Research article
DOI: https://doi.org/10.48554/SDEE.2022.3.5

ENGINEERING ECONOMICS: SCIENTOMETRIC ANALYSIS OF THE SUBJECT AREA

Tatyana Kudryavtseva[1], Angi Skhvediani[1*], Viktoriia Brazovskaia[1], Marina Dracheva[1]

[1]Peter the Great St. Petersburg Polytechnic University, Saint-Petersburg, Russia
Corresponding author: skhvediani_ae@spbstu.ru

Abstract

Engineering economics is located at the intersection of the science of economics and engineering practice, which means it attracts the attention of both fields. Engineering economics focuses on solving engineering problems and making decisions based on systematic cost-benefit analysis. Modern technologies push for the development and implementation of new methods of efficiency evaluation, decision-making, risk analysis, etc. It is obvious that the number of studies related to engineering economics is constantly growing, but there is still a shortfall of systematic quantitative and visual studies in this area, which explains the relevance of this article. A keyword analysis and an analysis of co-authors were carried out using VOSviewer to carry out a scientometric study of engineering economics. The findings reveal that the central position in engineering economics is occupied by engineering and economic analysis, which is a combination of quantitative and qualitative methods for analysing differences in the economic efficiency of engineering alternatives. The most popular tools of engineering and economic analysis presented in scientific papers are risk analysis, cost-benefit analysis, replacement analysis, break-even analysis, method of option valuation, analysis of equivalent annual costs, and annual cash flows.

Keywords: engineering economics, engineering economics analysis, literature review, scientometric analysis, visualisation

Citation: Kudryavtseva, T., Skhvediani, A., Brazovskaia, V., Dracheva, M., 2022. Engineering Economics: Scientometric Analysis of the Subject Area. Sustainable Development and Engineering Economics 3, 5. https://doi.org/10.48554/SDEE.2022.3.5

Научная статья
УДК 330
DOI: https://doi.org/10.48554/SDEE.2022.3.5

ИНЖЕНЕРНАЯ ЭКОНОМИКА: НАУКОМЕТРИЧЕСКИЙ АНАЛИЗ ПРЕДМЕТНОЙ ОБЛАСТИ

Татьяна Кудрявцева[1], Анги Схведиани[1*], Виктория Бразовская[1], Марина Драчёва[1]

[1]Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия
Автор, ответственный за переписку: skhvediani_ae@spbstu.ru

Аннотация

Инженерная экономика находится на стыке экономической науки и инженерной практики, а значит привлекает внимание с обеих сторон. Инженерная экономика фокусируется на решении инженерных проблем и принятии решений, основываясь на систематической оценке экономического эффекта от них. Современные технологии подталкивают к разработке и внедрению новых методов оценки эффективности, принятия решений, анализа рисков и т. д. Очевидно, что количество исследований, связанных с инженерной экономикой, постоянно растет, однако все еще ощущается нехватка систематических количественных и визуальных исследований в этой области, что объясняет актуальность данной статьи. С помощью выбранного ПО для визуализации наукометрического исследования VOSviewer был проведен анализ по ключевым словам и анализ соавторов. В результате проведенного исследования было выявлено, что центральное место в инженерной экономике занимает инженерно-экономический анализ, который представляет собой комбинацию количественных и качественных методов для анализа различий в экономической эффективности инженерных альтернатив. Были выделены наиболее популярные инструменты инженерно-экономического анализа, представленные в научных работах: анализ рисков, анализ «затраты-выгоды», анализ замены, анализ безубыточности, метод опционов, анализ эквивалентной годовой стоимости и годовых денежных потоков.

Ключевые слова: инженерная экономика, инженерно-экономический анализ, литературный обзор, наукометрический анализ, визуализация

Цитирование: Кудрявцева, Т., Схведиани, А., Бразовская, В., Драчева, М., 2022. Инженерная экономика: наукометрический анализ предметной области. Sustainable Development and Engineering Economics 3, 5. https://doi.org/10.48554/SDEE.2022.3.5

1. Introduction

Given that natural resources and other materials needed for production have become increasingly scarce and expensive, it is no longer possible to simply develop and produce products and make no thorough cost analysis. In practice, engineers today have to evaluate and decide whether the benefits of implementing a project or process are more significant than the costs associated with them, and this task is solved with the help of engineering economics. Engineering involves the correct application of mathematical and natural science knowledge obtained as a result of research, experience, and practice to develop cost-efficient methods of using raw materials and energy for the benefit of mankind. The benefits and costs associated with any project that requires significant investment are usually carefully analysed by management to ensure that decisions are made to minimise costs as much as possible, since these decisions affect the overall efficiency of the firm.

Engineering economics involves the formulation, analysis, and evaluation of the expected economic outcomes of alternatives designed to achieve certain goals. In simple terms, it involves making economic decisions for engineering systems. This is a research area that encompasses applying various economic principles and computational methods to engineering processes and systems. Engineering economics uses economic concepts and methods to solve engineering issues to determine the best course of action. Engineering economics helps to systematically evaluate the economic benefits of proposed solutions for engineering problems, measure costs and benefits, provide estimates of future investments, and propose alternative uses of limited resources.

Scientometric research is an analysis of the chosen subject area to identify relevant topics for research and to search for gaps in scientific research (Eliseeva and Oleinik, 2022). This method of analysis can be used in various sciences, making it a universal method of information processing and conducting literary reviews (Blaginin et al., 2019). Scientometric analysis can also be used to increase the activity of scientists and increase their citations by highlighting the most popular keywords. For example, Kozyr (2022) compared the keywords of the topic "regional economy" in the elibrary.ru database to data in the JournalFinder system of Elsevier, thereby identifying unified keywords that Russian scientists should use when publishing scientific articles on regional economics.

Digital bibliographic and abstract databases, which allow the tracking of citations and other indicators of articles, are used to store data on scientific publications and their full texts. Such databases are also one of the main sources for obtaining scientometric data to conduct evaluation studies of subject areas. The largest international bibliographic databases are Web of Science and Scopus. In the Russian Federation, the most complete digital bibliographic and abstracting base is the "Scientific Electronic Library" (or elibrary.ru). This is the largest electronic library of scientific publications in Russia, integrated with the Russian Science Citation Index (RSCI)—a free public tool for measuring and analysing the publication activity of scientists and organisations created by the Ministry of Education and Science of the Russian Federation.

Scientometric research on the subject area of engineering economics is the study of the subject area "engineering economics" through the study of this science by quantitative methods. In world practice, there is a wealth of experience in the application of scientometric analysis of data obtained from the international abstract databases Web of Science and Scopus (Hossfeld et al., 2017). To conduct scientometric analysis, files of various formats can be downloaded from database systems containing brief information (author, title, source, abstract) about the paper (so-called article metadata). The resulting text file can be used in various applications capable of performing complex analyses based on downloaded data. In the process of working and using specialised software, various methods of information processing are used: clustering, grouping, identifying the most common elements, etc. (Sahil and Sood, 2021).

Scientometric research on the subject area of engineering economics is devoted to certain aspects. For example, Boltürk (2020) conducted bibliometric analysis on the subject area of the evaluation of investment projects in engineering economics. Heutel et al. (2016) considered the mastery of studies in

economics of climate engineering subject area, and as a result came to the conclusion that climate engineering technologies should become a fundamental part of future domestic and global climate policy. They also proposed several directions for future research. Interestingly, engineering and economics are quite often considered together in articles devoted to "green" technologies (Clark, 2014).

Based on the analysis of existing studies, the present study attempts to fill the research gap associated with the study of the subject area of engineering economics. The study addresses the following questions:

(1) What subject areas do engineering economics cover?

(2) Which authors and resources are the most popular in this area? Which articles are the most cited?

(3) What representative keywords are found in different periods? Which keywords are currently relevant?

In general, this article is a large-scale literature review and systematisation of the subject area of engineering economics. We expect the findings from this investigation to help new researchers choose the most relevant journals, articles, keywords, and popular authors, which, in turn, will help them determine the directions of future research.

2. Methodology

To conduct scientometric and bibliometric research, researchers often use electronic scientometric databases, such as Web of Science, Scopus, Google Scholar, and eLibrary.ru. This study used scientometric methods to assess the current situation in engineering economics research and to study trends in the development of engineering economics based on literary data on articles obtained from the Scopus database, as well as by empirical analysis of textbooks on engineering economics. Many specialised software designed for automated processing of arrays of information downloaded from bibliographic databases have been developed and upgraded for scientometric analysis. Although each of the presented databases has built-in capabilities for conducting analytics, it is necessary to have specialised software to conduct a deeper analysis and visualisation of the results obtained. To date, the main programs for conducting scientometric analysis and visualisation are the following: IN-SPIRE (1999), VantagePoint (2004), HistCite (2004), BibExcel (2009), CiteSpace (2004), Sci2 Tool (2009), Leydesdorff's Software (2004), Publish or Perish, VOSViewer (2010), InterDisciplinary Research, Network Workbench Tool (2007), SciMAT (2011). Some are commercial (paid) programs, whereas others are freely available. The VOSviewer program was chosen for this study because it is the most frequently used and freely available program.

VOSviewer[1] is an open-access program that can be used for various purposes. VOSviewer can be used to create data network-based maps. VOSviewer is a map creation and cluster allocation technologies. VOSviewer can be used for viewing and exploring maps. The program builds the map in various ways, each of which highlights its different aspects. Features such as zoom, scroll, and search, which facilitate a thorough study of the map, are offered. Initially, VOSviewer was designed for the analysis of bibliometric networks. The program, for example, can be used to create maps for publications, articles, or journals that are based on the social network, or to create keyword maps based on their simultaneous appearance on the network. VOSviewer is easy to use, and is also considered the most suitable for the analysis of bibliographic communication and cartography (Shah, 2020).

In this study, keyword analysis and document co-authorship analysis were carried out using VOSviewer. The following types of documents were included in the analysis: articles, abstracts from conferences, literary reviews, and textbooks, as these types of documents are mainly used to present scientific results. The phrase "engineering economics" was used to search the title, annotation, or keyword sections of VOSviewer. Articles with anonymous or unidentified authors were excluded from the

1 VOSviewer [Electronic resource]. URL: http://www.vosviewer.com/

analysis.

3. Results and discussion

We analysed 14 English-language textbooks on engineering economics (Table 1) to identify the main topics and concepts considered part of engineering economics.

Table 1. Textbooks on engineering economics

	Name	Author(s)	Year
1	Schaum's Outline of Engineering Economics	Jose Sepulveda, William E. Souder, Byron S. Gottfried	1984
2	Foundations of Engineering Economics	Eugene L. Grant, W. Grant Ireson, Richard S. Leavenworth	1990
3	Advanced Engineering Economics	Chan S. Park, Gunter P. Sharp	1990
4	Engineering Economic Analysis	Donald G. Newnan, Jerome P. Lavelle	1998
5	Engineering Economy: Applying Theory to Practice (Engineering and Technology)	Ted G. Eschenbach	2003
6	Foundations of Engineering Economic Analysis	John A. White	2012
7	Fundamentals of Engineering Economics and Decision Analysis	David L. Whitman, Ronald E. Terry	2012
8	Fundamentals of Engineering Economics	Leland Blank, Anthony Tarquin	2013
9	Contemporary Engineering Economics	Chan Park	2015
10	Engineering Economics	J. K. Yates	2016
11	Engineering Economics	Leland Blank, Anthony Tarquin	2017
12	Engineering Economics	William Sullivan, Elin Wicks, C. Koelling	2018
13	Engineering Economic Analysis	Don Newnan, Ted Eschenbach, Jerome Lavelle, Neal Lewis	2019
14	Engineering Economic Analysis	John A. White, Kellie S. Grasman, Kenneth E. Case, Kim LaScola Needy, David B. Pratt	2020

Table 2 presents the topics covered in the textbooks under study. The textbooks were analysed in chronological sequence. Topics are ranked by frequency of mention.

Table 2. Topics and frequency of mention

Topic	Frequency of mention
Replacement analysis	85.7%
Amortisation	85.7%
Taxation	85.7%
Present/future value	78.6%
Percentages and equivalences	71.4%
Techniques for choosing an investment alternative	71.4%
Introduction to Engineering Economics	64.3%
Profitability	64.3%
Sensitivity analysis	64.3%
Cost-benefit analysis	57.1%
Break-even analysis	57.1%
Time value of money	57.1%
Analysis of the equivalent annual value	57.1%
Inflation	57.1%
Risks and uncertainties	50.0%
Pay-off period	42.9%
Decision-making in engineering economics	42.9%

Cash flow calculation and estimation	42.9%
Risk analysis	42.9%
Public sector in engineering economics	42.9%
Investment attractiveness analysis	35.7%
Investment budget	35.7%
Nominal and effective interest rates	35.7%
Determination of the minimum acceptable rate of return	28.6%
Decision tree	21.4%
Economic analysis in the service sector	21.4%
Cost calculation	21.4%
Annual cash flow analysis	14.3%
Lending, loans, bonds, investing	14.3%
Multiple factors in the problems of engineering economics	14.3%
Accounting in engineering economics	14.3%
Compounding	7.1%
Preparation and submission of a feasibility study	7.1%
Transformation methods in cash flow modeling	7.1%
Utility theory	7.1%
Measurement of investment value under risk conditions	7.1%
Incremental analysis	7.1%
Spreadsheets in economic analysis	7.1%
Internal rate of return	7.1%
Mutually exclusive alternatives	7.1%
Project evaluation methods	7.1%
Financial leverage	7.1%
Analysis of real options	7.1%
Arithmetic and geometric gradients	7.1%
Project financing and non-economic attributes	7.1%
Independent projects with limited budget	7.1%
Equivalences for recurring cash flows	7.1%

The first chapters of most textbooks are devoted to the theoretical aspects of engineering economics: its significance and relevance, scope of application are considered, a brief overview of topics is given, and the basic foundations are described. Further, we identified a block of topics that provide insight into the essence of engineering economic analysis. We considered in detail the topics related to decision-making, as well as techniques for choosing among alternatives. Each textbook includes a chapter covering the topic of the time value of money. The basic concepts of this block are present and future value, nominal and effective interest rates, discounting, and cash flows. The types of cash flows, calculation methods, and management methods are described, as well as methods for calculating and justifying the discount rate. The block includes topics describing the methodology for evaluating the efficiency of engineering solutions (or projects). Some authors emphasise project management in a separate chapter in which a significant part is given to project financing. Concepts such as profitability (invested capital, equity, etc.), pay-off period, net present value, and internal and minimum acceptable rates of profitability are considered. A significant number of topics are devoted to risk analysis and management (in particular, project risks). Modelling is described under conditions of certainty, under conditions of risk, and under conditions of uncertainty. Sensitivity analysis, decision tree building, and scenario methods are considered in detail. Among the specific tools of engineering economics in the study materials are descriptions of cost-benefit analysis, break-even analysis, the option method, and analysis of the equivalent annual cost and annual cash flows.

Notably, many authors have addressed replacement analysis, which is found in more than 85%

of textbooks. When equipment wears out due to age, it leads to a decrease in deposition costs and an increase in operating and maintenance costs. As a result of increased operating and maintenance costs, it is often cost-effective to replace equipment after a certain period of use. The classical problem of equipment replacement is aimed at finding a replacement policy that minimises the total discounted value of equipment costs in conditions when the interest rate and cost structure remain constant over an infinite horizon (Hartman and Tan, 2014). The chapters on reporting cover reporting standards, cost calculation, and cost calculation methods, as well as cost accounting and cost management. As a rule, the final three chapters are devoted to accounting for depreciation, taxes, and inflation. In some textbooks, there are topics devoted to the public sector in engineering economics, investment budget preparation, and economic analysis in the service sector. Topics on business valuation, production theory, aspects of microeconomics and macroeconomics, utility theory, inventory management and logistics, asset valuation, outsourcing decision-making methods, and linear programming (simplex and graphical methods) are less frequently covered.

Engineering economics, as a separate field of research, has developed relatively recently. This does not mean that earlier economic laws were not taken into account when making engineering decisions. Final economic efficiency has always been one of the top priorities for engineers. The beginning of the engineering interest in economic assessment was in 1887 with The Economic Theory of the Location of Railways by the civil engineer A. M. Wellington, who wrote about what, in his opinion, was ignored by many engineers during railway locations: the expected costs and revenue.

The founder of engineering economics is Eugene L. Grant. The first edition of his textbook, Foundations of Engineering Economics, was published in 1930. The eighth edition of this textbook states that the formulation of the investment budget (of a company or state) is one of the vital tasks for the implementation of strategic management decisions (Grant et al., 1990). Each project is the result of a multitude of management decisions, each of which has been evaluated for efficiency. In many cases, economists need engineering expertise to make decisions. When implementing engineering solutions, the technological components and the analysis and estimation of expected costs and benefits are important. They form the essence of engineering economics.

Blank and Tarquin (2017) indicated that the need for an engineering economy is primarily conditioned upon the work that engineers do, analysing, synthesising, and coming to a conclusion while working on projects of any scale. In other words, engineering economics is at the heart of decision-making. These decisions involve the fundamental elements of cash flows—money, time, and interest rates. Blank and Tarquin (2017) identified the following as the main tasks of engineering economics: the formulation, evaluation, and analysis of the expected economic outcomes of alternatives designed to achieve certain goals. Mathematical methods simplify the economic estimation of alternatives (Blank and Tarquin, 2013). Eschenbach (2003) stated that engineering economics estimates the economic results of the products, projects, and processes that engineers develop. These products, projects, and processes often require significant investments and have a long service life. When comparing several options for project execution, a question arises: "Which of the alternatives is more profitable in the long run?" There are cases when one alternative may be cheaper in construction, and the other in operation. The task of engineering economics is to evaluate the effectiveness of all options and choose the most profitable alternative (Newman et al., 2019).

Newnan and Lavelle (2019), in their book Engineering Economic Analysis, interpreted the essence of engineering economics through the concepts of problem- and decision-making (problem solving). The authors identified three criteria for the problem, referring it to the subject area of engineering economics (Newnan et al., 2019). First, the problem must be significant enough to deserve the effort to solve it. Second, the problem cannot be solved at a time "in the head", but requires careful analysis and systematisation of influencing factors and possible outcomes. Third, the problem contains economic aspects that are critically important for analysis and decision-making. If the problem satisfies the three criteria considered, then engineering economic analysis is suitable for its solution. White et al. (2012)

described engineering economics as a set of methods for applying economic analysis techniques to compare engineering alternatives. The authors defined engineering economic analysis as a combination of quantitative and qualitative methods for analysing differences in the economic efficiency of engineering alternatives. The authors believe that the possibility of using economic analysis for decision-making in the public sector of the economy has given a serious impetus to the development of engineering economics. Whitman and Terry (2012), in their textbook Fundamentals of Engineering Economics and Decision Analysis, defined the purpose of engineering economics as providing engineers with all the necessary economic functionality for decision-making (to choose among alternatives). The authors noted that there are always at least two alternatives. In cases where there is one project (or one implementation method), inaction is considered the second alternative.

In his textbook Contemporary Engineering Economics, Park (2015) focused on the increased role of engineers in making economic decisions. This is because the design and production processes are becoming more comprehensive and complex. For example, it is difficult to evaluate the equipment's condition and make a decision about its replacement without a technical specialist. Engineers are involved in all stages of the production cycle and are familiar with all the subtleties of production, which allows them to more accurately estimate the cost of a particular solution. Yates (2016) revealed the essence of engineering economics through the need for engineers to analyse the cost benefit of their proposed solutions. If there are multiple alternatives, then it is necessary to evaluate each and choose the most efficient one. For private projects, the most profitable alternative is chosen, whereas for public projects, the alternative with the greatest positive effect on society should be selected.

In the textbook Engineering Economics by Sullivan, Wicks, and Koelling (2018), Newnan and Lavelle reveal the work of engineers through the concept of problem solving. Engineers are finding new ways to make their work more efficient in economic terms. Engineering solutions do not exist in a vacuum but in an economic environment. Since there are many possible solutions to each problem, a question arises: "Which of them will be the most cost-efficient?" Engineering economics can answer this question. Engineering economics provides a system for evaluating the economic effects of implemented engineering solutions. Regardless of the scope of implementation, engineers should remember the "economic exhaust" from their solutions. There is an opinion among engineers that they do not need to think about the financial component; however, in real life, projects should not only be physically feasible but also economically attractive, and even the most advanced engineering developments may not be in demand if they are not profitable. Therefore, in the current era, in which technological solutions are becoming more complicated every day, engineering economics is more relevant than ever before.

We found 2,480 publications in the bibliographic database Scopus[2] when we queried "Engineering Economics." Figure 1 shows the distribution of the number of publications by year.

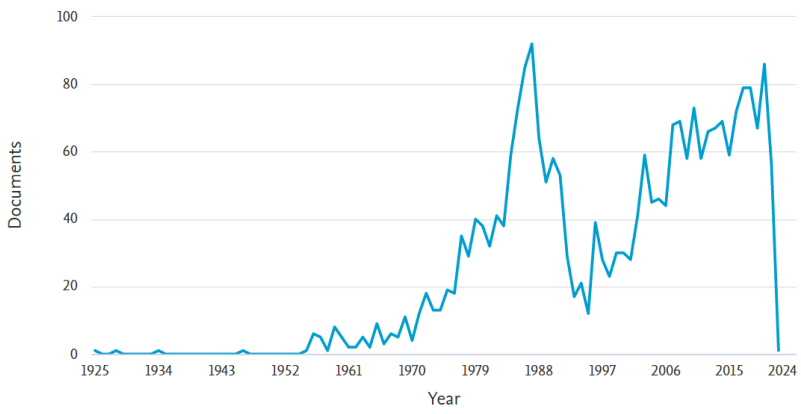

Figure 1. Distribution of the number of publications on engineering economics by year

2 Scopus bibliographic database [Electronic resource URL: https://www.scopus.com

The two peak points in the number of publications are 1987 and 2020 (92 and 86 publications, respectively). In 1987, this was associated with the meeting of the Association for the Advancement of Cost Engineering (AACE), for which most of the publications (25%) were prepared. AACE is the world's largest community of professionals in value engineering. The association is the organiser of a number of educational programmes aimed at improving professional and technical skills and holds annual meetings, seminars, exhibitions, presentations, and social and certification programmes. The organisation also publishes a monthly international magazine, Cost Engineering Journal, which contains the latest information on value engineering[3]. The main topics discussed at the annual meetings of the association include project management, accounting, cost management and estimation, risk assessment and risk management, decision-making, and quality management.

The graph of the distribution of published documents on engineering economics by source (Figure 2) also shows the above-mentioned meeting. The figure shows that currently, the main magazine publishing articles on engineering economics is Engineering Economist.

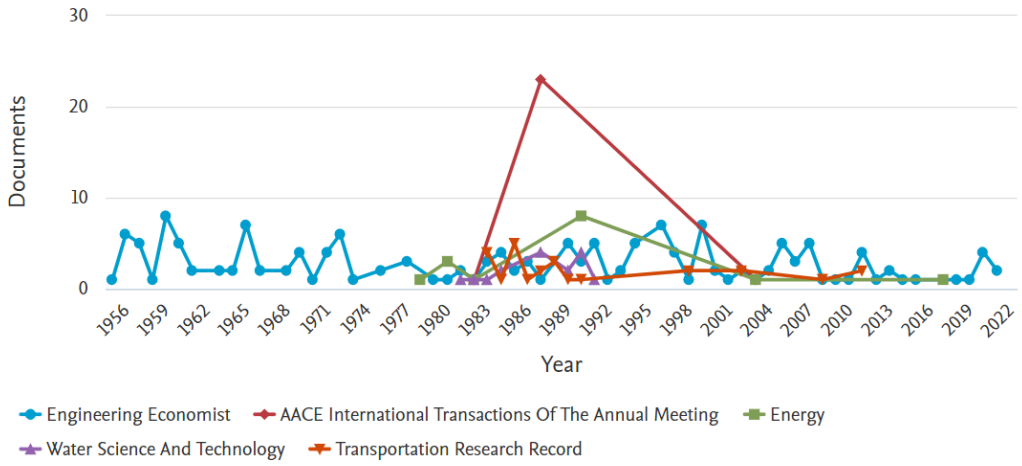

Figure 2. Distribution of the number of publications on engineering economics by source

Engineering Economist is devoted to the problems of capital investments. It is an international magazine that publishes research on capital investment, including financial risk management, project solution economy, and education in engineering economics[4]. Figure 3 shows the most published authors. It is worth noting that the textbooks of five of them (Chan S. Park, Jerome P. Lavelle, Ted G. Eschenbach, John A. White, and William Sullivan) were analysed in the first part of this article.

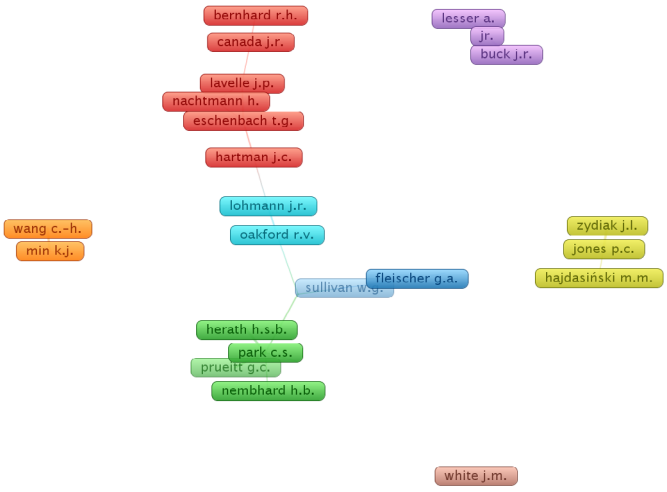

Figure 3. The most published authors in Engineering Economist

3 AACE Conference [Electronic resource]. URL: https://web.aacei.org/

4 The Engineering Economist [Electronic resource]. URL: https://www.tandfonline.com/toc/utee20/current/

Take, for example, the subject area of articles in Engineering Economist. Figure 4 shows the most common keywords, which we conditionally divided into four clusters. The first cluster is dedicated to investment and investment projects. It also includes the concepts of cash flow, profitability, internal rate of return, discount rates, profit, and net present value. In the second thematic block, it is possible to highlight the budgeting of capital investments, budget control, and inventory management. The third block of keywords includes project management, cost accounting, and decision-making. Mathematical models, risk management, cost-benefit analysis, Monte Carlo method, sensitivity analysis, and real options are also mentioned in the third block. The fourth cluster includes keywords on the topic of engineering economic education. Thus, we can distinguish four broad topics: investment design, economic analysis, budgeting, and engineering economic education.

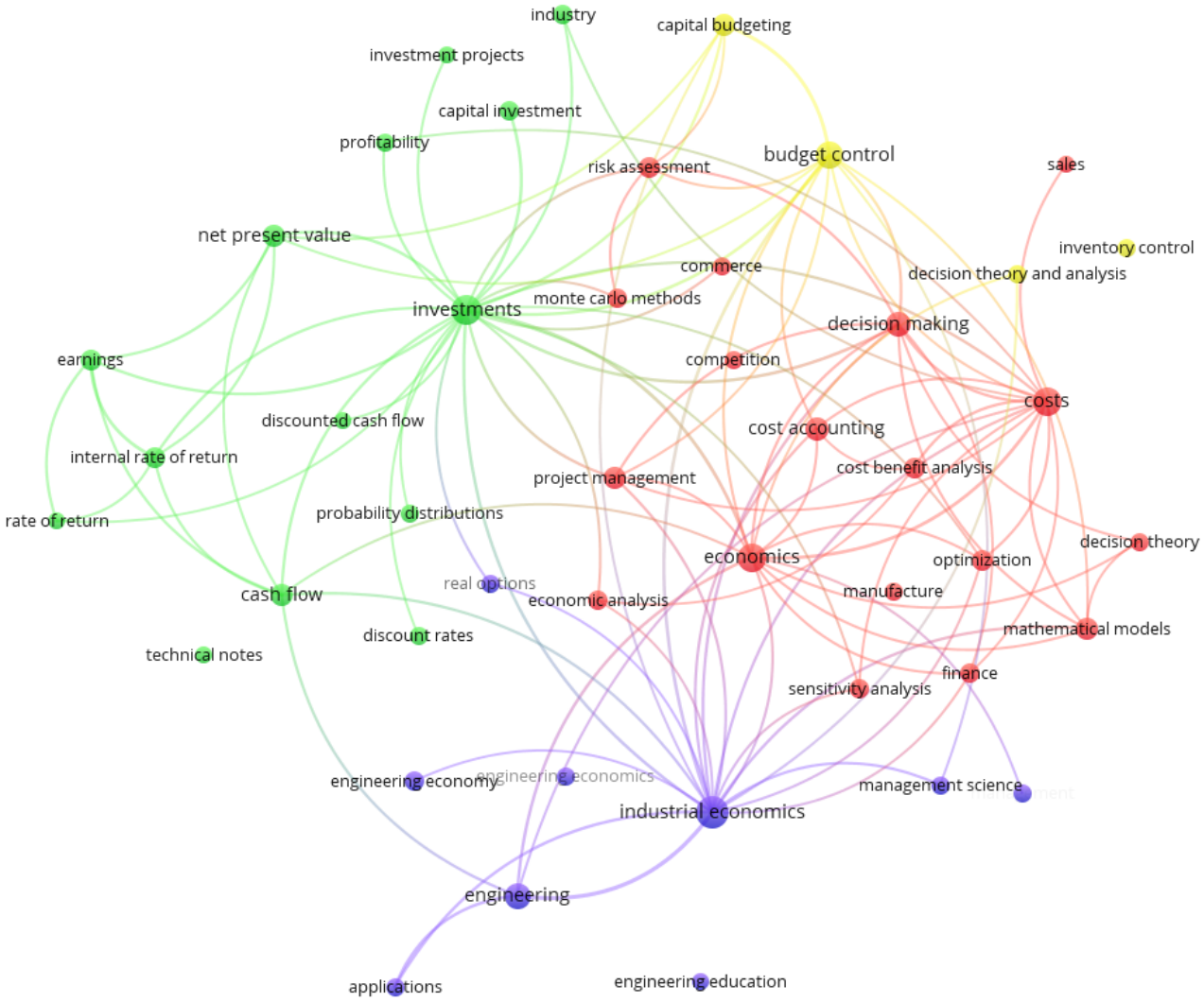

Figure 4. Keywords in Engineering Economist

Figure 5 shows the top 10 authors publishing in the field of engineering economics. It is worth noting that seven of them are also authors of textbooks on engineering economics: T. G. Eschenbach, Sullivan, J. C. Hartman, N. Lewis, G. J. Thuesen, J. P. Lavelle, and C. S. Park.

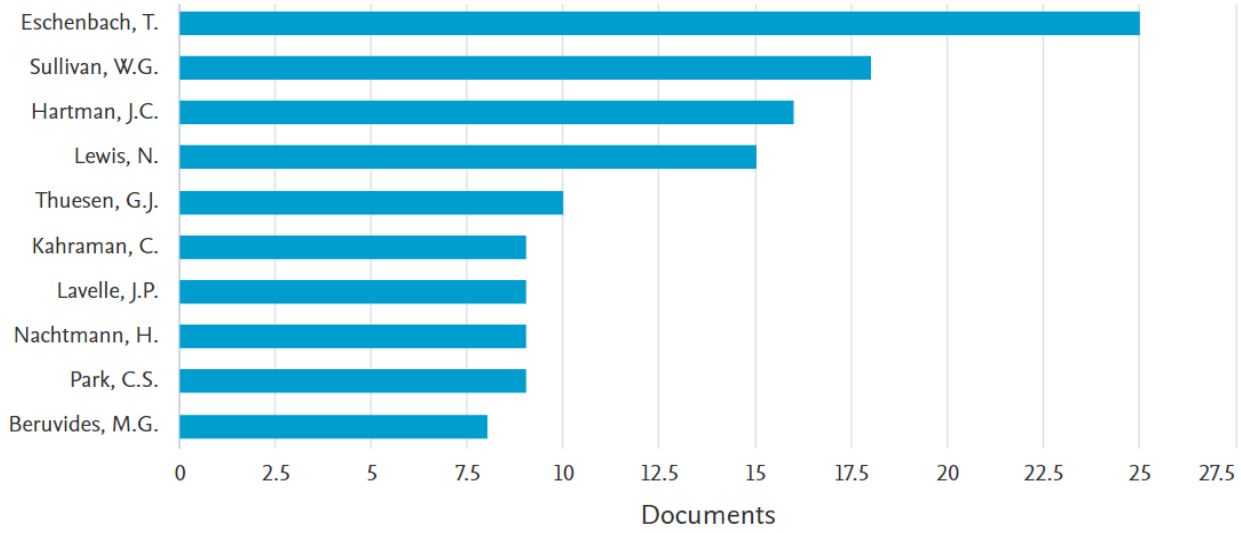

Figure 5. Distribution of the number of publications on engineering economics by author

One of the key topics of works by T. G. Eschenbach is engineering economic education. His most cited article is devoted to the same topic: Empirical Analysis of Teaching Engineering Economics (Needy et al., 2000). This paper presents the results of a two-part study on the teaching of engineering economics at US universities. Eschenbach's top five most cited articles include three articles describing sensitivity analysis: tornado diagrams (Eschenbach, 2006), stochastic sensitivity analysis (Eschenbach and Gimpel, 1990), and the use of graphs for sensitivity analysis (Eschenbach and McKeague, 1989). A bias towards finance is visible in his recent works. In particular, in 2017, together with J. P. Lavelle and N. Lewis, Eschenbach presented the work Personal Finance Coverage in Engineering Economics Courses (2017) at the ASEE conference. Another recent article (jointly with N. Lewis) is devoted to teaching students the importance of diversification (Eschenbach and Lewis, 2015). The content of most texts on engineering economics implies that a relatively small number of courses in engineering economics include investment issues. However, according to the authors, students should be taught financial literacy. A brief discussion of the investment model helps to understand the relationship between risk and return, and the importance of diversification.

In the works of W. G. Sullivan, two main directions can be distinguished: automation of production (his most cited article is devoted to this) (Sullivan, 1986) and new technology implementation in the process of engineering economic education. There are also articles covering the historical component (Thuesen and Sullivan, 1999) and the new paradigm of engineering economics (Sullivan, 1991). A significant part of the works of J. C. Hartman is dedicated to real options. The author writes about their application for real engineering projects (Eschenbach et al., 2007), the specifics of using various interest rates—discrete and continuous (Eschenbach et al., 2009)—risk-free and market-based (Eschenbach et al., 2008), the integration of real options with a decision tree and risk modelling (Eschenbach, 2008), expected costs, and different views on the implementation of projects using real options (Lewis et al., 2010).

Most of the literature on real options is devoted to the mathematical details of how to perform real options analyses and does not take into account real applicability for engineering projects. Since engineering economic analysis has long included decision trees, sensitivity analysis, modelling, and other tools, a key question is: Does real options analysis add anything significant to this set? Most analysis methods do not take into account the corresponding costs to the proper extent and provide an inflated option value, which leads to overly optimistic conclusions. Specialists from different fields tend to look at solutions to one problem in different ways. Articles devoted to finance usually consider theoretical solutions that can be mathematically justified. In articles written by economists-engineers, as a rule, they look for solutions that can be applied to solve real problems. As for real options, theoretical prescriptions exceed the number of real cases, which limits the possibilities of their application to solving engineering

problems. Works by J. C. Hartmann offer insights into teaching engineering economics at different levels of education.

N. Lewis published multiple works together with the above-mentioned authors: teaching finance in the course of engineering economics, with J. P. Lavelle and T. G. Eschenbach; engineering education, with T. G. Eschenbach; and real options, with J. C. Hartman and T. G. Eschenbach. G. J. Thuesen published several works in collaboration with W. G. Sullivan and C. S. Park. These works are devoted to engineering and economic education (historical aspects, evolution, and new trends). His independent publications also cover this area, and his most-cited work describes the methodology for choosing the discount rate. As mentioned above, J. P. Lavelle worked in collaboration with T. G. Eschenbach, J. C. Hartman, and N. Lewis. His subject areas are decision-making, engineering, and economic education, finance in engineering economics, and personal finance (investing). The works of C. S. Park are devoted to economic analysis. The author writes about the theory of fuzzy sets (Chiu and Park, 1994), decision-making under uncertainty (Miller and Park, 2002), real options (Park and Herath, 2000), and R&D projects (Herath and Park, 1999). Several articles have also been published in engineering and economic education (together with G. J. Thuesen and W. G. Sullivan).

Figure 6 presents the keywords most commonly found in articles on engineering economics. Depending on the year of publication, the words are in different colours (purple – earlier articles, and yellow – later ones). The figure shows that the topics presented in the publications almost completely duplicate the topics covered in the textbooks on engineering economics. The following blocks are distinguished: engineering and economic education, decision-making and engineering economic analysis, cost accounting and cost efficiency, production optimisation, and software development and implementation. The tools that are considered in publications include calculation of net present value, sensitivity analysis, cost-benefit analysis, etc. There are also topics dedicated to investment. Notable works include those on ecology and sustainable development, since this topic is not presented in textbooks but is quite popular in articles.

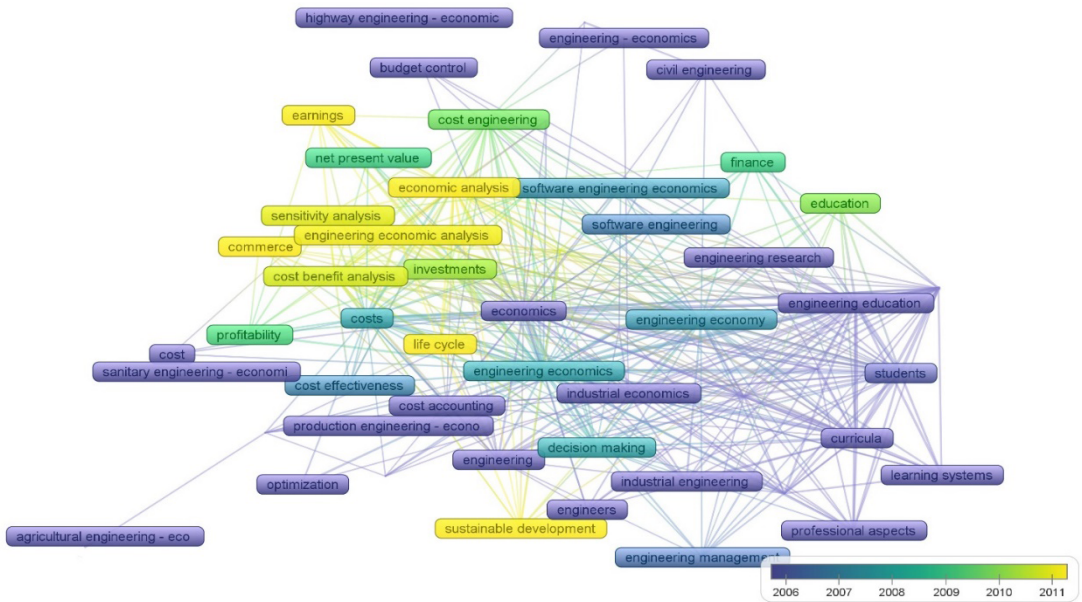

Figure 6. Keywords in articles on engineering economics

Regarding current topics in engineering economics, we analysed the keywords in publications over the past seven years (Figure 7).

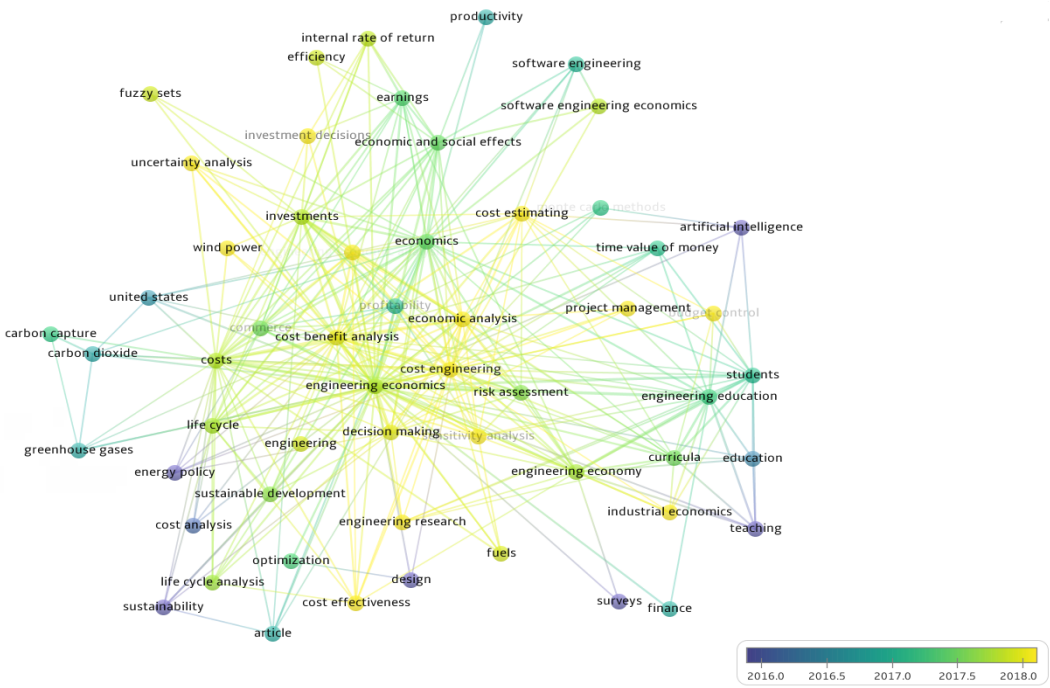

Figure 7. Keywords in articles on engineering economics for 2015–2021

The figure shows that traditional topics related to engineering and economic education, decision-making, engineering economic analysis, investment efficiency evaluation, risk modelling, and cost estimation remain popular. As mentioned above, a significant portion of the articles are devoted to sustainable development as well as software implementation. Concepts such as fuzzy sets and uncertainty analysis have been mentioned more often in the last couple of years. There are also articles on artificial intelligence.

Based on these analyses, the questions posed at the beginning of the study were answered. Concerning the first research question, engineering economics covers many subject areas: engineering and economics education, decision-making methods, finance in engineering economics, personal finance, investing, economic analysis, and R&D projects. Accordingly, engineering economics is a multifaceted subject area that combines various economic issues related to engineering areas (Amadi-Echendu et al., 2010). Our literature review revealed that most scientometric analyses have included the subject areas of engineering economics; however, there has been no scientometric analysis of engineering economics. With regard to the most popular authors and resources, the most popular and frequently cited authors are T. G. Eschenbach, W. G. Sullivan, J. C. Hartman, N. Lewis, G. J. Thuesen, J. P. Lavelle, and C. S. Park.

In answer to our third research question, we identified the most representative keywords that can guide the identification of the topics relevant for research in this subject area. The following blocks of topics were prominent: engineering and economic education, decision-making and engineering economic analysis, cost accounting and cost efficiency, production optimisation, software development and implementation. Calculation of net present value, sensitivity analysis, cost-benefit analysis, investments, etc. are popular tools used in academic studies in the subject area. We highlighted a separate stream of research on the topic of ecology and sustainable development, which is not presented in textbooks but is quite popular in scientific studies. In recent years, the concepts of "fuzzy sets" and "uncertainty analysis" have been mentioned more often, and studies on artificial intelligence have also emerged.

The concept of engineering economics is interpreted through decision-making (Simon, 1966). The company's activities are based on a variety of solutions, each of which should pass through a feasibility study (Tirachini, 2020). Engineering developments do not exist by themselves; they face a competitive environment. Thus, it is very important to choose the best possible solution. Projects should not only be

feasible but also be economically attractive. Engineering economics deals with evaluating alternatives and choosing which will be better in the long run (Li et al., 2019). However, engineers need the help of economists to make decisions and choose among alternatives; by contrast, the role of engineers in making economic decisions has been growing. This is because technologies are becoming more complex, and certain concepts cannot be evaluated without the participation of technical specialists. For example, this applies to decisions on equipment replacement or disposal to make which it is necessary to evaluate equipment conditions.

Our results reveal that the central position in the engineering economy is occupied by engineering economic analysis, which is a combination of quantitative and qualitative methods for analysing differences in the economic efficiency of engineering alternatives (Dźwigoł et al., 2018). We can conclude that the most popular tools of engineering and economic analysis presented in scientific papers are risk analysis, cost-benefit analysis, replacement analysis, break-even analysis, method of option valuation, analysis of equivalent annual cost, and annual cash flows. A significant part of scientific studies in engineering economics are devoted to engineering and economic education (Rudskoy et al., 2018), and its main task is also revealed—to teach students of technical specialties all the necessary functionality to make cost–benefit decisions. The real world of engineering economics includes such components as uncertainty, risk, and productiveness tradeoffs (Simonovic, 2020), the cost of which cannot be measured in monetary terms. Engineering economics also takes into account the time value of money in order to balance current and future income and expenses. Summing up, we can single out the main task of engineering economics – the evaluation and comparison of alternatives as a basis for making decisions that minimise costs and maximise profits for business. Nevertheless, further investigations are needed to analyse the spread of engineering economics, its specifics in different countries, the stages of its development, and its relationship with other disciplines.

4. Conclusion

The basis of engineering economics is the integration of engineering and economic knowledge. As an independent area, engineering economics was formed relatively recently (1930), but the economic return from technical solutions has always been taken into account by engineers. The concept of engineering economics is interpreted through decision-making, but engineering developments do not exist by themselves; they face a competitive environment, so it is very important to choose the best possible solution. Therefore, engineering economics deals with evaluating alternatives and choosing which will be better in the long run. On the one hand, engineers need the help of economists to make decisions and choose among alternatives; on the other hand, the role of engineers in making economic decisions has been growing.

The central position in engineering economics is occupied by engineering and economic analysis, which is a combination of quantitative and qualitative methods for analysing differences in the economic efficiency of engineering alternatives. The most popular tools of engineering and economic analysis presented in the scientific papers in question are risk analysis, cost-benefit analysis, replacement analysis, break-even analysis, method of option valuation, analysis of equivalent annual cost, and annual cash flows. A significant part of scientific works in engineering economics are devoted to engineering and economic education, given the current necessity of teaching students of technical specialties all the necessary functionalities to make cost-benefit decisions.

This study revealed that engineering economics takes into account the time value of money to balance current and future income and expenses, and its main task is to evaluate and compare alternatives as a basis for making decisions that minimise costs and maximise business profits.

Acknowledgements

This research was funded by the Grant Council of the President of the Russian Federation. Project № МК-1969.2022.2

References

Amadi-Echendu, J.E., Willett, R., Brown, K., Hope, T., Lee, J., Mathew, J., et al., 2010. What is engineering asset management? In Definitions, concepts and scope of engineering asset management (pp. 3–16). Springer, London.

Blaginin V.A., Akulova P.E., Zyryanova V. A., Kuhar' V.S., 2019. Naukometricheskij analiz sel'skohozyajstvennogo nauchnogo napravleniya [Scientometric analysis of the agricultural scientific direction]. Agrarian Bulletin of the Urals 9 (188). Available at: https://cyberleninka.ru/article/n/naukometricheskiy-analiz-selskohozyaystvennogo-nauchnogo-napravleniya. (in Russ.)

Blank L., Anthony J., Tarquin, A., 2017. Engineering Economy. New York: McGraw-Hill Education, 644 p. Available at: https://razak.utm.my/shamsul/wp-content/uploads/sites/189/2016/03/Engineering-Economy.pdf

Blank, L., Tarquin, A., 2013. Basics of Engineering Economy. Available at: https://industri.fatek.unpatti.ac.id/wp-content/uploads/2019/03/097-Basics-of-Engineering-Economy-Leland-Blank-Anthony-Tarquin-Edisi-1-2007.pdf

Boltürk, E., 2020. Engineering economics using fuzzy sets: A literature review. International Conference on Intelligent and Fuzzy Systems. Springer, Cham, pp. 1675–1682.

Chiu C.Y., Park, C.S., 1994. Fuzzy cash flow analysis using present worth criterion. The Engineering Economist 39 (2), 113–138.

Clark, W., Woodrow, W., Cooke, G., 2014. The green industrial revolution: Energy, engineering and economics. Elsevier Inc., 568 p. ISBN: 978-0-12-802314-3. Available at: https://books.google.ru/books?hl=ru&lr=&id=hLSYBAAAQBAJ&oi=fnd&pg=PP1&dq=Clark,+W.,+Woodrow,+W.,+Cooke,+G.,+2014.+The+green+industrial+revolution:+Energy,+engineering+and+economics&ots=WPkWqgYUX4&sig=We3TYf5nxeSckeqUxZn443RA06Y&redir_esc=y#v=onepage&q=Clark%2C%20W.%2C%20Woodrow%2C%20W.%2C%20Cooke%2C%20G.%2C%202014.%20The%20green%20industrial%20revolution%3A%20Energy%2C%20engineering%20and%20economics&f=false

Dźwigoł, H., Dźwigoł-Barosz, M., 2018. Scientific research methodology in management sciences. Financial and Credit Activity: Problems of Theory and Practice 2 (25), 424–437.

Eliseeva, I. N., Olejnik, Yu. N., 2022. Metodologiya, teoriya, istoriya psihologii lichnosti [Methodology, theory, history of personality psychology]. LitRes. (in Rus.)

Eschenbach, T., Lewis, N., Henrie, M., Baker, E., Hartman, J.C., 2007. Real options and real engineering projects. Engineering Management Journal 19 (4), 11–19.

Eschenbach, T.G., 2006. Constructing tornado diagrams with spreadsheets. The Engineering Economist 51 (2), 195–204.

Eschenbach, T.G., 2003. Engineering Economy. New York: Oxford University Press.

Eschenbach T.G., Gimpel R.J., 1990. Stochastic sensitivity analysis. The Engineering Economist. 1990 35 (4), 305–321.

Eschenbach, T.G., McKeague, L.S., 1989. Exposition on using graphs for sensitivity analysis. The Engineering Economist 34 (4), 315–333.

Eschenbach, T. 2008. Waiting costs for real engineering projects evaluated with real options. In IIE Annual Conference. Proceedings. Institute of Industrial and Systems Engineers (IISE), p. 1273.

Eschenbach T., Lavelle J.P., Lewis N., 2017. Personal finance coverage in engineering economy courses. 2017 ASEE Annual Conference & Exposition.

Eschenbach T., Lewis N., 2015. Teaching students about the value of diversification–a retirement portfolio's efficient frontier. 2015 ASEE Annual Conference & Exposition, pp. 26–29.

Grant, E.L. 1990. Principles of engineering economy. In: Grant, E.L., Ireson, W.G., Leavenworth, R.S. (Eds.), Wiley, p. 608.

Hartman J.C., Tan C.H., 2014. Equipment replacement analysis: A literature review and directions for future research. The Engineering Economist 59 (2), 136–153.

Herath H.S.B., Park C.S., 1999. Economic analysis of R&D projects: An options approach. The Engineering Economist 44 (1), 1–35.

Heutel, G., Moreno-Cruz, J., Ricke, K., 2016. Climate engineering economics. Annual Review of Resource Economics 8, 99–118. https://www.doi.org/10.1146/annurev-resource-100815-095440

Hossfeld U., Levit G. S., Prokudin D., 2017 Selection methods of digital information resources for scientific heritage studies: A case study of Georgy F. Gause. ACM International Conference Proceeding Series Part F133135, 69–74. https://www.doi.org/10.1007/978-3-030-02846-6_11

Kozyr, N.S., 2022. The keywords for regional economies: Scientometric analysis. Scientific and Technical Libraries (6), 100–121. (In Russ.) https://www.doi.org/10.33186/1027-3689-2022-6-100-121

Lewis N., Eschenbach T., Hartman J., 2018. Integrating real options with decision trees and simulation. Available at: https://www.researchgate.net/publication/289775053_Integrating_real_options_with_decision_trees_simulation_Uncertainty_in_the_graduate_engineering_economy_course

Lewis N., Eschenbach T., Hartman J., 2009. Real options and the use of discrete and continuous interest rates. 2009 Annual Conference & Exposition, pp. 1410–1418.

Lewis N., Eschenbach T., Hartman J., 2009. Real options: Risk-free and market interest rates.

Lewis, N., Eschenbach, T., & Hartman, J.C., 2010. Real options: Divergent view on implementation. Annual National Conference of the American Society for Engineering Management, pp. 54–59.

Li, J., Xiao, F., Zhang, L., Amirkhanian, S.N., 2019. Life cycle assessment and life cycle cost analysis of recycled solid waste materials in highway pavement: A review. Journal of Cleaner Production 233, 1182–1206.

Miller L.T., Park C.S., 2002 Decision making under uncertainty—real options to the rescue? The Engineering Economist 47 (2), 105–150.
Needy, K.L., Nachtmann, H., Lavelle, J.P., Eschenbach, T.G., 2000. An empirical analysis of engineering economy pedagogy. The Engineering Economist 45 (1), 74–92.
Newnan D.G., Lavelle J. P., Eschenbach T., 1998. Essentials of engineering economic analysis. Taylor & Francis.
Newnan, D., Eschenbach, T., Lavelle, J., Lewis, N., 2019. Engineering Economic Analysis. Oxford University Press, vol. 2, 227 p.
Oakford R.V., Thuesen G.J., 1968. The maximum prospective value criterion. The Engineering Economist 13 (3), 141–164.
Park, C.S., Herath, H.S.B., 2000. Exploiting uncertainty—investment opportunities as real options: A new way of thinking in engineering economics. The Engineering Economist 45 (1), 1–36.
Park, C.S., 1990. Advanced Engineering Economics. In: Park, C.S., Sharp, G.P (Eds.), John Wiley and Sons Ltd, International Ed edition, Inc., New York, NY, p. 635.
Park, C.S., 2015. Contemporary Engineering Economics, Global Edition. Pearson Education, p. 986.
Rudskoy, A.I., Borovkov, A.I., Romanov P.I., 2018. Analiz otechestvennogo opyta razvitiya inzhenernogo obrazovaniya [Analysis of domestic experience in the development of engineering education]. Higher Education in Russia 1, 151–162. (in Russ.)
Sahil, Sood, S. K., 2021. Scientometric analysis of natural disaster management research. Natural Hazards Review 22 (2), 04021008.
Sepulveda, J., 1984 Schaum's Outline of Engineering Economics. Sepulveda, J. (Ed.), McGraw-Hill, p. 107.
Shah, S.H.H., Lei, S., Ali, M., Doronin, D., Hussain, S.T., 2020. Prosumption: Bibliometric analysis using HistCite and VOSviewer. Kybernetes 49 (3), 1020–1045. https://www.doi.org/10.1108/K-12-2018-0696
Simon, H.A., 1966. Theories of decision-making in economics and behavioural science. In: Surveys of Economic Theory. Palgrave Macmillan, pp. 1–28.
Simonovic, S.P., 2020. Systems approach to management of water resources—Toward performance based water resources engineering. Water 12 (4), 1208.
Sullivan, W.G., 1991. A new paradigm for engineering economy. The Engineering Economist 36 (3), 187–200.
Sullivan W.G., 1986. Models IES can use to include strategic, nonmonetary factors in automation decisions. Industrial Engineering18 (3), 42–50.
Sullivan, W., Wicks, E., Koelling, C. 2018. Engineering Economy. Pearson Education International, p. 696
Thuesenm G.J., Sullivan, W.G., 1999. Engineering economy. Ahistorical perspective. 1999 Annual Conference, p. 423–432.
Tirachini, A., 2020. Ride-hailing, travel behaviour and sustainable mobility: An international review. Transportation, 47 (4), 2011–2047
White, J. A., Grasman, K. S., Case, K. E., Needy, K. L., Pratt, D. B., 2020. Fundamentals of engineering economic analysis. John Wiley & Sons.
White, J.A., Case, K.E., Pratt, D.B., 2012. Principles of Engineering Economic Analysis, 6th ed. John Wiley & Sons, p. 928.
Whitman, D.L., Terry, R.E., 2012. Fundamentals of engineering economics and decision analysis Synthesis Lectures on Engineering 7 (1), 1–219.
Yates, J.K., 2016. Engineering Economics. CRC Press.

Список источников

Amadi-Echendu, J.E., Willett, R., Brown, K., Hope, T., Lee, J., Mathew, J., et al., 2010. What is engineering asset management? In Definitions, concepts and scope of engineering asset management (pp. 3–16). Springer, London.
Blank L., Anthony J., Tarquin, A., 2017. Engineering Economy. New York: McGraw-Hill Education, 644 p. Available at: https://razak.utm.my/shamsul/wp-content/uploads/sites/189/2016/03/Engineering-Economy.pdf
Blank, L., Tarquin, A., 2013. Basics of Engineering Economy. Available at: https://industri.fatek.unpatti.ac.id/wp-content/uploads/2019/03/097-Basics-of-Engineering-Economy-Leland-Blank-Anthony-Tarquin-Edisi-1-2007.pdf
Boltürk, E., 2020. Engineering economics using fuzzy sets: A literature review. International Conference on Intelligent and Fuzzy Systems. Springer, Cham, pp. 1675–1682.
Chiu C.Y., Park, C.S., 1994. Fuzzy cash flow analysis using present worth criterion. The Engineering Economist 39 (2), 113–138.
Clark, W., Woodrow, W., Cooke, G., 2014. The green industrial revolution: Energy, engineering and economics. Elsevier Inc., 568 p. ISBN: 978-0-12-802314-3. Available at: https://books.google.ru/books?hl=ru&lr=&id=hLSYBAAAQBAJ&oi=fnd&pg=PP1&dq=Clark,+W.,+Woodrow,+W.,+Cooke,+G.,+2014.+The+green+industrial+revolution:+Energy,+engineering+and+economics&ots=WPkWqgYUX4&sig=We3TYf5nxeSckeqUxZn443RA06Y&redir_esc=y#v=onepage&q=Clark%2C%20W.%2C%20Woodrow%2C%20W.%2C%20Cooke%2C%20G.%2C%202014.%20The%20green%20industrial%20revolution%3A%20Energy%2C%20engineering%20and%20economics&f=false
Dźwigoł, H., Dźwigoł-Barosz, M., 2018. Scientific research methodology in management sciences. Financial and Credit Activity: Problems of Theory and Practice 2 (25), 424–437.
Eschenbach T., Lavelle J.P., Lewis N., 2017. Personal finance coverage in engineering economy courses. 2017 ASEE Annual Conference & Exposition.

Eschenbach T., Lewis N., 2015. Teaching students about the value of diversification–a retirement portfolio's efficient frontier. 2015 ASEE Annual Conference & Exposition, pp. 26–29.
Eschenbach T.G., Gimpel R.J., 1990. Stochastic sensitivity analysis. The Engineering Economist. 1990 35 (4), 305–321.
Eschenbach, T. 2008. Waiting costs for real engineering projects evaluated with real options. In IIE Annual Conference. Proceedings. Institute of Industrial and Systems Engineers (IISE), p. 1273.
Eschenbach, T., Lewis, N., Henrie, M., Baker, E., Hartman, J.C., 2007. Real options and real engineering projects. Engineering Management Journal 19 (4), 11–19.
Eschenbach, T.G., 2003. Engineering Economy. New York: Oxford University Press.
Eschenbach, T.G., 2006. Constructing tornado diagrams with spreadsheets. The Engineering Economist 51 (2), 195–204.
Eschenbach, T.G., McKeague, L.S., 1989. Exposition on using graphs for sensitivity analysis. The Engineering Economist 34 (4), 315–333.
Grant, E.L. 1990. Principles of engineering economy. In: Grant, E.L., Ireson, W.G., Leavenworth, R.S. (Eds.), Wiley, p. 608.
Hartman J.C., Tan C.H., 2014. Equipment replacement analysis: A literature review and directions for future research. The Engineering Economist 59 (2), 136–153.
Herath H.S.B., Park C.S., 1999. Economic analysis of R&D projects: An options approach. The Engineering Economist 44 (1), 1–35.
Heutel, G., Moreno-Cruz, J., Ricke, K., 2016. Climate engineering economics. Annual Review of Resource Economics 8, 99–118. https://www.doi.org/10.1146/annurev-resource-100815-095440
Hossfeld U., Levit G. S., Prokudin D., 2017 Selection methods of digital information resources for scientific heritage studies: A case study of Georgy F. Gause. ACM International Conference Proceeding Series Part F133135, 69–74. https://www.doi.org/10.1007/978-3-030-02846-6_11
Kozyr, N.S., 2022. The keywords for regional economies: Scientometric analysis. Scientific and Technical Libraries (6), 100–121. (In Russ.) https://www.doi.org/10.33186/1027-3689-2022-6-100-121
Lewis N., Eschenbach T., Hartman J., 2009. Real options and the use of discrete and continuous interest rates. 2009 Annual Conference & Exposition, pp. 1410–1418.
Lewis N., Eschenbach T., Hartman J., 2009. Real options: Risk-free and market interest rates.
Lewis N., Eschenbach T., Hartman J., 2018. Integrating real options with decision trees and simulation. Available at: https://www.researchgate.net/publication/289775053_Integrating_real_options_with_decision_trees_simulation_Uncertainty_in_the_graduate_engineering_economy_course
Lewis, N., Eschenbach, T., & Hartman, J.C., 2010. Real options: Divergent view on implementation. Annual National Conference of the American Society for Engineering Management, pp. 54–59.
Li, J., Xiao, F., Zhang, L., Amirkhanian, S.N., 2019. Life cycle assessment and life cycle cost analysis of recycled solid waste materials in highway pavement: A review. Journal of Cleaner Production 233, 1182–1206.
Miller L.T., Park C.S., 2002 Decision making under uncertainty—real options to the rescue? The Engineering Economist 47 (2), 105–150.
Needy, K.L., Nachtmann, H., Lavelle, J.P., Eschenbach, T.G., 2000. An empirical analysis of engineering economy pedagogy. The Engineering Economist 45 (1), 74–92.
Newnan D.G., Lavelle J. P., Eschenbach T., 1998. Essentials of engineering economic analysis. Taylor & Francis.
Newnan, D., Eschenbach, T., Lavelle, J., Lewis, N., 2019. Engineering Economic Analysis. Oxford University Press, vol. 2, 227 p.
Oakford R.V., Thuesen G.J., 1968. The maximum prospective value criterion. The Engineering Economist 13 (3), 141–164.
Park, C.S., 1990. Advanced Engineering Economics. In: Park, C.S., Sharp, G.P (Eds.), John Wiley and Sons Ltd, International Ed edition, Inc., New York, NY, p. 635.
Park, C.S., 2015. Contemporary Engineering Economics, Global Edition. Pearson Education, p. 986.
Park, C.S., Herath, H.S.B., 2000. Exploiting uncertainty—investment opportunities as real options: A new way of thinking in engineering economics. The Engineering Economist 45 (1), 1–36.
Sahil, Sood, S. K., 2021. Scientometric analysis of natural disaster management research. Natural Hazards Review 22 (2), 04021008.
Sepulveda, J., 1984 Schaum's Outline of Engineering Economics. Sepulveda, J. (Ed.), McGraw-Hill, p. 107.
Shah, S.H.H., Lei, S., Ali, M., Doronin, D., Hussain, S.T., 2020. Prosumption: Bibliometric analysis using HistCite and VOSviewer. Kybernetes 49 (3), 1020–1045. https://www.doi.org/10.1108/K-12-2018-0696
Simon, H.A., 1966. Theories of decision-making in economics and behavioural science. In: Surveys of Economic Theory. Palgrave Macmillan, pp. 1–28.
Simonovic, S.P., 2020. Systems approach to management of water resources—Toward performance based water resources engineering. Water 12 (4), 1208.
Sullivan W.G., 1986. Models IES can use to include strategic, nonmonetary factors in automation decisions. Industrial Engineering18 (3), 42–50.
Sullivan, W., Wicks, E., Koelling, C. 2018. Engineering Economy. Pearson Education International, p. 696
Sullivan, W.G., 1991. A new paradigm for engineering economy. The Engineering Economist 36 (3), 187–200.
Thuesenm G.J., Sullivan, W.G., 1999. Engineering economy. Ahistorical perspective. 1999 Annual Conference, p. 423–432.
Tirachini, A., 2020. Ride-hailing, travel behaviour and sustainable mobility: An international review. Transportation, 47 (4), 2011–2047.

White, J. A., Grasman, K. S., Case, K. E., Needy, K. L., Pratt, D. B., 2020. Fundamentals of engineering economic analysis. John Wiley & Sons.
White, J.A., Case, K.E., Pratt, D.B., 2012. Principles of Engineering Economic Analysis, 6th ed. John Wiley & Sons, p. 928.
Whitman, D.L., Terry, R.E., 2012. Fundamentals of engineering economics and decision analysis Synthesis Lectures on Engineering 7 (1), 1–219.
Yates, J.K., 2016. Engineering Economics. CRC Press.
Благинин В.А., Акулова П.Е., Зырянова В.А., Кухарь В.С. Наукометрический анализ сельскохозяйственного научного направления. Аграрный Вестник Урала 9(188)
Елисеева, И.Н., Олейник, Ю.Т., 2022. Методология, теория, история психологии личности. LitRes.
Рудской, А. И., Боровков, А. И., Романов, П. И., 2018. Анализ отечественного опыта развития инженерного образования. Высшее образование в России (1), 151-162.

The article was submitted 29.07.2022, approved after reviewing 23.08.2022, accepted for publication 25.08.2022.

Статья поступила в редакцию 29.07.2022, одобрена после рецензирования 23.08.2022, принята к публикации 25.08.2022.

About authors:
1. Tatiana Kudryavtseva, Doctor of Economics, professor, Graduate School of Industrial Economics, Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia.
https://orcid. org/0000-0003-1403-3447, kudryavtseva_tyu@spbstu.ru
2. Angi Skhvediani, Candidate of economic science, senior lecturer, Graduate School of Industrial Economics, Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia.
https://orcid.org/0000-0001-7171-7357, shvediani_ae@spbstu.ru
3. Viktoriia Brazovskaya, research assistant, Graduate School of Industrial Economics, Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia.
https://orcid.org/0000-0002-9252-7410, brazovskaya_vv@spbstu.ru
4. Marina Dracheva, Master of Economics, Graduate School of Industrial Economics, Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia. marinadracheva74@gmail.com

Информация об авторах:
1. Татьяна Юрьевна Кудрявцева, д.э.н., профессор, Высшая инженерно-экономическая школа, Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия.
https://orcid.org/0000-0003-1403-3447, kudryavtseva_tyu@spbstu.ru
2. Анги Ерастиевич Схведиани, к.э.н., доцент, Высшая инженерно-экономическая школа, Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия.
https://orcid.org/0000-0001-7171-7357, shvediani_ae@spbstu.ru
3. Виктория Владимировна Бразовская, ассистент, Высшая инженерно-экономическая школа, Санкт- Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия.
https://orcid.org/0000-0002-9252-7410, brazovskaya_vv@spbstu.ru
4. Марина Игоревна Драчева, магистр, Высшая инженерно-экономическая школа, Санкт-Петербургский политехнический университет Петра Великого, Санкт-Петербург, Россия. marinadracheva74@gmail.com