

Analyzing the Societal Impact of Academic Research Using Fuzzy Inference Models

Tadeusz Grzeszczyk

Warsaw University of Technology, Faculty of Management, Poland

tadeusz.grzeszczyk@pw.edu.pl

Abstract: Improving universities' social impact is a significant problem in the higher education sector, which can be solved by appropriately shaping public policies, strategies of individual scientific organizations, and academic practices. Effectively conducting social impact analyses can support improving organizations' functioning mechanisms and individual academics' impact practices. These analyses can use data analysis methods and systems that are helpful for better understanding the positive or negative effects of decisions regarding selecting organizational impact strategies. The study of social impact and interactions between scientific organizations and their stakeholders is multifaceted and complex. Therefore, it requires the use of interdisciplinary approaches and sophisticated knowledge-based models. It is worth paying attention to fuzzy logic, which is useful in building such models and developing research on their application to support knowledge management necessary for conducting comprehensive analyses of the social impact of various scientific organizations. This is justified by the need to learn about the mechanisms of functioning systems of relations between scientific organizations and their stakeholders, as well as the types of influence occurring and knowledge exchange during the implemented interaction processes. The pace of changes in the scientific community environment forces an increase in openness for introducing analysis models adequate for the dynamic progress in developing new computational technologies. The main goal of this paper is to create a fuzzy inference model that helps support knowledge management for ongoing analysis and assessment of the social impact of research. The presented theoretical considerations, relating to the construction of the proposed model, are supplemented with a proposal for its implementation, which may later facilitate extensive verification studies based on empirical data. The obtained preliminary research results allow for the formulation of fundamental limitations, the overcoming of which creates a reasonable basis for further development of research on subsequent models of the analysis of social impact.

Keywords: Societal impact analysis, Social impact of academic research, Knowledge-based models, Knowledge management, Fuzzy logic

1. Introduction

Assessing research practices as sufficient is not simple because they refer to symbolic capital based on social recognition and knowledge (Bourdieu et al., 2004). An effective social impact analysis is crucial for improving research strategies by academic institutions and commercial organizations, and shapes the attitudes of individual researchers. Publicly funded institutions in the United Kingdom and Australia have considerable experience with social impact analysis and drawing practical conclusions. Various other countries have also recently introduced or accumulated experience with difficulties in understanding concepts, terminology, and conducting informed analysis.

Performing such analyses is not a straightforward task because the relationships between scientific organizations and their environment and stakeholders are complex and multifaceted. This entails the need to rely on expert opinions or complex methods and systems for data analysis. The problem of analyzing and assessing the societal impact of research is still insufficiently researched, and no proper solution has been found to date. The concept of "impact" is ambiguous and defined differently in individual countries that develop public instruments and assessment systems for improving scientific research supported by public funds. In the case of some systems, the importance of "engagement or partnerships" with nonacademic surroundings is emphasized (in the Netherlands and Poland), improving "outreach" (Portugal) or relationships with the "socioeconomic environment" (France) and, for others, the key terms are "third mission of the universities" (Belgium and Italy), "valorization" (Belgium and France), "knowledge utilization" (the Netherlands) or "knowledge exchange" (Hungary) (Bandola-Gill et al., 2021). Interesting methodological approaches, which can assess the socioeconomic impact of academic research, are being developed in countries where there are no nationwide research impact assessment systems that are modelled on the British Research Excellence Framework or the Australian Excellence in Research. Instead, specific proposals and solutions are being formulated and developed that improve approaches based on knowledge management and adaptive learning systems, the use of which is to support better practices for analyzing and realizing impact (Phipps et al., 2024).

It is noteworthy that, in this context, frequent attention is paid to issues relating to knowledge management. Among the many possible solutions, interdisciplinary approaches and complex knowledge-based models, e.g.,

using new computational technologies and AI, may look promising. The use of interdisciplinary approaches and AI technologies enables the implementation of knowledge-based systems, which allow for intelligent data analysis with the support of methods that help the generation of decision rules based on incomplete and uncertain empirical data. Among such methods, there are mathematically inspired solutions of a symbolic nature, such as fuzzy logic. Mathematical tools based on this type of logic are proven mathematical tools that are useful in many different applications and for creating models with interesting properties. They can support the collection and management of knowledge that is beneficial for the implementation of multi-aspect analyses of the social impact of research conducted by scientific organizations. The dynamic development of new computational technologies and artificial intelligence justifies the proposal to use such models. The use of fuzzy knowledge-based models enables support for knowledge management regarding social impact, exploration of highly complex relationships between scientific organizations and their immediate and distant environment, and learning about the mechanisms of knowledge exchange relating to the implementation of interaction processes.

The main goal of this paper is to create a fuzzy inference model that helps support a knowledge management scheme for ongoing analysis and assessment of the social impact of research. The knowledge used is represented in the form of fuzzy if-then rules. The knowledge base built from these rules can be continuously updated thanks to a feedback loop. Theoretical considerations concerning the basics of design and implementation of the proposed model are presented. The theoretical content is supplemented with practical remarks that may be useful during the implementation of later broader studies devoted to empirical verification of the proposed model. Conducting the preliminary studies described in this paper allows us to outline the limitations and challenges, which will possibly be overcome thanks to further progress in research on increasingly perfect models of social influence analysis.

2. Analyzing the Societal Impact of Academic Research

Increasingly more universities are preparing reports on their research, teaching, and service activities in the context of the United Nations Sustainable Development Goals (UN SDGs). This is seen as having real benefits, e.g., improving reputation, strengthening university engagement with stakeholders, supporting innovative research, and promoting transdisciplinary research ideas. However, it is not a simple task to achieve; comments from skeptics sometimes include accusations of greenwashing (De Villiers et al., 2025).

Among the UN SDGs, the social aspects of the activities of universities play an important role. In recent years, it has become possible to observe the growing importance of analyses concerning these aspects performed in terms of improving the quality of research and their significance for the environment of scientific institutions. In particular, growing interest is being aroused by the issues of the societal impact of research and performance-driven assessment technologies, which are conducted to improve the quality of research, and the rationality of decision-making regarding the expenditure of public funds for these purposes and stimulating the global competitiveness of research centers. The development of methodological foundations (i.e., research quality indicators and measures and methods of impact assessment) for the correct conduct of these analyses not only promotes the development of competitiveness but also facilitates the construction of a foundation for a responsible and measurable contribution to the knowledge-based economy. In addition, it helps in the commercialization of scientific research results at various levels: organizational, national, and international (Oancea, 2019).

Analysing and assessing the societal impact of academic research is not an easy task. There are currently lively debates on understanding the basic concepts and terminology used. Key topics discussed in these discussions include the real possibilities of influencing nonacademic audiences and the negative consequences of improperly defining and formalizing impact for the purposes of analyses conducted within research funding systems. In particular, the unclear distinction of impact relating to outcomes (e.g., socioeconomic effects) or emphasizing the importance of selected processes (i.e., partnerships, engagement, or knowledge transfer, exchange, and utilization) (Bandola-Gill et al., 2021). It is worth paying attention to the aspect of streamlining the process of transferring generated scientific knowledge to society and improving the achieved societal impact as a result of increasing engagement with research stakeholders (Azagra-Caro & Boni, 2023).

Leading British solutions relating to the analysis and assessment of the impact of scholarly work outside of academia (the results of which are linked to public research funding) were introduced as part of the Impact Agenda and Research Excellence Framework 2014. The results of such analyses provoke lively discussions on science policy and the development of innovation, and even the possibility of formulating recommendations for decision-makers on how to democratize research impact assessments, supporting equitable and inclusive

research impact to increase equity in academic careers (Araci & Ozbilgin, 2025). The British solution has become a model to follow in various countries with significantly different public finance capabilities and science systems. The results of comparative analyses of, e.g., UK, Poland, and Norway indicate the need for further in-depth research on improving the methods used and adapting them to national realities, not only in terms of refining definitions and evaluation criteria but also aspects relating to specific features of academic culture (Wróblewska, 2024).

It is difficult to develop approaches, methods, and tools that support the analysis and assessment of social impact due to the aforementioned cultural diversity, difficulties in understanding the heterogeneity of cultural tools, and the need to take into account the existing nondeterministic mechanisms that prevent the simple application of patterns of thinking and behavior regarding explicit and implicit expectations (Williams & Michalska, 2024). Another challenge signaled in the literature is the need to move away from traditional and exclusively retrospective methods of analyzing the impact of research in the event of global or international crisis situations (e.g., relating to the coronavirus pandemic) toward iterative approaches enabling semiautomatic rapid ongoing assessment and the implementation of rapid responses of national research systems to crisis situations (Baaden et al., 2024). Intelligent systems using fuzzy logic are well suited to supporting the solving of poorly structured problems in an automated and expert-based manner. They are the subject of the next section.

3. Applying Fuzzy Inference-Based Models

Fuzzy rules can be used to represent and store knowledge from domain experts conducting multicriteria analyses and assessments of the societal impact of academic research. Empirical data from evaluators in such a situation constitutes the basis for discovering knowledge, which is then recorded in the form of rules. Knowledge recorded in this way reflects the experiences and hidden motivations of experts who make decisions in specific situations, based on reasons that are not always clear, and in specific conditions of a dynamically changing environment.

Fuzzy logic is the basis for the development of research relating to soft computational methods, which are very useful in cases where the studied problem is imprecisely described and difficult to estimate using quantitative methods. This is a typical situation for many issues in the field of analyzing social phenomena and problems. This type of logic allows for expanding the scope of possible research and complementing available approaches and methods that are important for fundamental support of the creation of knowledge systems, which are useful in supporting the solution of decision problems under conditions of uncertainty, for which domain expert knowledge is required.

Fuzzy logic facilitates the implementation of intelligent and complex systems operating in accordance with human-like reasoning. It finds numerous applications in solving problems requiring interpretation, analysis, and evaluation of phenomena relating to the inherent ambiguities concerning social aspects, for which it is necessary to use imprecise and uncertain data (Sekhi et al., 2025). The aforementioned properties of fuzzy logic mean that it is suitable for implementing multicriteria analysis and evaluation processes of the societal impact of academic research, for which deterministic methods based on two-valued logic and classical set theory are inappropriate. Classical solutions do not accept the uncertain assignment of objects to sets, generalizations, and gradation of estimated values of variables. In the case of classical set theory, objects should be precisely and unambiguously assigned to sets. For the newer theory of elements, this approach is different, and some objects may partially belong to defined sets. In the case of analyzing the societal impact, it is necessary to use ambiguous and incomplete data, as well as to use inference tools under conditions of uncertainty. Fuzzy methods are used to solve many problems, the solution of which is impossible or unprofitable using standard mathematical models.

Fuzzy logic is the basis for proposing approaches to reasoning based on imprecise conclusions and building knowledge bases about objects characterized by fuzzy attributes; knowledge is represented using fuzzy if-then rules. Knowledge recorded in databases is understandable to humans thanks to readable forms. This formal representation of knowledge assumes its recognition in the form of information granules. Knowledge granularity and fuzzy information enable its practically useful modeling using the following categories of sets: classical (crisp) and fuzzy. Such a view of sets constitutes, as well as granulation, knowledge organization, and causation, the basis of human-centric computing analogous to human cognition (Zadeh, 1997). Granular fuzzy logic systems can be used to store various types of knowledge and effectively support knowledge management processes thanks to the previously developed mathematical tools and algorithms for learning, discovering, and

generalizing knowledge, on the basis of which it is possible to infer and draw practically useful conclusions (Pedrycz & Song, 2012). Granular fuzzy rule-based models often achieve high levels of accuracy, significant interpretability, prediction intervals with sound robustness, and high granular performance (Pang et al., 2022).

In the granular rule modeling systems discussed here, fuzzy sets are the basis for designing and implementing knowledge-based fuzzy systems. Knowledge is represented in the form of if-then rules constructed with antecedents and consequences: IF x is A THEN y is B . In these rules, x and y are variables that have linguistic values A and B in accordance with the concept of fuzzy sets (Zadeh, 1965). There is a vast literature available on the applications of artificial intelligence supporting knowledge management processes (Girón et al., 2025). AI technologies are generally used for intelligent information processing and, within such applications, various research areas relating to fuzzy reasoning can be observed (Zhang, 2025). Fuzzy logic is the basis for the development of systems supporting knowledge management in various areas, e.g., supply chain management (SCM) (Ettahiri & Elmaallam, 2019), demand forecasting in SCM (Subramanian et al., 2025), knowledge-based stakeholder analysis (Grzeszczyk & Kuchta, 2021), performance measurement systems (Lee & Wong, 2017), formulating actionable recommendations based on analyses of complex decision-making scenarios for infrastructure projects (Hajimirzajan et al., 2025) and benchmarking the knowledge management performance in companies (Kale & Karaman, 2011).

The most commonly used solutions based on fuzzy logic include fuzzy inference models, which are known for their use in fuzzy control and generating decision rules useful in various applications in decision support systems. For the years 2004–2024 and the keywords “fuzzy inference systems” and “decision support systems,” 417 results were obtained for the search conducted in April 2025 in the Scopus database (including Article Title, Abstract, and Keywords). An upward trend is noticeable in this time series, illustrating the number of publications. The largest number of publications was assigned to the fields of computer science (60%) and engineering (43%). Relatively few in decision sciences (6%), business, management, and accounting (6%), and social sciences (5%). This results in significant research potential regarding the applications of fuzzy inference systems in decision support in business, management, and economics.

Fuzzy inference models are suitable for solving classification and regression problems, enabling the discovery and accumulation of knowledge from imprecise empirical data in a way inspired by human reasoning. They are well suited for representing nonlinear relationships between input variables and output variables, and for solving decision problems involving subjective factors, attitudes, and circumstances, e.g., regarding mergers and acquisitions processes for acquirer and deal-specific factors (Campbell et al., 2016). Fuzzy logic also supports analyses where variables are not precisely defined. Fuzzy inference models are also a proven tool useful for implementing effective prediction methods and management control systems for enterprises (Nasiboglu & Nasibov, 2025; Nicolas et al., 2021).

Intelligent fuzzy inference systems require defining input and output linguistic variables, as well as the knowledge base, which is built on fuzzy rules. Their operation requires converting crisp input values into fuzzy values. The operation of a typical model is based on three stages of the following sequence of actions: fuzzification, inference, and defuzzification. The first stage concerns determining the membership grade of crisp input datasets, while the second stage involves the resulting membership function based on the input membership grades. The last stage concerns outputting crisp values corresponding to the modified membership function of conclusions (Gomes & Basilio, 2024).

Knowledge-based fuzzy systems operating in accordance with the idea of fuzzy inference models are useful for supporting the analysis and assessment of the societal impact of research. This is particularly justified due to the complexity and variability of the problems studied, the turbulent nature of the organization’s environment resulting from, among others, the frequently changing requirements of sponsors and regulations, as well as the growing competition between scientific institutions. The high pace of change and the dynamic nature of the processes of analysis and assessment of social impact require the provision of tool support for experts in the form of intelligent systems based on the discovery and collection of domain expert knowledge. The processes of managing this knowledge are very complex, requiring the processing of ambiguous, inaccurate, and uncertain data. Progress in this type of research can be achieved through experiments with a selected model of fuzzy logic, which is the subject of the next section of this paper.

4. Methodology and Results

Research was performed to find answers to the following research question: What is the need and possibility of using fuzzy inference models for analyzing the societal impact of academic research? Finding answers to such a question allows for obtaining the effects of a theoretical, cognitive, and application nature.

The following assumptions were adopted for the developed fuzzy inference model:

- a multi-aspect approach, which ensures taking into account various quantitative and qualitative variables,
- universality of the model expressed in terms of the possibility of its application at various levels—individual research teams and entire organizations,
- primacy of the learning process over the static use of knowledge resources,
- feedback allows for continuous updating of the knowledge base and dynamic adaptation to occurring changes,
- based on a systemic approach integrating interdisciplinary solutions,
- two-stage design—from a general model to a formalized form facilitating its implementation,
- preliminary experiments covering implementation and initial verification using empirical data,
- knowledge base regarding objects characterized by fuzzy attributes with knowledge that is represented using fuzzy if-then rules,
- use of the Sugeno-type model as a fuzzy inference system,
- fuzzy logic allows for taking into account the ambiguity and uncertainty characteristics of different expert opinions regarding the societal impact of research,
- empirical basis for model verification is experience relating to knowledge discovery and multicriteria analysis.

The integrative nature of systems research offers valuable opportunities for developing models that draw on interdisciplinary approaches to address the complex challenge of assessing the social impact of research (Grzeszczyk, 2025). To support this effort, new socio-technical decision support systems should be designed to meet the evolving demands of a paradigm shift toward decision-making frameworks that systematically incorporate social and ethical considerations (Raza, 2022).

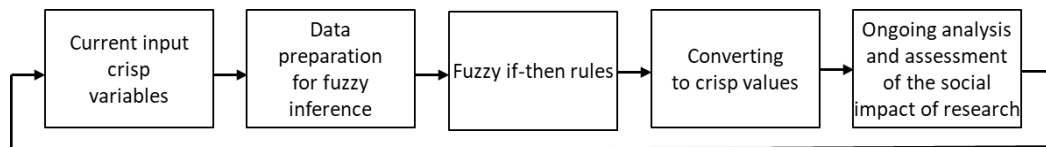


Figure 1: Fuzzy inference model for ongoing analysis and assessment of the social impact of research

The results of the modeling processes were presented in the form of a model of the system for collecting and sharing technological knowledge based on specific mathematical and computer solutions (Figure 1). Data analysis using the method based on fuzzy logic allows for taking into account the ambiguity, vagueness, and uncertainty characteristic of empirical data relating to different expert opinions on emerging technologies. In particular, the Sugeno-type model was used as the fuzzy inference system.

The process begins with current input crisp variables, which represent measurable indicators relevant to societal outcomes. These inputs undergo data preparation for fuzzy inference, where they are transformed into fuzzy numbers through a fuzzification process. Using fuzzy if-then rules, the inference engine evaluates these fuzzy values against expert-defined logical conditions that model the relationships among social factors. The resulting fuzzy outputs are then translated back into interpretable, actionable figures through defuzzification, a process of converting to crisp values. These outputs represent the assessed impact in a form suitable for reporting or policy guidance. The final step, ongoing analysis and assessment of the social impact of research, involves interpreting these results in context and using them to inform strategy or resource allocation. A feedback loop links this final stage back to the beginning, enabling the refinement of rules and input variables based on observed outcomes, thus enhancing the relevance and accuracy of future assessments. This cyclical process supports dynamic, evidence-based evaluation in the social sciences.

The model implementation was performed using the fuzzy logic toolbox from MATLAB Software, which implemented the Sugeno knowledge base in accordance with available best practices (Sivanandam et al., 2007). The use of proven mathematical and computer tools based on fuzzy logic when designing a formalized

form of the model creates conditions for further development of methodological research relating to subsequent implementations and further improvement of the proposed solutions.

The problem of assessing social impact is largely heuristic in nature because the processed empirical data originates from, e.g., experts who make decisions based on personal experiences reflecting subjective hidden knowledge. Knowledge gathered in the knowledge base is created mainly as a result of its discovery from empirical data in the learning process. Knowledge is saved in the base in the form of fuzzy if-then rules and is continuously updated thanks to the use of a feedback loop. The experimental implementation of the model and the obtained preliminary results from its examination confirmed the practical usefulness of the proposed solution.

5. Conclusions

As part of the research synthetically presented in this paper, a model based on the Sugeno-type fuzzy inference system was developed, which is used to support the analysis and assessment of the societal impact of academic research. Theoretical considerations were enriched with a proposal for experimental implementation and application of the model. The conducted research aimed to find an answer to the research question regarding the possibility and validity of using fuzzy logic models in this field. The use of a systemic approach facilitated the interdisciplinary theoretical analysis of the model, as well as the demonstration of its practical usefulness during empirical experiments.

Advances in artificial intelligence and machine learning may influence the development of further methodological research in this field. In future processes for improving the proposed model, it is worth examining other available information technology solutions, developing subsequent models toward integrated solutions that are characterized by the desired features of dynamic, holistic systems, and to a greater extent, taking into account diverse groups of stakeholders. These considerations require an approach enriched with various types of feedback, so that the developed model not only provides correct analysis results but is also a source of recommendations facilitating the taking of actions improving the societal impact of academic research.

Acknowledgments

This scientific work was financed from the state budget under the program of the Minister of Science and Higher Education in Poland, called "Science for Society II" (project no. NdS-II/SP/0409/2023/01). The amount of co-financing and the total value of the project was PLN 280,500.



Ministry of Science and Higher Education
Republic of Poland

Ethics declaration: Ethical clearance is not required for this research.

AI declaration: AI tools were used in the modeling processes described in this paper.

References

- Araci, O., & Ozbilgin, M. (2025). Noninclusive Impact: Rethinking Research Impact Through an Equity Lens and Equality Interventions. SSRN. <https://doi.org/10.2139/ssrn.5123937>
- Azagra-Caro, J. M., & Boni, A. (2023). Enlarging the knowledge transfer realm through engagement with research stakeholders: A conversation attempt with action research. *Tapuya: Latin American Science, Technology and Society*, 6(1), 2213596. <https://doi.org/10.1080/25729861.2023.2213596>
- Baaden, P., Hollmann, V., & Jovanović, M. (2024). Rapid assessment of crisis response using a new semi-automatic iterative method—How national research systems address the SARS-CoV-2 pandemic. *Research Evaluation*, 34, rvaf005. <https://doi.org/10.1093/reseval/rvaf005>
- Bandola-Gill, J., Flinders, M., & Brans, M. (2021). Incentives for Impact: Relevance Regimes Through a Cross-National Perspective. In R. Eisfeld & M. Flinders (Eds.), *Political Science in the Shadow of the State* (pp. 35–63). Springer International Publishing. https://doi.org/10.1007/978-3-030-75918-6_2
- Bourdieu, P., Nice, R., & Bourdieu, P. (2004). *Science of science and reflexivity*. University of Chicago Press.
- Campbell, J. T., Sirmon, D. G., & Schijven, M. (2016). Fuzzy Logic and the Market: A Configurational Approach to Investor Perceptions of Acquisition Announcements. *Academy of Management Journal*, 59(1), 163–187. <https://doi.org/10.5465/amj.2013.0663>

- De Villiers, C., Dimes, R., & Molinari, M. (2025). Determinants, mechanisms and consequences of UN SDGs reporting by universities: Conceptual framework and avenues for future research. *Journal of Public Budgeting, Accounting & Financial Management*, 37(2), 329–349. <https://doi.org/10.1108/JPBAFM-07-2023-0125>
- Ettahiri, F. E., & Elmaallam, M. (2019). The impact of Fuzzy Logic on Knowledge Management in the context of Supply Chain: A state of art. *Proceedings of the 2nd International Conference on Networking, Information Systems & Security*, 1–6. <https://doi.org/10.1145/3320326.3320395>
- Girón, D. C. A., Yovera, S. E. R. Y., Torres De Salinas, F. D. M. G., Soto, F. G. C., & Cadenas, D. I. V. (2025). The relationship between knowledge management and artificial intelligence: A thematic analysis from Scopus. *Iberoamerican Journal of Science Measurement and Communication*, 5(1), 1–10. <https://doi.org/10.47909/ijsmc.1713>
- Gomes, A. D. O., & Basilio, J. C. (2024). A Fuzzy Inference Model to Identify the Current Industry Maturity Stage in the Transformation Process to Industry 4.0. *IEEE Transactions on Automation Science and Engineering*, 21(2), 1607–1622. <https://doi.org/10.1109/TASE.2023.3242225>
- Grzeszczyk, T. A. (2025). Using Systemic and Praxeological Approaches for Modeling Social Impact Assessment of Research, In: Moffett S., Reid A. (ed.), *Proceedings of the 24th European Conference on Research Methodology for Business and Management Studies*, 24(1), 18–24. <https://doi.org/10.34190/ecrm.24.1.3685>
- Grzeszczyk, T. A., & Kuchta, D. (2021). Applying Fuzzy Modelling to Stakeholder Analysis, In: Costa C., Au-Yong-Oliveira M. (ed.), *Proceedings of the 20th European Conference on Research Methodology for Business and Management Studies*, ACPI, pp.108-115, DOI:10.34190/ERM.21.015.
- Hajimirzajan, A., Kazemian, M., & Fischer, S. (2025). A Fuzzy Framework for Assessing and Prioritizing Railway Infrastructure Retrofitting Against Seismic Hazards – A Case Study. *Acta Polytechnica Hungarica*, 22(4), 263–286. <https://doi.org/10.12700/APH.22.4.2025.4.16>
- Kale, S., & Karaman, E. A. (2011). A fuzzy logic model for benchmarking the knowledge management performance of construction firms. *Canadian Journal of Civil Engineering*, 38(4), 464–475. <https://doi.org/10.1139/111-019>
- Lee, C. S., & Wong, K. Y. (2017). A Fuzzy Logic-Based Knowledge Management Performance Measurement System for SMEs. *Cybernetics and Systems*, 48(4), 277–302. <https://doi.org/10.1080/01969722.2017.1284532>
- Nasiboglu, R., & Nasibov, E. (2025). Efficiency analysis of the rule-based defuzzification approach to fuzzy inference system for regression problems. *Kybernetika*, 109–132. <https://doi.org/10.14736/kyb-2025-1-0109>
- Nicolas, C., Müller, J., & Arroyo-Cañada, F.-J. (2021). A Fuzzy Inference System for Management Control Tools. *Mathematics*, 9(17), 2145. <https://doi.org/10.3390/math9172145>
- Oancea, A. (2019). Research governance and the future(s) of research assessment. *Palgrave Communications*, 5(1), 27. <https://doi.org/10.1057/s41599-018-0213-6>
- Pang, Y., Wang, L., Liu, Y., & Guo, J. (2022). Fuzzy rule-based models via space partition and information granulation. *Neural Computing and Applications*. <https://doi.org/10.1007/s00521-022-06974-3>
- Pedrycz, W., & Song, M. (2012). Granular fuzzy models: A study in knowledge management in fuzzy modeling. *International Journal of Approximate Reasoning*, 53(7), 1061–1079. <https://doi.org/10.1016/j.ijar.2012.05.002>
- Phipps, D., Graham, K., & Nason, E. (2024). Canadian approaches to research impact and its assessment. *Research Evaluation*, 34, rvaf003. <https://doi.org/10.1093/reseval/rvaf003>
- Raza, S. A. (2022). A paradigm shift to ethical decision-making—Incorporating systemic epistemology into complex socio-technical decision support systems research. *Journal of Decision Systems*, 32(1), 177–200. <https://doi.org/10.1080/12460125.2021.2015840>
- Sekhi, I., Kovács, S., & Nehéz, K. (2025). Enhancing Decision-making in Uncertain Domains through Optimized Fuzzy Logic Systems. *Periodica Polytechnica Electrical Engineering and Computer Science*, 69(1), 63–78. <https://doi.org/10.3311/PPee.38729>
- Sivanandam, S. N., Sumathi, S., & Deepa, S. N. (2007). *Introduction to Fuzzy Logic using MATLAB*. Springer Berlin Heidelberg. <https://doi.org/10.1007/978-3-540-35781-0>
- Subramanian, B., Mishra, A., V, B., Mandala, G., K, N., & S, S. (2025). Big Data and Fuzzy Logic for Demand Forecasting in Supply Chain Management: A Data-Driven Approach. *Journal of Fuzzy Extension and Applications*, Online First. <https://doi.org/10.22105/jfea.2025.488816.1703>
- Williams, K., & Michalska, S. (2024). Repertoires of research value: Performing societal impact across countries. *Research Evaluation*, 34, rvae063. <https://doi.org/10.1093/reseval/rvae063>
- Wróblewska, M. N. (2024). One size fits all? A comparative review of policy-making in the area of research impact evaluation in the UK, Poland and Norway. *Research Evaluation*, 34, rvaf010. <https://doi.org/10.1093/reseval/rvaf010>
- Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, 8(3), 338–353. [https://doi.org/10.1016/S0019-9958\(65\)90241-X](https://doi.org/10.1016/S0019-9958(65)90241-X)
- Zadeh, L. A. (1997). Toward a theory of fuzzy information granulation and its centrality in human reasoning and fuzzy logic. *Fuzzy Sets and Systems*, 90(2), 111–127. [https://doi.org/10.1016/S0165-0114\(97\)00077-8](https://doi.org/10.1016/S0165-0114(97)00077-8)
- Zhang, H. (2025). Application of Fuzzy Reasoning with Fusion Rules in Intelligent Information Processing. *Journal of Information & Knowledge Management*, 24(01), 2450094. <https://doi.org/10.1142/S0219649224500941>