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Application of multidimensional correspondence analysis to identify socioeconomic factors conditioning voluntary life insurance

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Abstract

Insurance companies in their current operations focus mainly on business risks related to insurance products and the best matching of the offer to the needs of potential customers. The selection of appropriate methods to determine the socio-economic characteristics of people who use voluntary life insurance can increase the effectiveness of their sales, while affecting the increase in the efficiency of the insurance industry. Using the multidimensional correspondence method, this document comprehensively identifies the factors conditioning voluntary life insurance. The survey is based on a set of data from a questionnaire. Surveys were conducted among Polish households from the region of Central Pomerania. The results show that access to financial services and products, savings and education determine the existence of life insurance in households from the region of Central Pomerania. This study contributes to literature and practice by showing that multidimensional correspondence analysis can be an effective method for identifying conditions that will increase supply and demand for life insurance.

Keywords: *Multiple Correspondence Analysis, Life insurance, Insurance companies, Central Pomerania, Poland*

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1. Introduction

Life insurance companies are suppliers of important financial services and products for households. Life insurance provides individuals and the economy with a number of important functions. In the face of growing urbanization, population mobility and the formalization of economic relations between individuals, families and communities, life insurance has become increasingly important in the financial decisions of households and individuals [1]. These decisions are made mainly in the context of seeking opportunities to reduce the risk of unforeseen events [2] that cause dysfunctions in household life. Demand for life insurance has increased dramatically in the last few decades, which is due in particular to longer life expectancy [3].

Decisions regarding life insurance are determined by a number of macroeconomic and microeconomic factors. Macroeconomic factors include such factors as: legal regulations, social security system, level of economic development, interest rate, inflation or level of development of the financial system of a given country [1, 4, 5]. In turn, among the microeconomic factors, there are social, demographic, economic and institutional factors [6, 1, 7, 3, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19]. Despite the multitude of studies in this regard, no consensus has been reached on the factors that influence the decision to buy life insurance by households.

The findings on this matter are not consistent. The determinants of life insurance purchase are different in various countries or regions. An incomplete understanding of the factors determining the purchase of life insurance affects the activities of insurance companies and the products and services they offer. Those factors need to be identified. In general, comprehensive identification of factors determining life insurance demand and their accurate assessment at a certain stage is the basis for effective increase of their sales. However, it is difficult to solve this problem by traditional methods, for example based on expert judgments [20, 21]. Therefore, this article presents a multidimensional approach to identify and assess the socio-economic characteristics of households conditioning the existence of voluntary life insurance in the Central Pomeranian Region. Based on the literature review and data from households obtained through a survey using a questionnaire, factors that were subject to empirical verification were identified. Then, the relationship of individual household characteristics to having and not having life insurance was analyzed. This is the basis for more effective activities of insurance companies in the area of sales policy of financial products, which are life insurance, as well as the implementation of new strategies for developing the life insurance market and extending the range of benefits of these products to a larger population. It is expected that presented in the study the multidimensional analysis of correspondence will help decision-makers to better identify socio-economic conditions that will increase the supply and demand for life insurance. The article is organized as follows. Section 2 discusses the method for identifying the determinants of life insurance purchases. Section 3 presents empirical data and results. Section 4 presents the conclusions and implications for the further actions of insurance companies.

2. Method

Multidimensional analysis of correspondence (compliance, connections, suitability) was used to identify the factors conditioning the possession of voluntary life insurance. It is a specialized method from the group of multidimensional methods of coexistence testing. This analysis solves one of the most difficult tasks, namely enables accurate recognition of the co-occurrence of categories of variables or objects, measured on a nominal scale [22]. By using the ordering and classification of objects described simultaneously by many features, it gives the possibility of an in-depth analysis of the studied phenomenon [23]. Hence, this analysis is widely used in sociological research, but it is also a useful research tool in psychology, medicine, biostatistics, IT, economics, management or political science [24, 25, 26, 27, 28, 29, 30, 31]. The advantage of this method is the ability to analyze relationships not only quantitative, but also nominal and ordinal. There are also no requirements regarding the distributions to which the analyzed variables should be subject [32]. Multidimensional correspondence analysis is intended for the analysis of qualitative variables. It allows for graphical presentation of the results of data analysis in the form of a map of perception in low-dimensional space [33]. It is associated with data reduction, which translates into increased data transparency and easier interpretation. This is especially important when analyzing variables with many values [34].

In the study of the relationship between the two features, a simple correspondence analysis is applied using a contingency table. However, for many features, multivariate correspondence analysis is used. Afterwards one of the four ways to record the observed abundance of feature categories is applied. These include, among others, a complex marker matrix, a Burt matrix, a multidimensional contingency table, and a combined contingency table.

The starting point in the analysis of correspondence of many variables is the composite matrix of attachments **Z**. It is a matrix with dimension n r, where n is the number of objects, r is the number of categories of features. Each row of this matrix contains only zeros and one in the place where the selected category is selected. Complex marker matrix Consists of blocks (sub matrices) corresponding to the following variables:

$$\mathbf{Z} = [\mathbf{Z}_1, \mathbf{Z}_2, \dots, \mathbf{Z}_Q] \quad (1)$$

where: Q - number of features; $J = \sum_{q=1}^{Q} J_q, J_q$ – number of features of category q.

Elements of the complex marker matrix take the values 0 and 1, depending on whether the object has a distinguished category of variables or not [35]. 1 - when a given feature has been observed in a given unit. 0 - when it was not observed. The composite matrix of **Z** markers for n statistical units and Q traits consists of sub matrices corresponding to individual traits. The Burt Matrix is determined based on the composite marker matrix:

$$\mathrm{B} = \mathbf{Z}^{\mathrm{T}}\mathbf{Z} = \left[b_{ij}\right]_{J\times J} \quad (2)$$

Burt's matrix, in the literature on the analysis of correspondence, is very often given as the basic matrix for analyzing the co-occurrence of multi-variable categories. It is a symmetrical block matrix ($b_{ij} = b_{ji}$) in which diagonal matrices containing the number of feature category occurrences are located on the main diagonal, and contingency tables for each pair of considered variables are located outside the main diagonal. The total number of Burt matrix (the sum of the numbers of all its features) is nQ^2. Burt's matrix is symmetrical therefore, the numbers of rows and columns are the same and they are determined according to the formula:

$$\sum_{j=1}^{J} b_{ij} = b_{i.} = b_{.j} = Q \cdot \sum_{j=1}^{J} b_{jj} = Q \cdot \mathrm{Z}^{\mathrm{T}}1 \quad (3)$$

where: b_{ij} - elements of Burt's matrix; J - total number of categories of all features.

The edge frequencies of rows and columns are equal to:

$$p_{i.} = \frac{Q \cdot b_{ij}}{n \cdot Q^2} = \frac{Q \cdot \mathrm{Z}^{\mathrm{T}}1}{n \cdot Q^2} = \frac{\mathrm{Z}^{\mathrm{T}}1}{n \cdot Q} \quad (4)$$

The values of $p_{i.}$ Are part of the diagonal matrix of edge frequencies of rows, and thus columns. At the same time, they are components of the edge frequency vector **r**. The observed frequency matrix is calculated according to the formula:

$$\mathrm{P} = \frac{1}{n \cdot Q^2}\mathrm{B} \quad (5)$$

The main purpose of correspondence analysis is to present the analyzed data set in a maximum of three-dimensional space, while maintaining the fullest possible information about the diversity of rows and columns. The matrix distribution method according to singular values is used for this. According to the Greenacre criterion, projection into a lower dimension space is done by the distribution of matrix **A** according to singular values:

$$\mathrm{A} = \mathrm{D}_r^{-1/2}(\mathrm{P} - \mathrm{rr}^{\mathrm{T}})\mathrm{D}_r^{-1/2} = \mathrm{U}\Gamma^2\mathrm{U}^{\mathrm{T}} \quad (6)$$

where: P - observed frequency matrix; $r = [p_{i.}]$ - vector of edge frequency; D_r - diagonal matrix of the edge frequencies of rows; U - eigenvalue matrix$\lambda_k$of matrix A; $\Gamma^2 = [\gamma_k^2]$ - diagonal matrix containing squares of singular values $\gamma_k$of matrix A, $k\epsilon\{1, 2, \dots, K\}$, $K = \sum_{q=1}^{Q}(J_q - 1)$; J_q - number of features of category q.

The singular values of matrix **A** are equal to the square roots of eigenvalues, i.e.

$$\gamma_k^2 = \lambda_k, k\epsilon\{1, 2, \dots, K\} \tag{7}$$

An important concept in the analysis of correspondence is the concept of inertia, which is identified with variance. The total inertia is indicated here because the total inertia of the columns is equal to the total inertia of the rows. Close to zero total inertia means there is a small chance that there will be a significant relationship between categories of features. Total inertia is the sum of eigenvalues:

$$\lambda = \sum_{k=1}^{K} \lambda_k \tag{8}$$

The λ_k values are called major inertia. On their basis, the so-called percentage of inertia (λ_k/λ), which means that part of the original inertia that has been explained by the k projection dimension. In the next step, a matrix is determined containing the coordinates of the feature categories on all axes of real relationships:

$$\mathrm{F} = \mathrm{D}_r^{-1/2}\mathrm{U}\Gamma \tag{9}$$

The next stage of the study is to determine the real space of co-existence of categories of variables K. The space dimension of real relationships based on Burt's matrix analysis is determined on the basis of the formula:

$$K = \sum_{q=1}^{Q} \left(J_q - 1\right) \tag{10}$$

where: J_q - number of the categorical variable q (q = 1, 2, ..., Q); Q - number of variables.

In the search for a lower dimension of space for the presentation of results, while maintaining the least distortion of the initial configuration, the share of the inertia of the set dimension in the total inertia is used, i.e. the sum of all main inertia:

$$\tau_{K^*} = \frac{\sum_{k=1}^{K^*} \lambda_k}{\sum_{k=1}^{K} \lambda_k} = \frac{\sum_{k=1}^{K^*} \lambda_k}{\lambda} \tag{11}$$

where: $K^*\epsilon\{1, \dots,\ K\}$ is the selected projection dimension. Choose K^* for which τ_{K^*} has a value close to 1, and increasing the dimension of the space does not cause a sharp increase in this indicator.

When the Burt matrix is very extensive, the real dimension of the category coexistence space is very high, then a method should be used to determine the optimal dimension K^* of the space. The applied method is the procedure proposed by Greenacre [36]. It is based on a Burt matrix or composite marker matrix. The optimal dimension $K^*$of space is the largest number k for which eigenvalues meet the condition:

$$\lambda_k > \frac{1}{Q}$$

$$K^* = \max\left\{k \in \{1, \dots, K\}: \lambda_k > \frac{1}{Q}\right\} \tag{12}$$

Greenacre also gives the method of "improving" coordinates [36] obtained as a result of the transformation of the Burt matrix, according to the following formula:

$$\tilde{\mathrm{F}} = \mathrm{F}^*\Gamma^{-1}\widetilde{\Lambda} \tag{13}$$

where: $\widetilde{\Lambda}$ - diagonal matrix of the first K^* eigenvalues modified according to the formula:

$$\widetilde{\lambda_k} = \left(\frac{Q}{Q-1}\right)^2 \left(\sqrt{\lambda_k} - \frac{1}{Q}\right)^2 \tag{14}$$

F^*- matrix of the first K^* category coordinates from the matrix F [22, 33, 36].

Based on the correspondence analysis, the location of points relative to the projection center or relative to other points describing categories of features is assessed. The location of points near the projection center means that their profiles are close to the average profile, while the location far from the center means the independence of the features. The close proximity of several points indicates the existence of links between categories of corresponding features. In the case of co-occurrence of features in a space larger than three or when the distribution of points on the chart does not allow to clearly distinguish classes [37, 38], classification methods are used to present relationships between categories of features [39]. Links between categories of features are indicated by using a dendrogram.

3. Empirical results

3.1. Data

The research was based on survey data conducted among 1,000 households of Central Pomerania in Poland. The survey was conducted in the second quarter of 2019, using the direct survey technique. In the course of the research, the number of 746 correctly completed questionnaires was obtained (return rate of 74.6%). The scope of the study covered 2018. The dominant group of households were entities living in rural areas (46.2%), households from cities with over 50,000 inhabitants. inhabitants (27.2%) and smaller towns (up to 50 thousand inhabitants - 26.5%). Due to the development phase of the household, the most numerous group were marriages / partnerships with dependent children (47.1%). Half of the surveyed population were three-person households. In 62.2% of the analyzed households, the head of the family was a man. The average age of the head of the household was 45 years. Almost 65% of the population were units in which the head of the household had at most secondary education. 27.9% of respondents declared higher education. For the majority of respondents (61.1%), the basic source of income was remuneration from employment. Next, the respondents indicated: income from non-agricultural business activity (14.5%), retirement and disability pensions (13.5%) and income from agricultural activity (9.5%). 17.6% of the units included in the study were characterized by an average monthly net income per person in the household not exceeding the level of PLN 1,000. In the case of 36.6% of respondents, the amount of income category considered was higher than PLN 2,000/person. 50.9% of the analyzed households were characterized by a steady increase in income in 2004-2018, while 61.4% of entities were characterized by a steady increase in expenditure in this period. 34.5% of expenditure was allocated to the purchase of food and non-alcoholic beverages. Over half of the population (50.9%) diversified their sources of income. 92.3% of entities in the surveyed group of households in Central Pomerania used financial services or products, including half of this group (50.3%) declared having a life insurance policy.

3.2. Identification of factors conditioning voluntary life insurance - analysis results

Based on the questionnaire, potential household characteristics affecting life insurance were selected (Table 1). For each qualitative feature whose number of possible variants was greater than 1, an appropriate number of new features reflecting individual categories was introduced.

Table 1. Set of potential features accepted for the study

Name Features	Description of the feature and its categories
LIN	life insurance: without life insurance; has life insurance
AGE	under 45 years old; above 45 years old
EDU	education of the head of a household: basic; basic vocational; secondary; post-secondary; higher
EC	economic education of the head of the household: yes; no
LHM	number of household members: less than 3 people (<3 people); 3 or more people (3+ people)

SHME	share of household members engaged in gainful employment in the total number of members of the household: <0.5; 0.5-0.99; 1
SCH	share of children in the total number of people in the household: 0; <0.5; ≥0.5
DP	household development phase: single young person's household; young marriage/partnership without a child; single person with a dependent child/child; marriage/partnership with dependent children; marriage/partnership in middle or old age without dependent children; single household older person; other
TSE	socioeconomic type of household (main source of income): employees; farmers; self-employed; pensioners; other
LOK	household location: village; city up to 50,000 residents; a city of over 50,000 residents
SI	steady income increase since 2004: yes; no
INC	average monthly net income per person in a household: up to PLN 1000; PLN 1001-1500; PLN 1501-2000; above PLN 2,000
HARD	difficulties in accessing financial services or products: yes; no
SAV	funds collected in the form of savings in the household: yes; no
DEB	household debt: yes; no

In the case of examining the relationship between the categories of dependent features and categories of features associated with it, a Burt matrix of 46×46 was obtained. The dimension of the real space of coexistence of the feature categories was 31. Then, a lower dimension of the space common to row and column profiles was sought, so that as much of the total inertia as possible was explained. The matrix of standardized differences was distributed according to singular values and it was examined to what extent the total inertia was explained by the eigenvalues of the lower dimension spaces. Table 2 presents the eigenvalues of the matrix λ_k of standardized differences (squares of singular values γ_k), the percentage of inertia λ_k/λ and the cumulative percentage, i.e. the share of eigenvalues from the K dimension in total inertia.

Table 2. Eigen and singular values and the degree of explanation of the total inertia

Number of dimensions	Values		Percentage	
K	singular	eigen	intertia	accumlated
1	0.5030	0.25304	12.2	12.2
2	0.4574	0.20925	10.1	22.4
3	0.3423	0.11717	5.7	28.0
4	0.3138	0.09847	4.8	32.8
5	0,3010	0.09063	4.4	37.2
6	0.2926	0.08564	4.1	41.3
7	0.2814	0.07920	3.8	45.2
8	0.2795	0.07813	3.8	48.9
9	0.2747	0.07544	3.7	52.6
10	0.2710	0.07341	3.6	56.1
11	0.2614	0.06835	3.3	59.5
12	0.2594	0.06726	3.3	62.7
13	0.2553	0.06517	3.2	65.9
14	0.2508	0.06292	3.0	68.9
15	0.2461	0.06057	2.9	71.8
16	0.2442	0.05963	2.9	74.7

17	0.2383	0.05680	2.7	77.5
18	0.2330	0.05428	2.6	80.1
19	0.2271	0.05156	2.5	82.6
20	0.2226	0.04954	2.4	85.0
21	0.2175	0.04729	2.3	87.3
22	0.2121	0.04500	2.2	89.5
23	0.2050	0.04203	2.0	91.5
24	0.1997	0.03986	1.9	93.4
25	0.1855	0.03440	1.7	95.1
26	0.1778	0.03162	1.5	96.6
27	0.1672	0.02795	1.4	98.0
28	0.1318	0.01738	0.8	98.8
29	0.1108	0.01228	0.6	99.4
30	0.0815	0.00664	0.3	99.7
31	0.0759	0.00576	0.3	100.0
		λ = 2.06667		

The optimal projection dimension of the variable category space, according to the Greenacre criterion, is selected based on the condition: $\lambda > 1/Q$. In the analyzed case, the value $1/Q = 1/15 = 0.067$ and indicates the space R^{12}. Table 2 presents singular and eigenvalues modified according to Greenacre's proposal. Analyzing the modified eigenvalues and the share in the inertia of the total inertia of individual dimensions (Table 3), a two-dimensional space was selected for the graphic presentation of the coexistence of the categories of features, which maps about 74.2% of the total inertia.

Table 3. Modified eigen and singular values and the degree of explanation of the total inertia

Number of dimensions	Values		Percentage	
K	singular	eigen	intertia	accumlated
1	0.19968	0.03987	46.8	46.8
2	0.15277	0.02334	27.4	74.2
3	0.05411	0.00293	3.4	77.7
4	0.03407	0.00116	1.4	79.0
5	0.02567	0.00066	0.8	79.8
6	0.02032	0.00041	0.5	80.3
7	0.01342	0.00018	0.2	80.5
8	0.01229	0.00015	0.2	80.7
9	0.00940	0.00009	0.1	80.8
10	0.00723	0.00005	0.1	80.8
11	0.00180	0.00000	0.0	80.8
12	0.00064	0.00000	0.0	80.8

Graphic presentation of the results of correspondence analysis in two-dimensional space is shown in Figure 1.

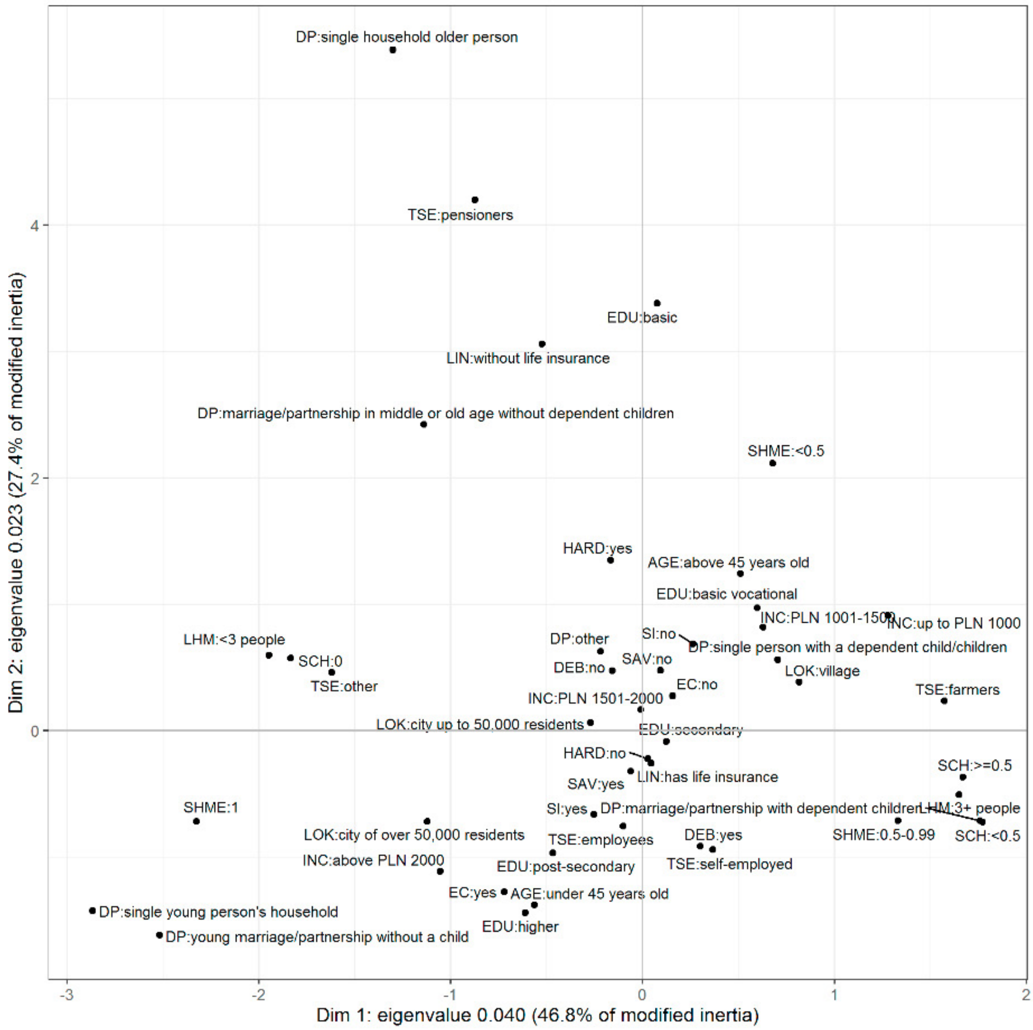

Fig. 1. Presentation of the results of relationships of feature categories in R^2.

Based on the analysis, it can be concluded that respondents who had life insurance indicated no difficulties in accessing financial services and products. This means that the purchase of a life insurance policy is not only a result of consumer demand. Supply-side factors are also important. The activities of insurance companies in the field of brokerage and distribution of life insurance determines their availability, impact on the price and scope of insurance coverage [40]. Life insurance was also conditioned by households accumulating funds in the form of savings. Sen and Madheswaran [9] came to similar conclusions indicating that saving has a positive relationship with the demand for life insurance. Savings are the resultant of household disposable income. As income increases, savings increase. They can be used for investments, including life insurance, as some insurance products combine insurance with the investment component. They are so-called life insurance with an investment fund. Savings are also a form of self-insurance. According to Peter [41] self-insurance and market insurance can have a substitution or complementary relationship. Thus, life insurance can help meet specific needs and provide an effective risk management strategy. Choosing a life insurance policy allows households to cope with many shocks they experience [42] and also enables them to increase wealth [43]. Similar findings are observed in relation to the level of education. Having a life insurance policy was associated with the secondary education of the household head. In turn, the lack of life insurance was associated with the primary education of the household head. This means that education can promote insurance awareness and risk understanding, and thus supports life insurance demand [44]. A higher level of education is associated with a stronger desire to protect insured dependents and to provide them with an adequate standard of living [45]. Particular attention is paid to safeguarding the child's future [46]. This is evidenced by studies conducted according to which households of a lonely, elderly person and marriage / partnership in middle or older age without dependent children did not use life insurance. Like the households of pensioners, they also did not have life insurance. This is due on the one hand to the low incomes of this social group, and on the other hand to the state's social policy regarding social security for people who have reached retirement age. Many times, it has been proven in life insurance research that the probability of having life insurance decreases with age. Older age implies less need for insurance coverage. An important role is also played by the amount of life insurance premium, which increases with age [47].

Conclusion

The study presents the application of a multidimensional compliance analysis to examine the relationships between categories of features that characterize the possession of life insurance by households from the Central Pomerania region. On the basis of a review of the literature and data contained in the questionnaire, a selection of analyzed features was made, which were assigned appropriate categories. The results of the analysis prove that the respondents who had life insurance indicated that they had no difficulties in accessing financial services and products. They were also people who declared collecting funds in the form of savings. Relationship with having life insurance also had a feature such as secondary education. In turn, the lack of life insurance category was associated with such categories as: basic education, pensioners, the household of a lonely, elderly person and marriage/partnership in middle or older age without dependent children. Obtained research results allow to provide implications for future activities of insurance companies, which should be aimed at increasing the demand and supply of life insurance. The obtained research results suggest that insurance mediation should play an important role in this process. This is an important element of life insurance distribution due to the complexity of insurance products and low insurance awareness of the majority of the population. It is also important to provide a comprehensive sales service and adapt the insurance product to the individual needs of customers who differ due to a number of socioeconomic features. This is also due to the fact that life insurance is used for various purposes, including to provide the insured with income after reaching retirement age, to provide livelihood for relatives after the death of the insured, to secure the future of their children, and to accumulate wealth. At the same time, the conducted studies prove that the level of education and maintaining funds in the form of savings conditioned the existence of life insurance. Education plays a significant role in the process of increasing household insurance awareness, which contributes to increasing the sale of life insurance policies. That is why the importance of preventive actions of insurance companies has been emphasized many times. In turn, households with savings by having additional security in the form of life insurance will increase their protection in the event of unforeseen events. They are also people who are most likely looking for alternative forms of resource allocation to increase their wealth.

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