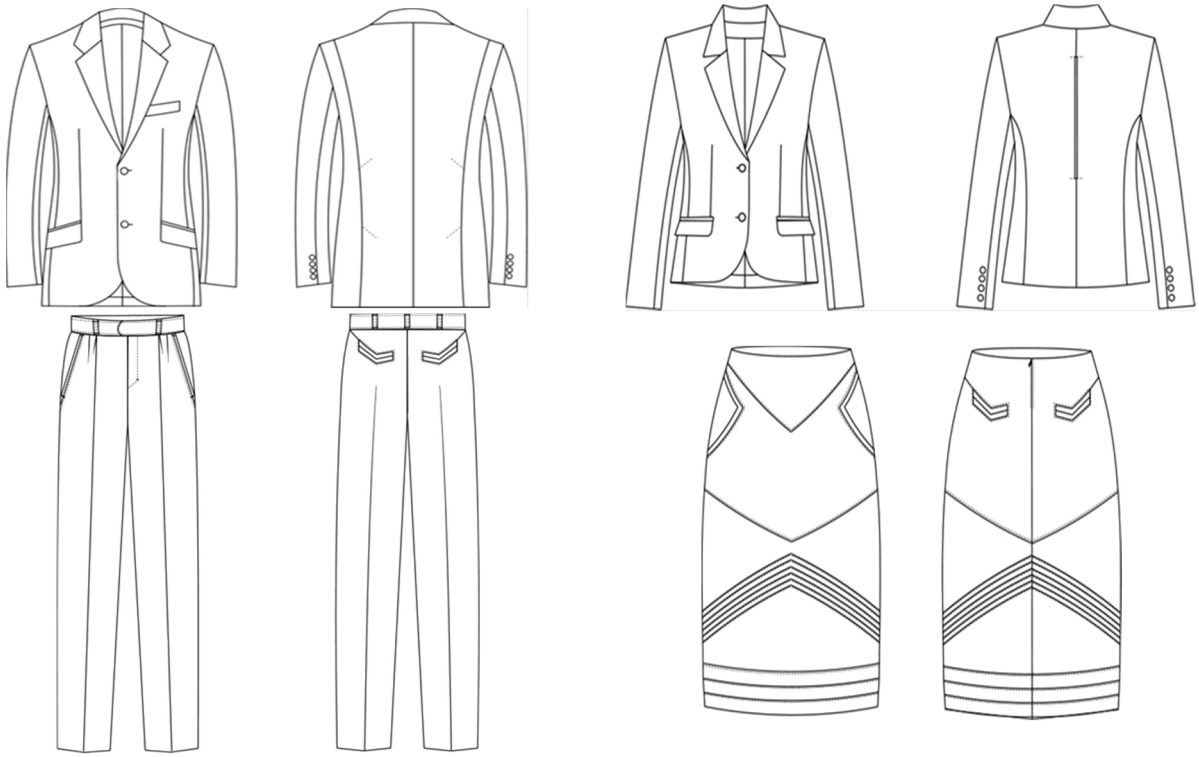

Figure 1 The general looks of the new suits

The absolute values of the tolerances are determined in accordance with the material indices and the design features of the shoulder and waist clothing. In the design of the women's jacket dynamic compliance is provided by the presence of a counter-fold at the back, in the men's jacket - two-sided folds from the shoulder to the waist. The technology of processing knots and elements of clothing through the use of reinforced threads and adhesive tapes has been improved. The guaranteed lifetime is increased up to 30 months. All products allow up to 15 cycles of dry cleaning.

3 CONCLUSIONS

The article deals with the development of advanced sets of conductors' uniforms of passenger rail transport, which have been developed on the basis of certain dominant requirements for materials, structures, manufacturing technologies and cost.

1. The requirements standardized and recommended by the consumers have been analyzed and their list has been compiled to the material, construction, manufacturing technology and economic indicators. It has been determined that while designing garments, the input information contains numerical indicators, statistics and factors that are not mathematically formalized.
2. Based on the conducted analysis, the nomenclature of indicators of conductors' uniforms of men's and women's clothing for shoulder (jacket and ladies' jacket) and waist (skirt and trousers) products has been proposed.
3. A careful analysis of the content task formulation, taking into account the specifics of designing uniforms, necessitated the modification of the original algorithm by the method of expert estimation. A method of ranking factors and indicators based on *normalized* weight coefficients in three stages has been proposed. In the first stage, the experts rank four factors that determine the requirements for material, structure, manufacturing technology and economic performance of the product. The second stage is the ranking of individual indicators of material and ready-made product. In the third stage, to estimate the reliability of the obtained results, the degree of concordance of experts' opinions has been estimated by the magnitude of the concordance coefficient.
4. According to the ranking results, dominant indicators for groups of factors have been established:
   - concerning the material - crease-resistance, breaking loading, air permeability, water resistance, the content of natural fibers in the raw material composition, abrasion resistance, colors resistance to chemical treatments, wet treatments, ultraviolet radiation, sweat action, relative elongation;

- concerning the structure - dynamic and static conformities, ease of usage of the product, lining availability;
- concerning the manufacturing technology - the breaking seams loading, the level of technical manufacturing of the product, all structural elements accessible to the external perception;
- economic - product cost, guaranteed lifetime.

5. The research obtained results were realized during the creation of advanced models of women's suit (ladies' jacket and skirt) and men's suit (jacket and pants).

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