

FEATURES OF USING VBA IN TEACHING ACTUARIAL MATHEMATICS

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ABSTRACT

The article is devoted to the analysis of practice of application of specific computational techniques within MS Excel, including VBA, for teaching selected topics in actuarial mathematics.

Formulation of the problem. With the evolution of financial and actuarial models towards complexity and reliance on machine learning and data science, there is a growing demand for modern mathematicians, particularly actuaries, to acquire new skills and knowledge. This demand is being driven by new fintech trends in banking and insurance, such as smart payments, real-time credit risk assessment, automated reputation management, customer analytics, fraud detection and cryptocurrency trading. As a result, the training of future actuaries must meet high standards to ensure they are equipped to handle the sophisticated mathematical calculations required by insurance companies and other financial institutions.

Materials and methods. To yield results, both theoretical methods, which involve analyzing books and publications, in particular in professional journals in the domains of finance and actuarial mathematics, and empirical methods, entailing the observation of the educational process aimed at training prospective actuaries, are employed in this study.

Results. A study aimed at tackling the challenges encountered in teaching actuarial mathematics topics, such as life expectancy and mortality tables, revealed that incorporating a balanced blend of theoretical concepts and hands-on applications, coupled with illustrating mathematical models through real-world examples and reinforcing diverse computational techniques, constitutes a cornerstone of successful training for aspiring actuaries. Leveraging a versatile and user-friendly tool like VBA (Visual Basic for Applications) integrated into MS Excel enables educators to customize examples and assignments to match the intricacy and emphasis of their syllabus, thereby offering students a more targeted learning journey.

Conclusions. The teaching of mathematical disciplines, especially financial and actuarial mathematics, in academic programmes for future actuaries requires the adaptation of traditional methods and approaches. In particular, the integration of VBA is key to teaching specific actuarial mathematics concepts, which aims to equip students with the necessary practical competencies. VBA facilitates interactive learning by enabling students to manipulate variables and observe changes in calculations in real time, which improves their understanding of actuarial concepts. VBA also allows you to automate repetitive tasks involving complex mathematical calculations, which saves time and reduces errors. Therefore, its use is recommended when teaching topics involving tabular data, especially life expectancy.

KEYWORDS: *teaching actuarial mathematics; actuarial education; life contingency table; VBA; MS Excel.*

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ОСОБЛИВОСТІ ВИКОРИСТАННЯ VBA У ВИКЛАДАННІ АКТУАРНОЇ МАТЕМАТИКИ

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АНОТАЦІЯ

Стаття присвячена аналізу практики застосування конкретних обчислювальних прийомів у середовищі MS Excel, зокрема VBA, для викладання окремих тем актуарної математики.

Формулювання проблеми. Постійне ускладнення фінансових та актуарних моделей, що залучають машинне навчання і статистичний аналіз даних, спричиняє стійкий попит на сучасних математиків, зокрема актуаріїв, які повинні володіти новими навичками і знаннями. Цей попит посилюється новими фінтех-тенденціями в банківській та страховій сферах, такими як смарт-платежі, оцінка кредитних ризиків у режимі реального часу, автоматизоване управління репутацією, клієнтська аналітика, виявлення шахрайства та торгівля криптовалютами. Як наслідок, підготовка майбутніх актуаріїв повинна відповідати високим стандартам, щоб вони були здатні виконувати складні математичні розрахунки, яких вимагають страхові компанії та інші фінансові установи.

Матеріали і методи. Для отримання результатів у дослідженні використано як теоретичні методи, що передбачають аналіз книг і публікацій, зокрема в професійних журналах у галузі фінансів та актуарної математики, так і емпіричні методи, що передбачають спостереження за навчальним процесом, спрямованим на підготовку майбутніх актуаріїв.

Результати. Дослідження, зосереджене на вирішенні проблем, що виникають при викладанні таких тем актуарної математики, як побудова таблиць тривалості життя і смертності, показало, що інтеграція безперервного поєднання теоретичних і практичних компонентів, що супроводжується демонстрацією математичних моделей на практичних прикладах і посиленні різних обчислювальних методів, є фундаментальним аспектом ефективної підготовки майбутніх актуаріїв. Використання в навчальному процесі такого інтегрованого в MS Excel гнучкого й легкого в опануванні інструменту, як VBA (Visual Basic for Applications), дозволяє викладачам адаптувати приклади та вправи відповідно до складності та цілеспрямованості їхнього навчального плану, надаючи студентам більш цілеспрямований досвід навчання.

Висновки. Викладання математичних дисциплін, особливо фінансової та актуарної математики, в рамках академічних програм підготовки майбутніх актуаріїв вимагає адаптації традиційних методів і підходів. Зокрема, інтеграція VBA має ключове значення для викладання специфічних концепцій актуарної математики, що має на меті забезпечити студентів необхідними практичними компетенціями. VBA полегшує інтерактивне навчання, даючи можливість студентам маніпулювати змінними та спостерігати за змінами в обчисленнях у реальному часі, що покращує розуміння актуарних концепцій. Також VBA дозволяє автоматизувати повторювані завдання, пов'язані зі складними математичними розрахунками, що економить час і зменшує число помилок. Тому при викладанні тем, що залучають табличні дані, особливо очікуваної тривалості життя, рекомендується його використання.

КЛЮЧОВІ СЛОВА: викладання актуарної математики; актуарна освіта; таблиця тривалості життя; VBA; MS Excel.

INTRODUCTION

Formulation of the problem. On January 1, 2024, a new edition of the Law of Ukraine “On Insurance” came into effect. This edition is the result of the active integration of Ukrainian insurance legislation into the requirements of the European Union. Additional requirements and standards are being implemented, including the approved and effective Regulation on the procedure for forming technical provisions by insurance companies (Board of the National Bank of Ukraine, 2023) and the International Financial Reporting Standard 17 “Insurance Contracts” (IFRS 17 Insurance Contracts, 2024). The requirements of the relevant regulatory documents provide for the construction and active implementation of complex models of actuarial mathematics.

Previously, most classical models were relatively simple and could, in principle, be calculated using a calculator or in Excel. However, nowadays, an increasing number of actuarial and financial mathematics models involve machine learning and data science methods. We are hearing more and more about fintech technology trends in banking and insurance. Cases related to smart payments, real-time credit risk assessment using intellectual data processing systems, automation of brand and company reputation management, customer-oriented analytics, fraud detection, and cryptocurrency trading are becoming increasingly common.

All of this necessitates the application of new skills and knowledge by modern mathematicians in the insurance and banking sectors — specifically, actuaries. Consequently, the training of such specialists must adhere to the highest standards, as their future roles as actuaries will involve crucial mathematical calculations for an insurance company.

Relevance of research. The training of actuaries includes shaping the insurance rate policy, computing insurance provisions and the necessary amount of the insurance company’s capital, ensuring its stability, reliability, and solvency, and controlling main risks such as underwriting, market, credit, operational, and liquidity risks.

Actuaries conduct quarterly verifications of the liquidity adequacy test of insurance companies, participate in preparing insurance and financial reports, and compile the annual actuarial report. The position of the responsible actuary entails making

strategic management decisions for the insurance company in collaboration with the chairman of the board and key officials of the insurer.

Educators and practitioners such as (Wu, 2015; Gan, 2017; Martínez et al., 2020) underscore the significance of incorporating VBA (Visual Basic for Applications) into actuarial practice and its role in cultivating essential competencies among students.

Aim of research. The aim of this study is to examine the effective application of specific computational techniques within MS Excel, including VBA, for teaching selected topics in actuarial mathematics, identify and analyze challenges encountered when teaching topics such as evaluating contingency tables using computational techniques in MS Excel, explore the effectiveness of utilizing VBA and other computational tools in addressing challenges related to teaching actuarial mathematics topics, propose strategies for integration of MS Excel and VBA into the curriculum for actuarial mathematics education.

THEORETICAL FOUNDATIONS OF THE STUDY

Disciplines such as mathematical analysis, algebra, financial analysis, fundamentals of economics, and, notably, probability theory and mathematical statistics, form the foundation for the qualitative preparation of actuarial models. For instance, many cash flow models incorporate a discounting model that blends financial analysis approaches with the scenario approach of probability theory.

At the core of any insurance company's operations lies a balanced insurance rate policy. Actuarial mathematics employs the balance equation to calculate the so-called fair price of the insurance rate. This equation ensures equality at the time of concluding the insurance contract between the expected present value of future benefits for the insurance company and the client's payments to the insurance company.

The initial approach to studying this model for a long-term life insurance contract involves working with probabilities of death and survival throughout the term of the insurance contract. For each year of the insurance contract, the value at the time of concluding the insurance contract of the discounted benefit, multiplied by the probability of receiving a benefit for the corresponding insurance year, is calculated.

For instance, the expected present value for a whole life insurance contract with the benefit of 1 paid at the end of the insured person's death is given by:

$$A_x = \sum_{k=0}^{\infty} v^{k+1} {}_k p_x q_{x+k}$$

where v represents the discount factor, and ${}_k p_x$ and q_{x+k} are the probabilities of surviving or dying, respectively, during one year for the insured person at the age of x years at the time of concluding the life insurance contract. Special actuarial notations are employed for the typical components of classic insurance contracts, facilitating the subsequent construction of actuarial models based on these components. Similar to A_x notations are used for a term life or pure endowment insurance contracts, for the endowment insurance contract, or for various annuity payments (International Actuarial Notation, 1949–1950).

However, this approach involves rather complicated calculations of sums. Therefore, an alternative is to use so-called commutation functions. The formulas for calculating the main commutation functions are as follows (Zubchenko, 2016):

$$\begin{aligned} D_x &= v^x l_x, & N_x &= \sum_{j=x}^{\omega} D_j, & S_x &= \sum_{j=x}^{\omega} N_j, \\ C_x &= v^{x+1} d_x, & M_x &= \sum_{j=x}^{\omega} C_j, & R_x &= \sum_{j=x}^{\omega} M_j. \end{aligned}$$

In this case, the main insurance functions for the whole life insurance, term life and pure endowment insurance can be calculated using commutation functions much more simply:

$$A_x = \frac{M_x}{D_x}, \quad A_{x:\overline{n}|}^1 = \frac{M_x - M_{x+n}}{D_x}, \quad {}_n E_x = \frac{D_{x+n}}{D_x}.$$

RESEARCH METHODS

Analysis of personal pedagogical experience in the organization of the educational process of certain issues of actuarial mathematics and discussion of results with colleagues. Theoretical (analysis of educational sources in the field of finance and actuarial mathematics) and empirical (observation of the educational process of training future actuaries) methods of scientific investigation.

RESEARCH RESULTS

However, it is extremely important for future actuaries to be able to quickly and effectively perform relevant calculations on the insurance basis -- the life table, which contains statistical data on the survival of individuals of the corresponding age. For example, the following figure shows the calculation of commutation functions for the educational training basis AM92 (Institute of Actuaries, 2002) (see Fig. 1).

For real case studies, students use life contingency tables from open sources, such as the State Statistics Service of Ukraine (State Statistics Service of Ukraine, 2022).

Relevant calculations of commutation functions, insurance functions, insurance rates, payments, and sums can conveniently be performed, for example, in Microsoft Excel. Here, a typical choice would be between using regular Excel tools with standard functions and the Visual Basic for Applications (VBA) editor built into Excel. For instance, to find the necessary value of the commutation function based on the insurance basis, one can use the standard Excel function VLOOKUP (Fig. 2).

However, as an alternative, you can write a universal macro in VBA, thus avoiding being "tied" to the cells of a specific Excel sheet (Fig. 3).

i	4,0%
i ⁽¹²⁾	0,03928
u	0,96154
d	0,03922

i ⁽¹²⁾	1,01820351
i/δ	1,01986927

age	l_x	d_x	q_x	p_x	u^{x+1}	D_x	N_x	C_x	M_x	R_x	S_x
17	10 000,0000	6,0000	0,000600	0,9994	0,4936	5 133,73	119 959,94	2,96	519,89	27 725,81	2 398 087,20
18	9 994,0000	5,9364	0,000594	0,9994	0,4746	4 933,32	114 826,20	2,82	516,93	27 205,92	2 278 127,26
19	9 988,0636	5,8630	0,000587	0,9994	0,4564	4 740,76	109 892,88	2,68	514,11	26 689,00	2 163 301,06
20	9 982,2006	5,8096	0,000582	0,9994	0,4388	4 555,75	105 152,13	2,55	511,43	26 174,89	2 053 408,17
21	9 976,3909	5,7564	0,000577	0,9994	0,4220	4 377,98	100 596,38	2,43	508,88	25 663,45	1 948 256,05
22	9 970,6346	5,7032	0,000572	0,9994	0,4057	4 207,16	96 218,40	2,31	506,46	25 154,57	1 847 659,67
23	9 964,9313	5,6700	0,000569	0,9994	0,3901	4 043,04	92 011,24	2,21	504,14	24 648,11	1 751 441,27
24	9 959,2613	5,6469	0,000567	0,9994	0,3751	3 885,32	87 968,21	2,12	501,93	24 143,97	1 659 430,03
25	9 953,6144	5,6337	0,000566	0,9994	0,3607	3 733,77	84 082,88	2,03	499,81	23 642,04	1 571 461,82
26	9 947,9807	5,6405	0,000567	0,9994	0,3468	3 588,13	80 349,12	1,96	497,78	23 142,23	1 487 378,94
27	9 942,3402	5,6671	0,000570	0,9994	0,3335	3 448,17	76 760,99	1,89	495,82	22 644,45	1 407 029,82
28	9 936,6730	5,7037	0,000574	0,9994	0,3207	3 313,66	73 312,82	1,83	493,93	22 148,63	1 330 268,83
29	9 930,9694	5,7600	0,000580	0,9994	0,3083	3 184,38	69 999,16	1,78	492,10	21 654,70	1 256 956,02
30	9 925,2094	5,8559	0,000590	0,9994	0,2965	3 060,13	66 814,78	1,74	490,33	21 162,60	1 186 956,85

Fig. 1. Calculation of commutation functions using AM92 mortality.

Source: calculated by the authors based on (Institute of Actuaries, 2002).

B4 : ✕ ✓ f_x =VLOOKUP(\$A4;'am92'!\$A\$9:\$L\$120;10;0)

	A	B	C	D	E	F	G
1		ВПР	vlookup				
2							
3	age	M _x	D _x	N _x	A _x	a _x	a ^k _x
4	17	519,889	5133,73	119960	0,10127	23,37	23,37

Fig. 2. Using VLOOKUP function in MS Excel.

Source: calculated by the authors based on (Institute of Actuaries, 2002).

```
Const ii = 0.04, delta = 3.92207131532813E-02, v = 0.961538461538461
Public Function bs(r)
Dim res
If r = "d" Then
res = "am92"
ElseIf r = "2d" Then
res = "am92@2"
ElseIf r = "d6" Then
res = "am92_6p"
End If
Set bs = ThisWorkbook.Worksheets(res)
End Function
Public Function M_x(x, r)
M_x = bs(r).Cells(x, 10)
End Function
Public Function D_x(x, r)
D_x = bs(r).Cells(x, 7)
End Function
Public Function N_x(x, r)
N_x = bs(r).Cells(x, 8)
End Function
```

Fig. 3. Using VBA macro instead of VLOOKUP.

Source: author's own elaboration.

```
Public Function ntar(x, n, l, k, m, kz, sex, prog)
ntar = (Alxn(x, n, "d", sex) + Exn(x, n, "d", sex)) / al_xlk_pr(x, l, k, "d", sex)
End Function
Public Function npr(x, n, l, k, s)
npr = s * (Alxn(x, n, "d") + Exn(x, n, "d")) / al_xlk_pr(x, l, k, "d")
End Function
Public Function gpr(x, n, l, k, s, init, f, e)
gpr = (init + s * (1 + f) * (Alxn(x, n, "d") + Exn(x, n, "d"))) / ((1 - e) * al_xlk_pr(x, l, k, "d"))
End Function
Set bs = ThisWorkbook.Worksheets(res)
End Function
Public Function M_x(x, r)
M_x = bs(r).Cells(x, 10)
End Function
Public Function D_x(x, r)
D_x = bs(r).Cells(x, 7)
End Function
Public Function N_x(x, r)
N_x = bs(r).Cells(x, 8)
End Function
```

Fig. 4. Using VBA macro.

Source: author's own elaboration.

The VBA approach is undoubtedly more versatile. As a further step in modeling the dynamics of an insurance company, VBA provides the opportunity to quickly program the calculation of the insurance net rate, net payment, and gross premium without being bound to specific Excel objects (Fig. 4).

And to present the calculation results in the form of a dynamic actuarial calculator, where, depending on the age, insurance program, contract term, payment term, frequency, loading for expenses of the insurance company, and insurance sum, one can calculate the net rate, gross rate, and gross premium (Fig. 5).

Age of insured person	35
Insurance Program	1
Term of the contract	20
Term of payments	20
Frequency of payments	1
Loading for expenses	20%
Sum insured	150 000

Net rate	3,2969%
Gross rate	4,1212%
Insurance sum	150 000,00
Gross premium	6 182

Fig. 5. Actuarial calculator.

Source: author's own elaboration.

A continuous combination of theoretical and practical components, along with the demonstration of the mathematical model on practical cases and reinforcement of several variants of calculations, are integral components of successfully training actuaries. The following figure shows an example of modeling the net premium insurance provision for the endowment life insurance contract (Fig. 6).

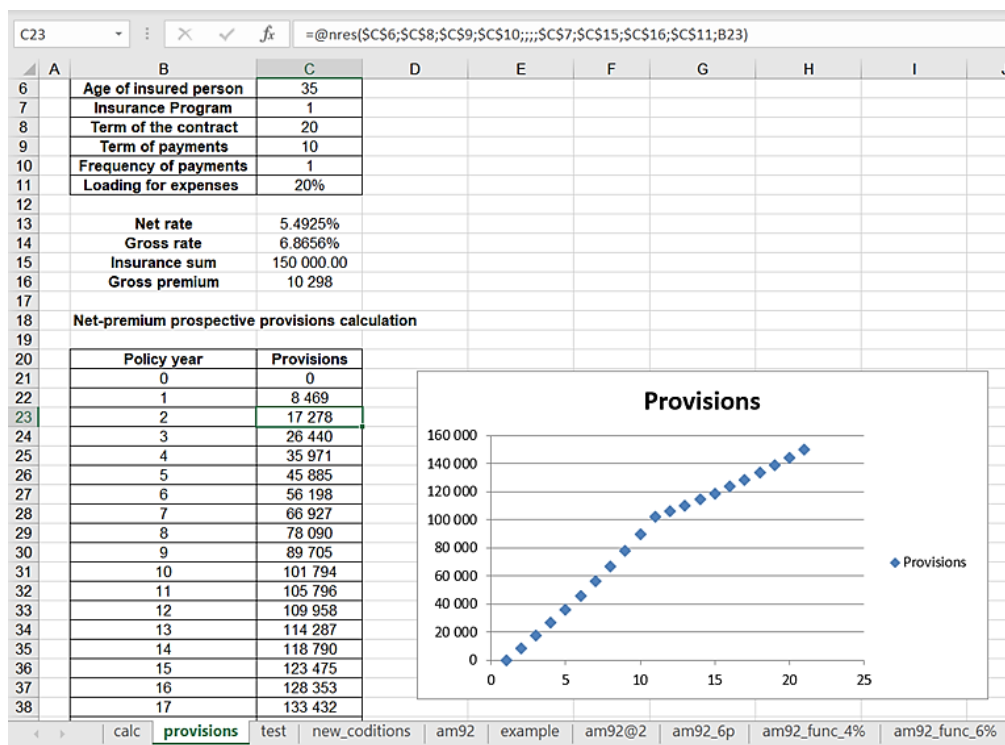


Fig. 6. Net premium insurance provision for the endowment life insurance contract.

Source: calculated by the authors based on (Institute of Actuaries, 2002).

DISCUSSION

Conducting actuarial mathematics courses at the Department of Probability Theory, Statistics, and Actuarial Mathematics involves the study of theoretical material during lectures in accordance with the developed programs, combined with practical exercises using modern software. Students are provided with all necessary recommendations, examples, and templates. An integral part includes group work, studying business cases, team competitions, group discussions, and Q&A sessions. Students implement individual projects, receiving step-by-step recommendations and constant support from instructors. This practical experience better prepares them for careers in the field by bridging the gap between theoretical knowledge and practical application.

Using VBA (Visual Basic for Applications) in teaching actuarial mathematics, especially when working with life expectancy tables, offers several advantages and features. Among them, the following should be highlighted.

Automation: VBA allows for the automation of repetitive tasks involved in actuarial calculations. This automation streamlines the process of working with life expectancy tables, saving time and reducing errors.

Customization: VBA enables customization of calculations based on specific requirements or scenarios. Educators can tailor examples and exercises to match the complexity and focus of their curriculum, providing students with a more targeted learning experience.

Interactivity: VBA facilitates interactive learning experiences by allowing students to manipulate variables and observe the resulting changes in calculations in real time. This hands-on approach enhances understanding and engagement with actuarial concepts related to life expectancy.

Visualization: VBA can be utilized to create visual representations of data derived from life expectancy tables, such as charts or graphs. Visualizations help students interpret and analyze the data more effectively, reinforcing key concepts and insights.

Integration with Excel: Since VBA is integrated with Excel, educators can leverage the spreadsheet software's familiar interface and functionality. This integration simplifies the process of incorporating VBA scripts into teaching materials and encourages students to apply their Excel skills in actuarial contexts.

The Department of Probability Theory, Statistics, and Actuarial Mathematics of Taras Shevchenko National University of Kyiv consistently develops materials and textbooks, covering topics in financial mathematics and risk theory (Mishura, 2016; Mishura & Ragulina, 2016; Mishura & Ralchenko, 2021), both life insurance (Zubchenko, 2016) and mathematical methods for insurance types beyond life insurance (Zubchenko & Yamnenko, 2023). Collaborating with the Public organization "Society of Actuaries of Ukraine," the department's professors actively participate in working groups focused on the development of insurance legislation, enhancing the efficiency of training actuaries and financial analysts, and standardizing Ukrainian actuarial and financial terminology (Zubchenko & Mishura, 2016, 2018).

The department has extensive experience in training actuaries. Graduates from the department are employed in the largest insurance companies in Ukraine and around the world, the National Bank of Ukraine, banks, and investment companies. Many students and alumni have successfully completed international qualification exams conducted by the British Institute and Faculty of Actuaries, thereby validating their highest qualifications at the international level.

CONCLUSIONS AND PROSPECTS OF FURTHER RESEARCH

In summary, utilizing VBA in teaching actuarial mathematics, particularly in the context of life expectancy tables, offers numerous benefits, including automation, customization, interactivity, visualization, integration with Excel, scenario analysis, debugging skills development, and real-world application. These features enhance the learning experience and equip students with valuable skills for their future careers as actuaries.

Actuaries are leading experts in risk management and financial uncertainties, making the actuarial profession one of the most successful in the world. We are actively working to ensure the highest standards of actuarial mathematics teaching.

Based on the benefits highlighted in the use of VBA for teaching actuarial mathematics, future research can focus on the following areas.

✓ **Effectiveness of VBA in Improving Student Learning Outcomes:** Conducting empirical studies to measure the impact of VBA-based teaching methods on student understanding, retention of concepts, problem-solving skills, and overall academic performance in actuarial mathematics courses.

✓ **Comparison with Traditional Teaching Methods:** Comparing the effectiveness of VBA-based teaching approaches with traditional methods (e.g., lectures, textbooks, problem sets) in terms of student engagement, comprehension, and long-term retention of knowledge.

✓ **Development of Advanced VBA Modules:** Creating advanced VBA modules and tools tailored specifically for actuarial mathematics education, addressing complex topics such as mortality modeling, pension valuation, risk assessment, and insurance pricing.

✓ **Long-Term Impact on Career Readiness:** Exploring the long-term impact of VBA-based learning experiences on students' preparedness for careers in actuarial science, including their ability to apply it in real-world actuarial practice, adapt to technological advancements, and pursue continuous professional development.

✓ **Industry Collaboration and Feedback:** Collaborating with actuarial firms, insurance companies, industry professionals, and professional organizations to gather feedback on the relevance and applicability of VBA-based teaching methods to the evolving needs of the actuarial profession.

By exploring these research areas, educators and researchers can contribute to advancing the field of actuarial mathematics education and preparing students for successful careers in the dynamic and evolving field of actuarial science.

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