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Analytical method to improve the decision-making criteria approach in managing digital social channels

Solomiia Fedushko [a,b,*], Kateryna Molodetska [c], Yuriy Syerov [a]

[a] Social Communication and Information Activity Department, Lviv Polytechnic National University, 79000, Lviv, Ukraine
[b] Department of Information Systems, Faculty of Management, Comenius University in Bratislava, 820 05, Bratislava, Slovakia
[c] Department of Computer Technologies and Systems Modeling, Polissia National University, Staryi Blvd., 7, Zhytomyr, 10008, Ukraine

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ABSTRACT

This study explores the decision-making process involved in managing digital communities in the digital social channel ecosystem, specifically in the context of antagonistic digital communication and harmful content dissemination. The rise of digital communities in social media has changed the way people interact with each other, form communities, and participate in social activities. However, these interactions can also lead to conflicts, and the dissemination of harmful content can pose a risk to users' information security. This research proposes a method to mitigate these issues and optimize efficacy while minimizing potential hazards. The proposed method is based on the analysis of the information situation in the management of digital communities under conditions of complete uncertainty, antagonistic behaviour, and partial uncertainty. The study examines the decision-making process involved in antagonistic interaction among users of digital social channels. The methods proposed in this research were implemented to prevent the adverse consequences of community conflicts and the dissemination of potential risks to the security of users' information through prompt and efficacious decision-making. The proposed strategy optimizes efficacy through the implementation of the Wald criteria while minimizing potential hazards by adhering to the Savage criteria. Additionally, the Hurwitz criteria, which presents a balanced approach incorporating both the maximum and minimum criteria, was also employed. The methods were tested within the online community present on the social media platform, Facebook social networks, and the results demonstrate that the suggested technique improves the effectiveness and validity of managers' decisions in digital communities. The study also highlights the use of social networks and the virtual sphere as tools for hybrid warfare on the internet, which can be effective. Effective community management is necessary to mitigate the negative effects of online interactions, and the proposed method offers a valuable tool for managers to make informed decisions and prevent adverse consequences.

1. Introduction

Digital social channels have brought about significant changes in how people interact with each other, form communities, and participate in social activities. Digital communities in digital social channels [1] have become an integral part of modern society, and their activities have a profound impact on how society operates. In this academic essay, we will explore the ways in which communities

* Corresponding author. Department of Social Communications and Information Activities, Lviv Polytechnic National University, Lviv, Ukraine.
E-mail address: solomiia.s.fedushko@lpnu.ua (S. Fedushko).

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in digital social channels are changing society [2,3]. Digital social channels [1] refer to online platforms and technologies that enable people to communicate, share information, and interact with others in a social context. These channels can take many forms, including social media sites like Facebook, Instagram, and Twitter, messaging apps like WeChat and WhatsApp, and online forums and discussion groups. The term "digital" refers to the fact that these channels are accessed and used through digital technologies, such as computers, smartphones, and other connected devices. Meanwhile, the term "social" refers to the fact that these channels are primarily used for socializing and connecting with others, rather than for purely functional purposes like work or commerce. Digital social channels have become an increasingly important part of modern communication and social interaction, with billions of people around the world using them daily. They provide a powerful tool for building and maintaining social connections, sharing information and ideas, and staying up-to-date on news and trends. However, they also raise important questions about privacy, security, and the impact of technology on society. Digital communities in digital social channels are groups of individuals who come together to share common interests, experiences, and knowledge on a virtual platform. These communities take various forms, ranging from social networks like Instagram, Twitter, and Facebook to specialized forums, chat rooms, and discussion boards. Communities in digital social channels provide a platform for people to connect with others who share similar interests and engage in meaningful conversations.

The rise of communities in digital social channels has significantly impacted society [4–6]. These communities have facilitated communication and collaboration among people from different parts of the world. Communities in digital social channels have enabled people to connect with others who share similar interests and engage in meaningful conversations. The impact of communities in digital social channels [7,8] can be seen in the following areas.

- Social and cultural impact. Communities in digital social channels have contributed to the creation of a global community that transcends geographic boundaries. These communities have provided a platform for people from different parts of the world to connect and engage in meaningful conversations. Communities in digital social channels have also contributed to the preservation and dissemination of cultural knowledge, traditions, and practices. Through digital communities, people can learn about different cultures and traditions, leading to increased tolerance and appreciation for diversity.
- Economic impact. Communities in digital social channels have also had an economic impact on society. These communities have facilitated the creation of new business models and provided a platform for entrepreneurs to connect with potential customers. Communities in digital social channels have also enabled people to access goods and services that were previously unavailable, leading to increased competition and reduced prices.
- Political impact. Communities in digital social channels have also significantly impacted politics. These communities have provided a platform for people to express their opinions and engage in political discourse. Communities in digital social channels have also facilitated political mobilization, leading to increased citizen participation in political processes.

Communities in digital social channels have become an integral part of modern society. These communities have facilitated communication, collaboration, and engagement among people from different parts of the world. The impact of communities in digital social channels can be seen in social, cultural, economic, and political spheres. As society continues to evolve, it is clear that communities in digital social channels will continue to play a critical role in shaping the way we interact with each other and participate in social activities.

In contemporary society, digital social channels have emerged as the principal driver of large-scale initiatives aimed at advancing the information society. These services function as a platform for creating and transforming companies and NGOs that represent the interests and aspirations of the citizenry. Furthermore, digital social channels play a vital role in structuring communication spaces and providing businesses with valuable social media analytics to support their decision-making processes. Additionally, these services have led to the emergence of digital communities and other forms of virtual networks that foster collaboration and engagement among individuals with shared interests. The continuous advancement of information technologies and their integration into all areas of public activity, along with the emergence of new knowledge, have made information a crucial factor in shaping economic activity. However, while modern information technologies offer many benefits, they also pose new threats to economic relations that are closely tied to information-based activities.

Communities within digital social channels have the capacity to transform society through the production and sharing of information. However, the information being shared within these communities is often untrustworthy, partial, inaccurate, and questionable, which creates opportunities for the manipulation of personal or societal opinions. Studies have demonstrated that threats to cybersecurity within digital social channels result in disordered and uncontrollable user interaction, which causes chaotic communication dynamics. To address this issue, it is necessary to decrease the data entropy level within the virtual sphere of digital social channels to stabilize the users' overall attitude. Enhancing the critical perception of users towards harmful content [9–11] and implementing regulations to govern the interactions and decisions made by community members can aid in reducing the issue of untrustworthy information in digital communities. This approach is considered a potential solution to this problem.

The goal of the paper is to survey the process of making the decision involved in antagonistic digital interaction [12–14] among users of digital social channels and to propose methods to mitigate the adverse effects of the dissemination of harmful content and the unfair practices of competitors within the digital social channel ecosystem. The study aims to optimize efficacy through the implementation of the Wald criteria while minimizing potential hazards by adhering to the Savage criteria [15–17]. Additionally, the Hurwitz criteria [17], which presents a balanced approach incorporating both the maximum and minimum criteria, is also employed. The methods that were created have been subjected to testing within the online community present on the social media platform, Facebook. The paper contributes to the existing literature on digital community management by highlighting the importance of effective decision-making in addressing these complex and dynamic digital ecosystems. The research proposes an innovative approach

that considers the condition in the process of making the decision of managing user societies of digital social channels in conditions of complete and partial uncertainty, as well as the decision-making process under conditions of user antagonistic and aggressive behaviour in the digital ecosystem. The antagonistic behaviour of users of a digital community is actions or behaviors exhibited by individuals within an online community that are hostile, confrontational, or intentionally disruptive to other members of the community. Examples of antagonistic behaviour in an online community can include trolling, flaming, cyberbullying, or harassment of other users. These actions can be motivated by a desire to cause emotional harm, gain attention, or simply disrupt the normal functioning of the community. Antagonistic behaviour can have a negative impact on the overall health and well-being of an online community, as it can drive away other members and create a toxic atmosphere. As such, many online communities have policies and procedures in place to address and discourage such behaviour, including moderation and reporting systems, community guidelines, and user bans or suspensions for repeat offenders. This proposed approach will provide cybersecurity for management actors and increase the efficiency and validity of managers' decision-making in digital communities, making a positive impact on the sustainable development of digital social channels.

The progress of digital communities has transformed the way individuals interact, share information, and collaborate with each other. Digital communities offer unique opportunities for knowledge sharing, collective problem-solving, and social interaction, making them essential tools for businesses, non-profit organizations, and governmental agencies. However, the management of digital communities presents significant challenges, particularly in the face of complete uncertainty, antagonistic behaviour of the digital ecosystem, and partial uncertainty.

The decision-making process within these conditions requires a comprehensive understanding of the factors at play, the goals of the community, and the underlying motivations of the community members. This paper aims to explore the decision-making criteria process in managing digital communities in the face of complete uncertainty, antagonistic and hostile behaviour of the digital ecosystem, and partial uncertainty. We examine the theoretical foundations of decision-making under these conditions and provide practical insights into how online community managers can navigate these challenges. Our research contributes to the existing literature on managing the digital community by highlighting the importance of effective decision-making in addressing these complex and dynamic digital ecosystems. By offering a comprehensive framework for managing digital communities in these conditions, we aim to provide a valuable resource for community managers seeking to achieve their goals and foster positive and sustainable digital communities.

Research innovations. In the present research, it has been proposed for the first time to consider the condition in the process of making the decisions of managing user groups of digital social channels in conditions of complete and partial uncertainty, as well as the decision-making process under conditions of antagonistic and aggressive behaviour of the digital ecosystem. This state-of-the-art approach will provide cybersecurity for management actors. This suggested method grows the validity and effectiveness of decision-making in digital community managers. Consequently, prerequisites are created for the sustainable development of digital social channels in the context of disseminating and executing menaces toward the users' and communities' cybersecurity. Implementing the developed methods in digital community management contributes to achieving the aim of community functioning and minimizing the negative effect on community users related to the expansion of harmful material and the conduct of deceitful individuals within the digital landscape of social media platforms.

Importance of the problem. The problem addressed in this paper is highly relevant in today's digital age, as digital communities have become a significant part of people's social activities and interactions. The rise of digital communities in social media platforms has brought about new challenges, such as conflicts and the dissemination of harmful content that can pose a risk to users' information security. These challenges require prompt and efficacious decision-making by community managers. This paper proposes a method to mitigate these challenges and optimize efficacy while minimizing potential hazards. The study explores the decision-making process involved in managing digital communities in the context of antagonistic digital communication and harmful content dissemination. The proposed method is based on the analysis of the information situation in the management of digital communities under conditions of complete uncertainty, antagonistic behaviour, and partial uncertainty.

The research is significant because it addresses the need for effective community management to mitigate the negative effects of online interactions. The proposed method offers a valuable tool for managers to make informed decisions and prevent adverse consequences. The study also highlights the use of social networks and the virtual sphere as tools for hybrid warfare on the internet, which can be effective.

The object of this study is the process of user interaction using digital platforms in the context of antagonistic behaviour of users of digital communities.

This paper is important as it addresses a significant problem that affects digital communities' efficacy and users' information security. The proposed method offers a valuable tool for community managers to make informed decisions and prevent adverse consequences, thereby enhancing the effectiveness and validity of managers' decisions in digital communities. The research has practical implications for real-world digital communities, and future research will focus on the implementation of the proposed method in real-world digital communities.

The main contributions of this research are.

1) The study highlights the effectiveness of utilizing the virtual sphere as an instrument used for hybrid warfare on the internet.
2) The research examines the process of making the decision involved in antagonistic digital communication among users of digital social channels and proposes methods to mitigate the adverse effects of the dissemination of harmful content and the unfair practices of competitors within the digital social channel ecosystem.

3) The study proposes a strategy that optimizes efficacy through the implementation of the Wald criteria while minimizing potential hazards by adhering to the Savage criteria. Additionally, the Hurwitz criteria, which presents a balanced approach incorporating both the maximum and minimum criteria, was also employed.
4) The research provides practical insights into how online community managers can navigate the complex and dynamic digital ecosystems of communities in the face of complete uncertainty, antagonistic and aggressive behaviour of the digital ecosystem, and partial uncertainty.
5) The methods proposed in the research have been subjected to testing within the online community present on the social media platform, Facebook.

Social networks and the virtual sphere have become powerful tools for hybrid warfare, which refers to the use of various tactics, including political, economic, military, and informational means to achieve strategic objectives. Hybrid warfare is executed by both governmental and non-governmental entities and is often used to achieve geopolitical goals without resorting to overt military action.

Social networks and the internet have provided new ways to disseminate information and influence public opinion. As a result, they have become attractive targets for those seeking to wage hybrid warfare. Through social media platforms, individuals and organizations can spread propaganda, disinformation, and fake news, all of which can be used to manipulate public opinion and sow discord. One common tactic used in hybrid warfare is the creation of fake social media accounts and bots. These accounts are often used to amplify certain messages or to spread false information. They can be used to create the appearance of grassroots support for a particular cause or to generate fake news stories that support a particular agenda.

Another tactic is the use of social media to target specific groups or individuals with personalized messaging. This can involve the use of social media algorithms to identify users who are likely to be receptive to a particular message and then target those users with ads or other content designed to influence their opinions. In addition to social media, other forms of online media can also be used in hybrid warfare. This can include the use of fake news websites or the creation of fake online personas to spread false information or manipulate public opinion.

The utilization of social networking platforms and the virtual arena as instruments for hybrid warfare underscores the importance of critical thinking and media literacy. It is important to be able to identify and evaluate sources of information and to recognize when information is being manipulated or distorted. By doing so, individuals can better protect themselves from the effects of hybrid warfare and help ensure that information is used responsibly and ethically. Thus, using the suggested approaches, online service managers exercise discretion in making operational determinations. The novelty of the suggested approach lies in its capacity to make prompt judgments during circumstances where users are in a confrontational state.

The basic idea of the research is to create a toolkit to support decision-making by managers of online communication of digital social channels in antagonistic interaction, to reduce the level of information uncertainty and ensure the sustainable functioning and development of such communities in the information space.

2. Related work

The theory of decision-making refers to the study of how individuals, groups, and organizations allocate scarce resources. It aims to understand how people weigh the costs and benefits of different options and arrive at a final decision. This field encompasses several approaches, including rational choice theory [18,19] (which assumes that individuals make decisions based on a rational, calculation of costs and benefits), behavioral decision theory [20–22] (which recognizes that psychological and emotional factors influence real-world decision-making), prospect theory [23,24] (which focuses on how people value gains and losses and how they perceive risk), and heuristics and biases [25–27] (which examines how people use mental shortcuts or rules of thumb to make decisions and how these shortcuts can lead to systematic errors). Regardless of the approach, decision-making theory [12,13] aims to improve our understanding of how people make decisions and to help individuals and organizations make better choices.

The uniqueness of the proposed analytical method for improving the decision-making criteria approach in managing digital social channels in the paper lies in its focus on the decision-making process involved in managing online communities in the face of complete uncertainty, antagonistic behaviour of the environment, and partial uncertainty. The study proposes an innovative approach that considers the information situation in the decision-making process of managing communities of online social services, which contributes to achieving the aim of community functioning and minimizing the negative effect on community users related to the proliferation of destructive content and actions of fraudulent competitors in the environment of online social service. The study also highlights the importance of effective decision-making in addressing complex and dynamic environments and provides practical insights for community managers seeking to achieve their goals and foster positive and sustainable online communities.

To conduct a thorough examination of relevant literature pertaining to our research, we have employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method [28]. Systematic reviews and analyses are methods of research synthesis that involve the comprehensive examination and analysis of all available data on a specific topic. These methods are commonly used in academic and scientific research to produce high-quality evidence-based conclusions. Systematic reviews involve a rigorous search and selection process for relevant studies, followed by a critical appraisal of their quality and a synthesis of their findings. Meta-analysis goes a step further by using statistical methods to combine the results of multiple studies, allowing for a more precise estimation of the overall effect size. Both systematic reviews and meta-analyses are considered essential tools for evidence-based decision-making in various fields, including medicine, psychology, and social sciences. PRISMA was developed to address the issue of incomplete and inconsistent reporting in systematic reviews. Systematic reviews are important tools for synthesizing evidence from multiple studies, but their value is limited if the results are not reported transparently and completely.

PRISMA was developed to provide a standardized material outlining a collection of instructions for documenting and publishing systematic reviews and analyses to improve their transparency, completeness, and comparability. By providing clear guidelines for what should be reported in a systematic review, PRISMA helps to ensure that the methods and results of these studies are easily interpretable and reliable. PRISMA comprises a set of directives to enhance its effectiveness through modification of the thoroughness and transparency of narration. PRISMA outlines guidelines for reporting systematic review. To adhere to PRISMA's protocols for a research paper, it is necessary to follow a series of steps as presented in Fig. 1.

- Plan and conduct a systematic review or meta-analysis following the PRISMA guidelines.
- The flow diagram should highlight the key stages in the study selection process, including the initial identification of potential studies, screening of abstracts, and full-text assessment.
- Develop a summary table of study characteristics and results.
- Use the PRISMA checklist to ensure the paper includes all necessary components for a systematic review.
- Reference PRISMA in the paper and include the flow diagram and summary table in the manuscript.
- Ensure the report includes potential sources of bias, limitations, and conflicts of interest.

The PRISMA benefits. The benefits of using PRISMA for reporting systematic analyses include improving transparency, accuracy, decision-making process, comparability, and credibility. PRISMA supports transparent and complete reporting of methods and results. This analysis facilitates the comparison and synthesis of results from different studies by standardizing the reporting of systematic reviews. The rigor and transparency of a systematic review increase its credibility and impact. Systematic reviews contribute to comprehensive and reliable evidence synthesis, contributing to better decision-making. PRISMA also provides recommendations for reporting sources of bias and limitations in a systematic review to guarantee the accuracy and reliability of the results. PRISMA improves the quality and credibility of systematic reviews and meta-analyses and increases confidence in the evidence they provide.

The PRISMA methodology was employed to perform an evaluation of the three major academic databases, namely Web of Science, Google Scholar, and Scopus. The outcomes of this study are presented using the PRISMA flow diagram that is generally used for systematic reviews. To identify a collection of records in Web of Science, Google Scholar, and Scopus databases, the following specific search queries were created: (ALL (decision-making AND criteria) OR ALL (conditions AND of AND complete AND uncertainty) OR TITLE-ABS-KEY (conditions AND of AND antagonistic AND behaviour AND of AND the AND digital ecosystem) OR TITLE-ABS-KEY (conditions AND of AND partial AND uncertainty)). The graph of the bibliometric landscape of this study is shown on Fig. 2.

The Web of Science, Google Scholar, and Scopus databases were subject to filtering based on predetermined criteria, including document type, languages, publication years, and access type. The authors of the study additionally applied further filtering in the form of research areas.

The study's outcomes of systematic reviews are depicted in Fig. 3 via the employment of the flow diagram of the PRISMA.

The PRISMA methodology was employed in the investigation of a range of issues, as outlined in Table 1 and reported in 44 scientific papers. Within this sample, a detailed evaluation of 21 scientific papers is presented below.

Based on the conducted PRISMA analysis, the research proposes a new strategy for preventing adverse consequences of community conflicts and dissemination of potential risks to user information by optimizing efficacy and minimizing potential hazards. This strategy utilizes three decision-making criteria, namely the Wald criteria, Savage criteria, and Hurwitz criteria.

The Wald criteria is a statistical test used to determine whether a particular parameter in a statistical model is significantly different from zero. In this research, the Wald criteria is employed to optimize efficacy, meaning that decisions are made based on the most efficient and effective course of action.

The Savage criteria, on the other hand, is used to minimize potential hazards by adhering to the principle of minimizing the worst possible outcome. This means that the decision-making process takes into account the potential negative consequences of each option and chooses the one with the least amount of risk.

The Hurwitz criteria is a balanced approach that incorporates both the maximum and minimum criteria. This means that the decision-making process takes into account both the potential benefits and potential risks of each option, and chooses the one that provides the highest benefit while minimizing the risk.

In comparison to recent methods, the proposed strategy in this research is unique in its use of a combination of decision-making criteria to optimize efficacy and minimize potential hazards. While other methods may focus on one or the other, this research emphasizes the importance of both efficiency and risk mitigation in decision-making. The use of the Wald criteria ensures that decisions are made based on the most efficient and effective course of action, while the Savage criteria and Hurwitz criteria ensure that potential

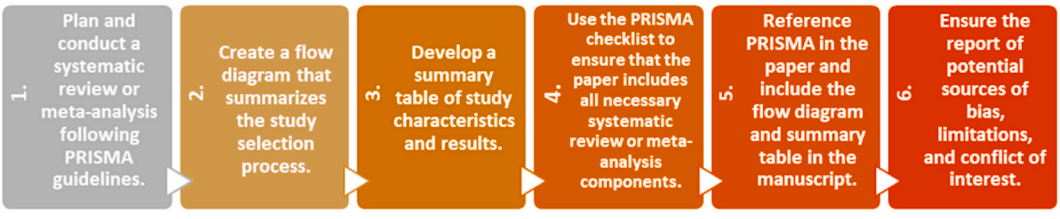

Fig. 1. Scheme of the stages of the PRISMA.

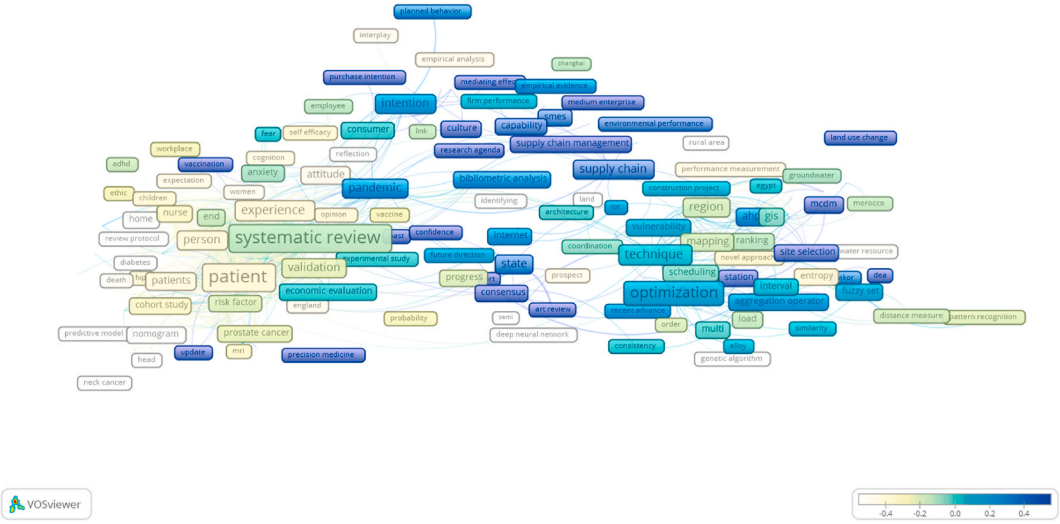

Fig. 2. Graph of the bibliometric landscape of this study.

hazards are minimized and both the potential benefits and risks are taken into account. The proposed strategy in this research is a comprehensive approach to decision-making that prioritizes both efficiency and risk mitigation, making it a valuable addition to current methods in preventing adverse consequences of community conflicts and dissemination of potential risks to user information.

Filled research gaps. This paper fills the gap by highlighting the importance of effective decision-making in addressing complex and dynamic digital ecosystems of communities. Additionally, the paper proposes an innovative approach to consider the current state of information during the process of making decisions about managing user groups of digital social channels in conditions of complete and partial uncertainty and under conditions of antagonistic and aggressive behaviour of the digital ecosystem. The approach increases the efficiency and validity of managers' decision-making in digital communities, creating prerequisites for the sustainable development of digital social channels in the context of distribution and realization of the threats to users' and communities' cybersecurity.

3. Methods

Within the realm of web community management, the concept of a decision-making situation pertains to the act of deliberating and implementing choices that bear consequences for the direction and advancement of the community. Such situations can arise in various aspects of web community management, including content moderation, member management, feature development, and policy creation.

The process of making the decision includes several stages, including detecting the issue or problem, gathering relevant information, evaluating potential options, and selecting the best course of action. Web community managers need to consider a range of factors in their decision-making, including community values and expectations, legal requirements, technical feasibility, and resource availability.

One key challenge in web community decision-making is balancing competing interests and needs. Managers must weigh the needs of different community members, including moderators, contributors, and visitors, and ensure that their decisions align with the community's goals and objectives. It is imperative for them to take into account the possible consequences that may arise from their decisions on community growth, engagement, and sustainability. To make effective decisions in web community administration, managers often use a range of tools and techniques, such as data analysis, stakeholder consultation, and risk assessment. They may also leverage community feedback and input to guide their decisions and build support for their actions.

The concept of a decision-making situation is essential to effective web community administration. By taking a deliberate, data-driven, and community-focused approach to decision-making, managers can drive positive outcomes and build strong, thriving digital communities.

A sustainable digital community is a digital space that fosters a sense of belonging, purpose, and social connection among its members over an extended period. In a sustainable digital community, members feel invested in the community's mission and values, are committed to supporting one another, and regularly engage in constructive discussions and activities.

Building and maintaining a sustainable digital community requires several key elements. Firstly, a clear and compelling purpose or mission that resonates with the community members is essential. A well-defined purpose can serve as a foundation for shared values, and it can help to align the community around a common goal. Secondly, effective community management is crucial for creating and maintaining a sustainable digital community. Effective management involves setting clear expectations for members, moderating content and behaviour to ensure that the community remains respectful and constructive, and engaging with members to encourage participation and build relationships. Thirdly, community members play a vital role in creating a sustainable digital community. Members who are willing to share their expertise, support others, and contribute to community initiatives can help to build a sense of

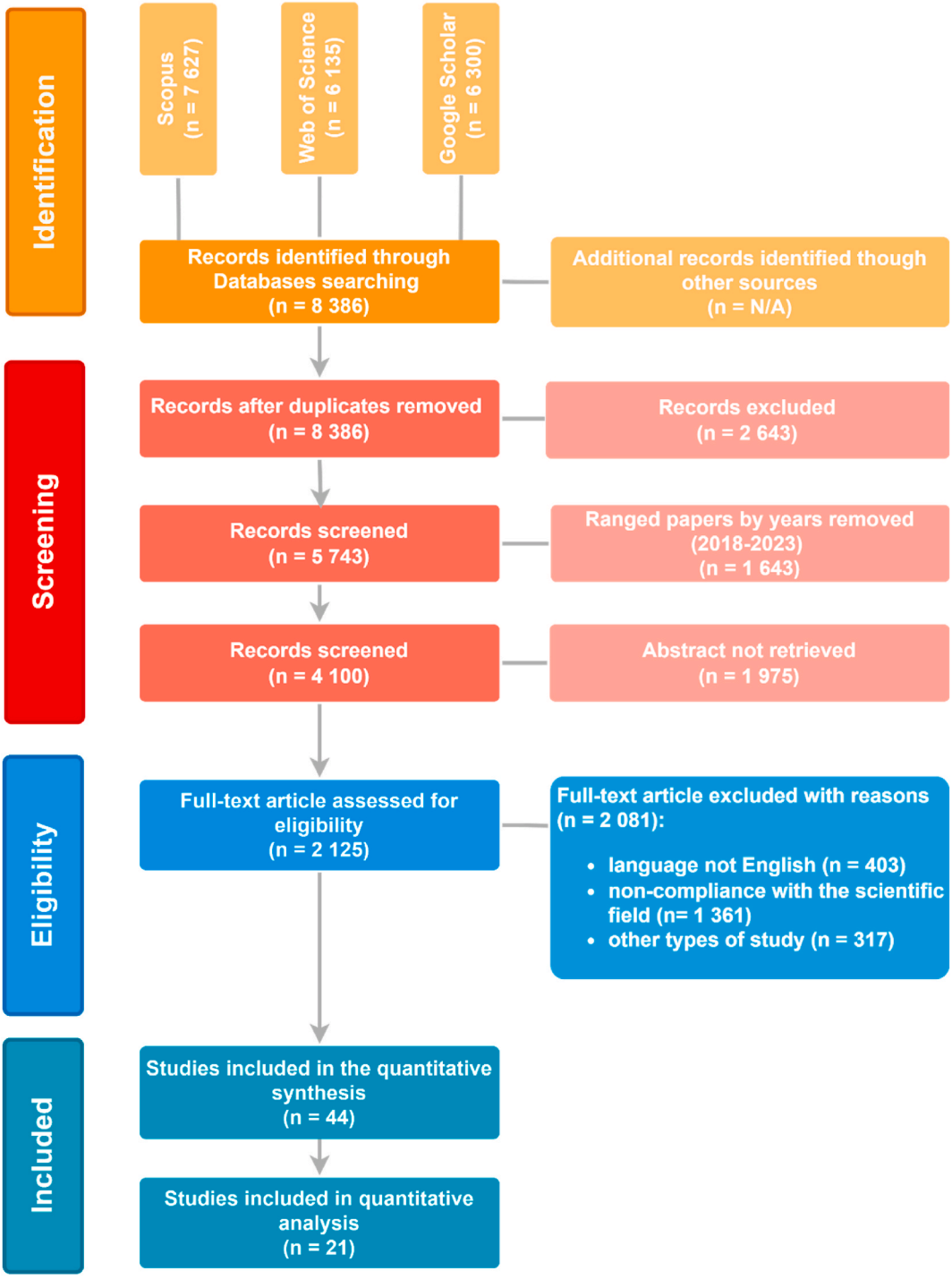

Fig. 3. The scheme of the flow diagram of the PRISMA based on conducting a systematic analysis.

community ownership and investment. Communication and transparency are essential for creating a sustainable digital community. Regular updates, open dialogue, and clear guidelines for decision-making can help to build trust and confidence among members.

In a sustainable digital community, members feel a sense of belonging and are motivated to engage and contribute over time. Such communities can be incredibly powerful for fostering social connections, providing emotional support, and driving positive social change. Creating a space where people can connect, share ideas, and collaborate with sustainable digital communities can help to create lasting and meaningful impacts on the lives of their members.

Table 1
Analysis of scientific paper selected by PRISMA methods.

Term	Explanation	The scientific works
The concept of a decision-making situation	The circumstances, conditions, and factors that influence the process of making a decision, including the available options, objectives, and constraints.	Svenson O. [29], Trevino L. K. [30], Dawes R. M., & Corrigan B. [31], Jelokhani-Niaraki M., Malczewski J. [32], Rinner C., Keβler C., Andrulis, S. [33], Gao J., Zhang C., Wang K., Ba S. [34], Mi X., Tang M., Liao H., Shen W., Lev B [35].
Decision-making criteria in conditions of complete uncertainty	Decision-making in conditions where there is no information available to assess the likelihood or consequences of different options makes it impossible to calculate the expected value of different choices.	Pažek K., & Rozman Č. [36], Starr M. [37], Pereira Jr J., Ekel P., Palhares R., Parreiras R. [38], Bugas D. [39], Thao N. [40], Kobus D., Proctor S., Holste S. [41], Bossert W., Pattanaik P., Xu Y. [42], Malyshev V., Piyavsky B., Piyavsky S. [43], Busemeyer J. [44], Ma J., Harstvedt J., Jaradat R., Smith B. [45], Vyatkin A., Fomina L., & Shmeleva Z. [46], Marchau, V. A., Walker W., Bloemen P., Popper S [47].
Decision-making criteria in conditions of antagonistic behaviour of the digital ecosystem	Decision-making in situations where the digital ecosystem or stakeholders have conflicting objectives makes it necessary to anticipate and respond to potential obstacles, risks, or resistance.	Vyatkin A. V., Fomina L. V., & Shmeleva Z. [48], Weerasuriya A., Zhang X., Wang J., Lu B., Tse K., Liu C. [49], Adem A., Çakıt E., Dağdeviren M. [50], Chakir I., El Khaili M., Mestari M. [51], Belhadi A., Kamble S. S., Mani V., Venkatesh V., Shi, Y. [52], Iqbal S., Sholihin M. [53], Schneeweiss C. [54], Bailey M., Simpson E., & Balsam P. [55], Bechara A [56].
Decision-making criteria under partial uncertainty	Decision-making in situations where some information is available but not sufficient to eliminate all uncertainty requires the use of subjective judgment or probabilistic reasoning to assess the likelihood or consequences of different options.	Jansen C., Schollmeyer G., & Augustin T. [57], Pelissari R., Oliveira M., Abackerli A., Ben-Amor S., Assumpção M. [58], Xu Y., Tung Y. [59], Troffaes, M. [60], Ahn B., Yager R. [61], Seuken S., Zilberstein S. [62], Madani K., Read L., Shalikarian L. [63], Xu J., Wu Z., Zhang Y. [64], Augustin T. [65], Wang Z., Xiao F., Cao Z. [66], Mashunin K., Mashunin Y. [67], Chen S., Liu J., Wang H., Augusto J. C. [68], Bochkov A., & Zhigirev N. [69], Keith A. J., Ahner D. [70], Kreinovich V. [71], Kaplan S., Barish N [72].

Managing a sustainable digital community requires a strategic approach that involves several stages. Each stage builds on the previous one, and together, they form a framework for creating and sustaining a thriving online community. Here are the stages in the management of a sustainable digital community [73,74].

1. Planning and Strategy. The first stage of managing a sustainable digital community involves planning and strategy development. At this stage, community managers should define the community's mission, purpose, and goals. They should also identify the target audience, key performance indicators, and success metrics. Additionally, community managers should create guidelines and policies for content creation and user engagement.
2. Launch and Growth. The second stage of managing a sustainable digital community involves launching the community and driving growth. Community managers should create a welcoming and engaging digital ecosystem that encourages members to participate actively. They should also focus on creating high-quality content that resonates with members and helps to drive engagement.
3. Engagement and Retention. The third stage of managing a sustainable digital community involves engaging and retaining members. Community managers should encourage active participation and facilitate discussions and events that create opportunities for members to connect and collaborate. Additionally, they should monitor user behaviour and respond to member feedback to ensure that the community remains relevant and valuable.
4. Performance and Optimization. The fourth stage of managing a sustainable digital community involves measuring performance and optimizing the community's growth and engagement. Community managers should track key metrics such as user engagement, retention, and satisfaction. They should also experiment with new features, initiatives, and campaigns to drive user engagement and community growth.

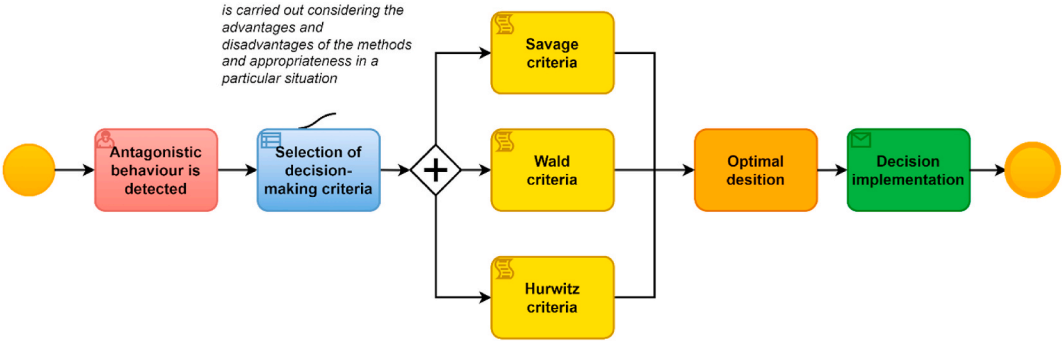

Fig. 4. The algorithm of process visualization using BPMN notation.

5. Evolution and Sustainability. The final stage of managing a sustainable digital community involves evolving and ensuring the community's long-term sustainability. Community managers should assess the community's progress, make necessary changes, and adapt to changing user needs and preferences. They should also plan for long-term growth and sustainability by building partnerships, generating revenue, and creating community programs that provide ongoing value to members.

Managing a sustainable digital community [75,76] requires a structured and strategic approach. By following these stages, community managers can create a thriving online community that fosters engagement, connection, and lasting impact.

To formalize the decision-making processes of community managers in social online services, we use the BPMN standard [77] for modeling business processes. The advantage of applying this approach is the unification of notation to ensure unity and clarity in the implementation processes between stakeholders. The scheme of the algorithm for visualizing processes using the BPMN notation is shown in Fig. 4.

After the kickoff point, the process of forming sustainable communities is initiated when online community managers detect signs of antagonistic user behaviour. For this purpose, they can use tools for monitoring the qualitative composition of the user group, and analyze comments and posts in the community. After selecting criteria for deciding on measures to ensure the sustainable development of the user community, it is necessary to choose criteria. If the main goal is to achieve the maximum level of gain despite conservatism, the Wald criteria [15,16] are used. In the case of prioritization of minimizing losses from destructive information impact on users, the Savage criteria are used. A balanced combination of the maximum and minimum criteria is the Hurwitz criteria [17], which is used in the case of a compromise between the loss of users and the rise in the quantity of newly registered users. After applying one of the criteria, we get an optimal solution that is implemented as a set of actions through information influence on users of the social Internet service. Thus, by combining approaches to creating sustainable communities of stakeholders, the goal of the group's functioning in a digital social channel is achieved.

Business processes are a critical component of any organization, as they define how tasks are completed and goals are achieved. In today's digital age, many businesses rely heavily on online platforms and communities to interact with customers and stakeholders. As a result, managing and maintaining these communities has become a crucial aspect of business operations. This table outlines five key business processes related to community management: content moderation, user management, community engagement, technical support, and crisis management. Each process involves several steps that are essential to ensuring the success of the online community. Let us take a closer look at these processes and the steps (Table 2) involved in each one.

The table outlines five essential business processes, including content moderation, user management, community engagement, technical support, and crisis management, with their respective descriptions and steps involved. In conclusion, these business processes are critical for the effective operation and maintenance of any online community or platform. Content moderation ensures that the platform's guidelines and policies are enforced, user management manages user accounts, and access rights, and ensures adherence to community guidelines. Community engagement fosters user participation and interaction, while technical support ensures the platform's smooth functioning. Lastly, crisis management enables quick and effective responses to emergencies or crises within the

Table 2
The steps of the decision-making processes of online community managers.

Business Process	Description	Steps
Content Moderation	Reviewing and approving or rejecting user-generated content	1. Establish community guidelines and content policies 2. Monitor user-generated content 3. Evaluate content for compliance with guidelines 4. Approve or reject content 5. Notify the user of the decision
User Management	Managing user accounts and access rights	1. Register and verify user accounts 2. Grant or revoke user access rights 3. Monitor user activity 4. Enforce community guidelines and content policies 5. Respond to user inquiries and support requests
Community Engagement	Encouraging user participation and interaction	1. Develop engagement strategies and initiatives 2. Communicate with users through various channels 3. Encourage user-generated content and discussions 4. Respond to user feedback and suggestions 5. Analyze engagement metrics and adjust strategies as needed
Technical Support	Troubleshooting technical issues and maintaining platform functionality	1. Monitor platform performance and identify issues 2. Respond to user technical support requests 3. Troubleshoot and resolve technical issues 4. Implement platform upgrades and improvements 5. Communicate with users about platform updates and changes
Crisis Management	Responding to and managing crises or emergencies within the community	1. Develop crisis management plan and protocols 2. Monitor for potential crises or emergencies 3. Respond quickly and appropriately to crises 4. Communicate with users and stakeholders about the crisis 5. Evaluate response and update crisis management plan as needed

community, minimizing their impact and providing reassurance to users and stakeholders.

The procedure of decision-making in sustainable digital communities can be complex, and using the Wald criteria and Savage criteria help community managers make effective decisions that align with community goals and values. Savage and Wald's decision-making model involves three main criteria: information availability, uncertainty, and risk.

In the context of sustainable digital communities, information availability refers to the amount and quality of data that community managers have to inform their decisions. To make informed decisions, community managers must have access to relevant and accurate data on community engagement, member behaviour, and user feedback. They can use tools such as surveys, analytics, and user research to gather this data. Uncertainty refers to the degree of unpredictability or ambiguity surrounding a decision. In the context of sustainable digital communities, community managers may face uncertainty in areas such as user behaviour, community growth, and member satisfaction. To mitigate uncertainty, community managers can use forecasting, scenario planning, and risk assessment techniques to identify potential risks and develop contingency plans.

Risk refers to the potential for negative consequences or losses resulting from a decision. In sustainable digital communities, risks may arise from decisions related to content moderation, feature development, and user engagement. To manage risk, community managers can use strategies such as user testing, community feedback, and data analysis to evaluate the potential impact of their decisions. Using Savage and Wald criteria [17], community managers can assess the available information, level of uncertainty, and potential risks associated with a decision. They can then use this information to evaluate options, make decisions that align with community goals and values, and take actions that promote community growth and sustainability.

The process of decision-making in sustainable digital communities can be complex, but by using the Savage criteria and Wald criteria, community managers can make informed and effective decisions. By considering the information available, the level of uncertainty, and the potential risks associated with a decision, community managers can develop a data-driven and strategic approach to community management that fosters engagement, connection, and lasting impact.

In this particular class of tasks undertaken by managers of digital social channels, the suggested algorithm for decision-making procedures is applied. The unique characteristics of the adversarial digital ecosystem in digital communication among online community users are characterized by intense conflict and a lack of tolerance towards alternative viewpoints.

Following the principles of decision theory, optimal values of the functions are achieved by using the Savage and Wald criteria [17]. The Wald and Savage criteria are utilized as selection criteria in decision-making when dealing with data that is aggressive and antagonistic in nature. These criteria are employed to determine the most optimal solution. The situation being examined pertains to the process of making decisions regarding the management of a strategy to cultivate a sustainable digital community, despite facing hostile behaviour from the digital social channels within a digital ecosystem.

In situations where there is increasing opposition on social media platforms, managers may make decisions that lead to achieving maximum success. The Wald criteria are useful in a digital ecosystem where the enemy uses advanced technologies to spread harmful information to users of digital social channels. However, due to goal-driven strategic discourse, the impact of such content on users is declining. This conservatism of the Wald criteria [17] (equations (1) and (2)) may restrict the level of success achieved by a sustainable digital community resulting from the decision made. Therefore, it may be appropriate to use the Savage criteria in certain conditions to regulate the losses resulting from decisions made by managers of digital social channels. The solution that provides the highest level of optimization, denoted as R_i, $i = \overline{1,n}$, is being taken into account.

$$F_{i0} = \max_{R_i \in R} \min_{E_j \subset E} F_{ji}^{+} \tag{1}$$

$$F_{i0} = \min_{R_i \in R} \max_{E_j \subset E} F_{ji}^{-} \tag{2}$$

Upon analyzing the usage of these criteria, a particular drawback was observed. In the event that a decision is made by the managers of an established online community amidst a digital ecosystem of adversarial opposition in the realm of digital social channels, the optimal solution according to Savage's criteria [17] would be $R_{i0} \in R$. However, if the non-optimal solution $R_i \neq R_{i0}$ is eliminated from the solution multiplier R, and a new diversity R^* is introduced, the previously optimal solution R_{i0} may no longer be optimal.

Digital communities have emerged as a fundamental component of our routine existence, furnishing a medium for individuals to establish contact, communicate, and participate with their peers. In these communities, decision-making is crucial in ensuring that the community operates smoothly and effectively. The decision-making process can be challenging, especially in sustainable digital communities, where diverse participants have different opinions and priorities. However, using the criteria of Hurwitz [17] and Hodges-Lehmann [33], it is possible to make informed and rational decisions that benefit the entire community.

On the other hand, the Hodges-Lehmann criteria is a statistical approach that aims to find the median difference between two data sets. These criteria are often used in decision-making when comparing different options or alternatives is needed. In sustainable digital communities, the Hodges-Lehmann criteria are used to compare different strategies or approaches to a problem. For example, when deciding whether to introduce a new feature to the community, the Hodges-Lehmann criteria can be used to compare the impact of different options and determine which one would be the most effective.

The Hurwitz criteria [17] is a decision-making approach that considers the importance of each criteria in the decision-making process. It considers the weight assigned to each criteria and how much it contributes to the overall decision. The Hurwitz criteria assume that some criteria are more important than others and that the decision should reflect this importance. In sustainable digital communities, the Hurwitz criteria can be used to weigh the factors that impact the community's health and growth. For example, when

making decisions about community rules, the Hurwitz criteria can be used to determine which factors, such as safety or inclusivity, are the most important.

However, the information digital ecosystem of digital social channels is not always characterized by active opposition to the outlined goals of sustainable digital communities and the relevant decisions of managers. The behaviour of such a digital ecosystem is often characterized by two aspects.

1) Managers of the digital social channel are aware of the true probability distribution on the set of states of this digital ecosystem. Although such information is not enough to accurately identify the information situation, it is possible to establish a certain degree of optimism or pessimism about digital ecosystem change.
2) Managers of digital communities have information about the states of the information digital ecosystem of services. Such information is intermediate between information situations in which the distribution of a priori probabilities of the set of states of the data digital ecosystem of services is given - decision-making under risk and the existence of a blurred set of states of the information digital ecosystem of digital social channels when they are formalized by qualitative indicators.

In such situations, decision-makers use the Hurwitz [17] or Hodges-Lehmann criteria [78]. The advantage of using the former is the ability to analyze decisions for optimistic and pessimistic scenarios. The second criteria allows us to provide a certain level of assurance in case the information about the state of the service's virtual sphere is not accurate. In the following, the Hurwitz criteria, which is characterized by relative simplicity, will be used for further research.

The concept of the Hurwitz criteria (equation (3)) is a weighted combination of the maximal and maximal criteria and consists in finding an optimal solution R_{i0}, $i = \overline{1,n}$, that satisfies the following condition:

$$\lambda \underset{E_j \in E}{min} F^{+}_{ji0} + (1-\lambda) \underset{E_j \in E}{max} F^{+}_{ji0} = \underset{R_i \in R}{max} \left\{ \lambda \underset{E_j \in E}{min} F_{ji} + (1-\lambda) \underset{E_j \in E}{max} F_{ji} \right\}, 0 \le \lambda \le 1 \tag{3}$$

In the case when the parameter λ takes the value 1 in equation (3), this criteria matches the Wald criteria [17,32]. If $\lambda = 0$, then we consider decision-making similar to the maximum criteria. It is imperative to acknowledge that the state of the digital ecosystem of digital social channels is characterized by the parameter λ, which acquires values in the interval $[0;1]$.

To determine the value of the parameter λ, we will further explain its essence. It corresponds to the chosen optimism-pessimism ratio of a decision maker regarding the strategy of the online community functioning in digital social channels. In this case, $\lambda = \frac{1}{2}$ in the case of a balance between the optimistic and pessimistic points of view. If the decision maker has identified the extreme case of the state of the virtual sphere of the services, then the parameter λ takes the values 0 for extreme optimism (the digital ecosystem is absolutely beneficial) and 1 for extreme pessimism (the digital ecosystem is extremely unfavorable for the community).

In practical situations, it is advisable to apply the modified Hurwitz criteria [17] (equation (4)), when each solution $R_i \in R$ corresponds to a separate value of the parameter λ_i, and the optimal solution satisfies the condition R_{i0}.

$$\lambda_i \underset{E_j \in E}{\min} F^{+}_{ji0} + (1-\lambda_i) \underset{E_j \in E}{max} F^{+}_{ji0} = \max_{R_i \in R} \left\{ \lambda_i \underset{E_j \in E}{\min} F_{ji} + (1-\lambda_i) \underset{E_j \in E}{max} F_{ji} \right\}, 0 \le \lambda_i \le 1 \tag{4}$$

4. Results

The decision-making situation of the manager of a sustainable digital community in digital social channels is described by a preference matrix (see equation (5)).

	R_1	R_2	R_3	R_4
E_1	4	7	9	3
E_2	5	6	5	2
E_3	7	3	7	4
E_4	3	9	8	7

(5)

It is necessary to engage in a process of optimization, the Wald criteria [15] is applied, see equations 6–10:

$$F_1 = \underset{E_j \subset E}{\min} F^{+}_{ji} = \min\{4;5;7;3\} = 3 \tag{6}$$

$$F_2 = \underset{E_j \subset E}{\min} F^{+}_{ji} = \min\{7;6;3;9\} = 3 \tag{7}$$

$$F_3 = \underset{E_j \subset E}{\min} F^{+}_{ji} = \min\{9;5;7;8\} = 5 \tag{8}$$

$$F_4 = \underset{E_j \subset E}{\min} F^{+}_{ji} = \min\{3;2;4;7\} = 2 \tag{9}$$

$$\max_{R_i \in R} \min_{E_j \subset E} F_{ji}^{+} = \{3; 3; 5; 2\} = 5 \tag{10}$$

The computations yielded that the most favorable resolution for this scenario is R_4.
Similarly, the Savage criteria [15–17] are optimizing solutions. The risk matrix (equation (11)) has the following format:

	R_1	R_2	R_3	R_4
E_1	4	7	4	8
E_2	8	9	11	10
E_3	2	4	5	8
E_4	10	1	7	7

(11)

Now let's calculate the minimum criteria (equation (12)) – (equation (16)):

$$F_1 = \max_{E_j \subset E} F_{ji}^{+} = \max\{4; 8; 2; 10\} = 2 \tag{12}$$

$$F_2 = \max_{E_j \subset E} F_{ji}^{+} = \max\{7; 9; 4; 1\} = 1 \tag{13}$$

$$F_3 = \max_{E_j \subset E} F_{ji}^{+} = \max\{4; 11; 5; 7\} = 4 \tag{14}$$

$$F_4 = \max_{E_j \subset E} F_{ji}^{+} = \max\{8; 10; 8; 7\} = 7 \tag{15}$$

$$\min_{R_i \in R} \max_{E_j \subset E} F_{ji}^{+} = \{2; 1; 4; 7\} = 1 \tag{16}$$

Following the Savage criteria [15,16], R_2 is considered the optimal solution
To find the optimal solution for the digital community under study, the Hurwitz criteria are used. Assume the risk matrix (equation (17)) has the following form:

	R_1	R_2	R_3	R_4
E_1	4	5	9	13
E_2	3	7	5	11
E_3	6	3	11	7
E_4	15	10	2	5

(17)

The Hurwitz criteria [17] are calculated for each solution using the following expression (equation (18)):

$$F_{\lambda i} = \lambda \min_{E_j \in E} F_{ji} + (1 - \lambda) \max_{E_j \in E} F_{ji} \tag{18}$$

Thus, we obtain the following equation 19–22:

$$F_{\lambda 1} = \lambda \bullet 3 + (1 - \lambda) \bullet 15 = 15 - 12 \bullet \lambda \tag{19}$$

$$F_{\lambda 2} = \lambda \bullet 3 + (1 - \lambda) \bullet 10 = 10 - 7 \bullet \lambda \tag{20}$$

$$F_{\lambda 3} = \lambda \bullet 2 + (1 - \lambda) \bullet 11 = 11 - 9 \bullet \lambda \tag{21}$$

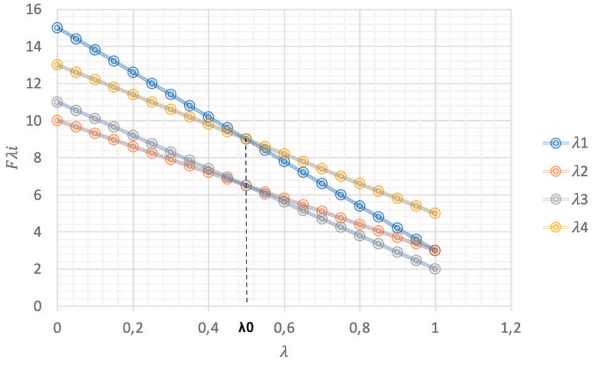

Fig. 5. Visualization of the Hurwitz curve and its subsets.

$$F_{\lambda 4} = \lambda \bullet 5 + (1 - \lambda) \bullet 13 = 13 - 8 \bullet \lambda \quad (22)$$

In the next step, construct a set of curves for different values of λ. The visualization of the Hurwitz curve and its subsets are shown in Fig. 5.

Fig. 5 shows that the curves $F_{\lambda 2}$ and $F_{\lambda 3}$ are non-optimal, while $F_{\lambda 1}$ and $F_{\lambda 4}$ are optimal. The next step is to find the value of the parameter λ_0, which divides the interval $[0; 1]$ into subsets $[0; \lambda_0]$ and $[\lambda_0; 1]$. We find the parameter λ_0 as the point of intersection of the curves $F_{\lambda 1}$ and $F_{\lambda 4}$, which has the value $\lambda_0 = 0,5$. In conclusion, when $\in [0; 0,5]$, the optimal solution is R_1, and when $\lambda \in [0,5; 1]$, the optimal solution is R_4.

The suggested methods are implemented in the university community on the Facebook social network [79]. The managers of the digital community have implemented the most effective solution, R_2, to enhance the number of users by engaging those who have opposing functional objectives. The modifications in the operation and efficiency of the community are depicted in Fig. 6. Over three months of executing the stable growth approach of the digital community, the number of users increased by 120% (based on data from the Facebook page [79]) between January and April of 2023.

Also, optimistic growth dynamics of the page visits (Fig. 7) are the increase of 51% on the Facebook page [79].

According to the statistical data obtained from the Facebook page (Fig. 8), the approach of stable growth of the digital community has resulted in a notable increase of 104.7% and 30.8% in the number of likes and follows, respectively, during the period of January to April 2023.

Within the context of the digital information ecosystem, there has been a significant rise of 120% in the number of comments made by users of Facebook [79], whereas the amount of posts and reactions has declined. This change is attributed to the ongoing transition methods within the digital community, which have brought about organizational modifications and enhanced connections between registered and new users.

The ongoing transition processes within the online community are responsible for the change, which has resulted in structural modifications and improved connections between new and established users.

Conversely, the elevated quantity of comments suggests that the engaged digital community users have developed an enhanced interest in the disseminated content. As illustrated in Fig. 9, once the transition procedures have been completed within the sustainable digital community, the level of user activity rises. This discovery validates the beneficial influence of the managers' implementation of the old community development approach, as evidenced by the growth in the activity level of users within the sustainable online community.

Fig. 9 depicts the outcomes of the analysis of a considerable data amount of activity of users in a sustainable digital community on a novel dataset group on the digital community of a university in the Facebook social network, with a total number of 419,865 users (increasing 120%). Fig. 9 presents a comprehensive representation of the activity of users within digital social channels. The chart displays the primary forms of interaction between users and the service, such as comments, posts, and other forms of active engagement. These findings indicate a substantial level of user involvement in the digital community, further demonstrating the online community's alignment with its intended objectives.

Fig. 10 shows the statistics of characteristics of sustainable digital community users in terms of age and gender indicators. Conducted analysis revealed that there are significant differences in the age and gender demographics of sustainable digital community users. The majority of sustainable digital community users are between the ages of 18 and 35, with a slight male bias. However, there are significant variations depending on the type of online community. For example, gaming communities typically exhibit a greater proportion of male users, whereas parenting communities tend to demonstrate a larger concentration of female users.

The outcomes of this work suggest that digital communities play an important role in providing social support and interaction for individuals. However, there are significant differences in the age and gender demographics of sustainable digital community users (Fig. 10), which could have implications for the design and management of digital communities. For example, community managers may need to consider gender-specific needs and preferences when designing and promoting their digital communities. Additionally, online community platforms may need to provide more support and resources for older users who may face challenges in navigating the digital landscape.

The obtained dataset of the university's Facebook page [79] is processed by using the software, Orange. This approach enables clear data presentation and facilitates the assessment of the efficiency of the developed decision-making method for both online community users and managers of digital social channels. Fig. 10 illustrates the changes in the number of active users of the community in the digital social channel after implementing the strategy. In the context of an antagonistic conflict, users from digital communities with

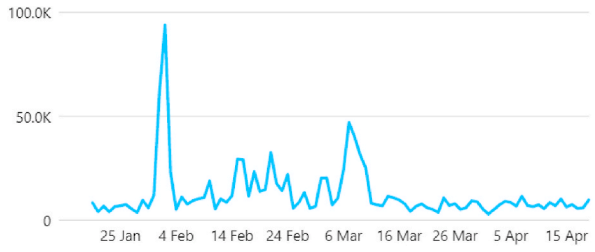

Fig. 6. Insights of sustainable digital community page reach: a) Facebook page reach; b) Instagram reach.

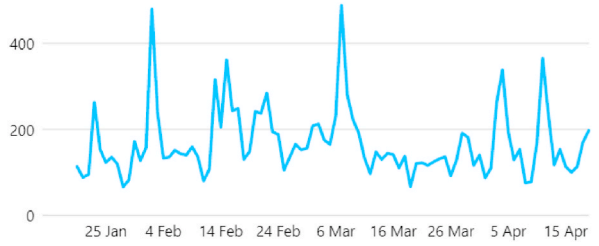

Fig. 7. Insights of sustainable digital community page visits.

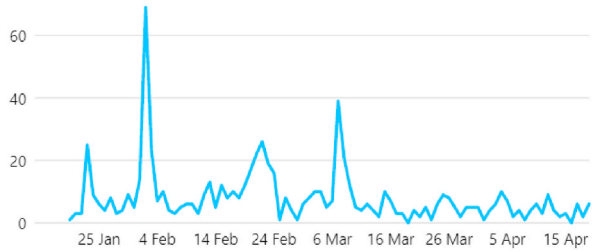

Fig. 8. Insights of sustainable digital community page likes and follows.

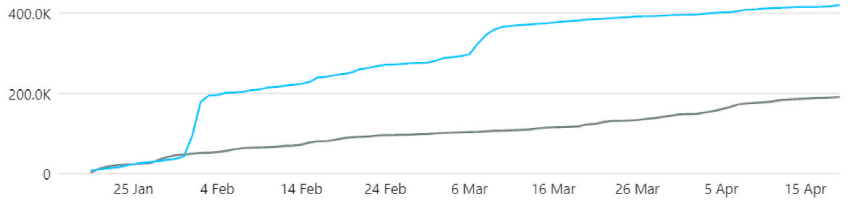

Fig. 9. An integrated indicator that reflects the level of activity exhibited by users in a sustainable digital community.

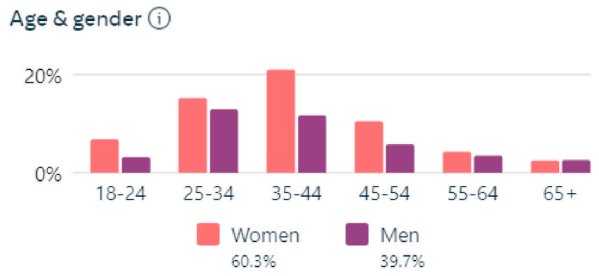

Fig. 10. The statistics of sustainable digital community users based on age and gender indicators.

opposing goals of functioning were recruited to grow the number of users. This implies that despite the conflict in the digital social channels, the mean quantity of individuals utilizing the platform did not exhibit a reduction.

The data presented in Fig. 11 reveals that there is a proportional relationship between the reactions indicator and the growth of the comments, active users, and users posts, indicators among users of the sustainable digital community.

Fig. 12 depicts the outcomes of the investigation conducted on various constituents of activity of the user, including user posts, user comments, active users, the total number of users, pending user requests, approved user requests, and declined user requests, concerning the indicator of the reaction. The execution of the optimal solution has enhanced the procedure of strategic decision-making by the digital community managers of the university. The examination of the activity of users in the sustainable digital community by the indicator of the total number of users (as illustrated in Fig. 12) manifests a consistent escalation in the number of active users number, resulting from the adoption of the best solution aimed at expanding the user base.

An internet-based collective is a for-profit venture that aims to reach a wide-ranging readership with its informative content. Presently, digital communities benefit from various platforms available for creating them and projecting their image across multiple channels in social digital ecosystems. The effectiveness of establishing and administering a virtual community relies on various aspects,

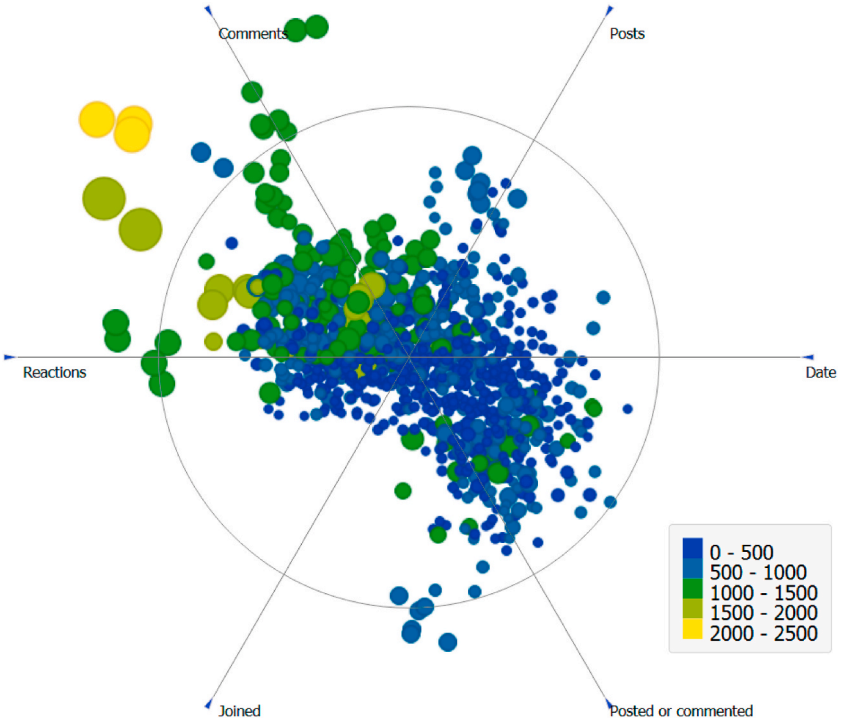

Fig. 11. The statistics pertaining to the user's activity in a sustainable digital community based on the indicator of the reaction.

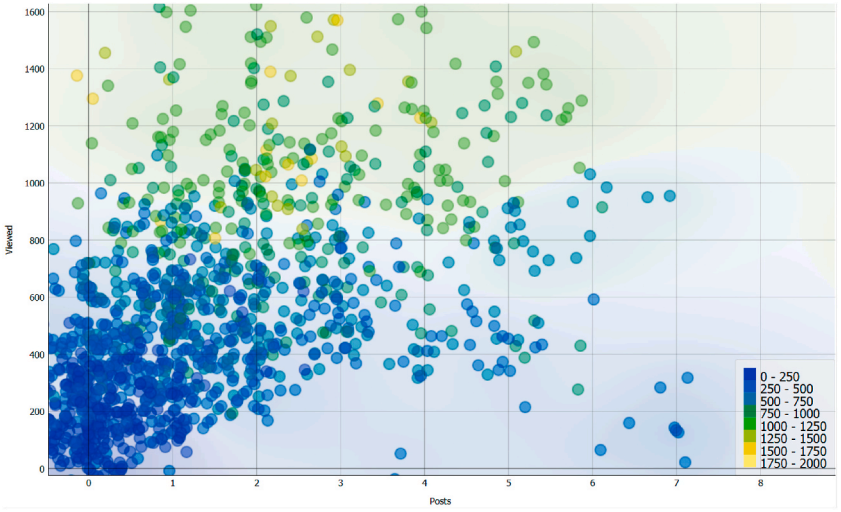

Fig. 12. The Total users' indicator statistics of a sustainable digital community users.

such as conceptualization, objective establishment, team assembly, project record keeping, platform choice, promotional efforts, data analysis, phases of the project life cycle, and risk mitigation. Risk management [80] and developing crisis response measures are crucial aspects of digital community management. Rapid decision-making plays a pivotal role in the crisis management of digital communities. Antagonistic and confrontational behaviour of individual online community users can lead to crises.

The management of digital communities during crisis periods involves implementing risk management strategies. Such crises may lead to unexpected levels of crisis indicators within digital communities, which may undermine the effectiveness of online projects through disruptive user conduct.

5. Discussion

The present study compared the outcomes of optimal decision-making by managers for implementing sustainable functioning strategies of sustainable digital communities under complete and partial uncertainty, as well as under conditions of antagonistic behaviour of the social digital ecosystem for all criteria. Results revealed that the most effective solution is to grow the users' number of a sustainable digital community by engaging users with the opposite goals of functioning in digital communities. This solution was found to maximize efficiency based on the Wald criteria and minimize risks according to the Savage criteria, and the Hurwitz criteria, which is a balanced combination of the maximum and minimum criteria.

The implementation of an approach of the growing community in the presence of antagonistic disagreement in the digital ecosystem follows an approach that involves redeploying available resources. According to research, it is more efficacious to involve existing users of digital social platforms rather than enlisting new users who may lose interest in the online community swiftly and fail to advocate its advantages.

The investigation of characteristics of information warfare on social media has revealed that in online community administration, decision-making using the Wald criteria requires mixed strategies against opposing forces. Implementing online teams with diverse strategies in an antagonistic digital ecosystem offers a variety of potential solutions, leading to rational decision-making and the successful accomplishment of the strategic objectives of the team.

The suggested approach presented in the study enhances the digital communities' efficiency, enables swift and effective crisis management by their owners, facilitates prompt decision-making by online community managers, develops crisis response plans, and implements strategies for the digital communities functioning in the users' antagonistic behaviour of social media.

6. Conclusions

This paper explored the process of making the decision involved in managing digital communities in complete uncertainty, antagonistic behaviour of the digital ecosystem, and partial uncertainty. The proposed methods were implemented to mitigate the adverse effects of the dissemination of harmful content and the unfair practices of competitors within the digital social channel ecosystem. The study highlighted the importance of effective decision-making in addressing complex and dynamic digital ecosystems and offered a comprehensive framework for managing digital communities in these conditions.

The goal of this study is to introduce an analytical technique that improves the decision-making criteria in managing digital social channels. The proposed approach seeks to improve the existing framework of making the decision by integrating analytical tools that effectively evaluate the process of making the decision. Through integrating this method, the study intends to address the challenges associated with managing digital social channels and enhance the overall decision-making process.

While the research was limited to the implementation of the proposed methods on one social networking platform, Facebook, it has introduced an innovative approach that provides cybersecurity for management actors and increases the efficiency and validity of managers' decision-making in digital communities. Implementing the developed methods in managing digital communities contributes to achieving the aim of community functioning and minimizing the negative effect on community users related to the proliferation of destructive content and activities of fraudulent competitors in the digital channels. This research contributes to the existing literature on digital community management and provides a valuable resource for community managers seeking to achieve their goals and foster positive and stainable digital communities.

The decision-making process in sustainable digital communities is complex and challenging. However, by using the Wald criteria, Savage criteria, and Hurwitz criteria, it is possible to make informed and rational decisions that benefit the community as a whole. Considered criteria ensure that decisions are made based on the most important factors and that the best options are chosen to promote the community's growth and sustainability. By using these criteria, community managers can ensure that their decisions are fair, unbiased, and data-driven, which can help to build trust and promote engagement within the community.

Limitations. In the research, there are the following limitations.

- Implementation of the research results on one social networking platform, Facebook, limits the possibility of generalizing the results to other platforms or digital communities.
- The study needs to increase the size of the sample used in the experiments to assess the validity and reliability of the findings.
- The study focused on users who already use digital social channels and did not take into account users who do not use these services, which leads to self-selection bias.
- The survey focused only on the decision-making process of online community managers and did not examine user perspectives or broader social and cultural factors that may influence online behaviour.

7. Future work

Future research goals include increasing the size of the sample used in the experiments to assess the validity and reliability of the findings. Moreover, the proposed methods need to be tested on various social networking platforms and digital communities to evaluate their applicability in different contexts. In addition, user perspectives and broader social and cultural factors that may influence online behaviour should be examined to provide a comprehensive understanding of the process of decision-making involved in digital community management. New approaches are developed to identify and moderate the antagonistic effects of hybrid warfare on the internet, which is a growing concern in the field of digital community management. This research opens up new avenues for future

studies on managing digital communities in dynamic and uncertain digital ecosystems.

Author contribution statement

Solomia Fedushko; Kateryna Molodetska; Yuriy Syerov: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

The data that has been used is confidential.

Additional information

Supplementary content related to this article has been published online at [URL].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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References

[1] H. Zhang, Z. Zang, H. Zhu, M. Uddin, M. Amin, Big data-assisted social media analytics for business model for business decision making system competitive analysis, Inf. Process. Manag. 59 (1) (2022), 102762, https://doi.org/10.1016/j.ipm.2021.102762.
[2] S. Kim, K. Hawkins, The psychology of social media communication in influencing prevention intentions during the 2019 U.S. measles outbreak, Comput. Hum. Behav. 111 (2020), 106428, https://doi.org/10.1016/j.chb.2020.106428.
[3] F. Davide, Multi-stakeholder digital collaboration and social innovation in social services: the cross project and the smart cities. Perspectives for Digital Social Innovation to Reshape the European Welfare Systems 2021, IOS Press. 267-294.
[4] S. Harris, A. Mak, Regenerative crisis, social media publics and internet trolling: a cultural discourse approach, Publ. Relat. Rev. 47 (4) (2021), 102072, https://doi.org/10.1016/j.pubrev.2021.102072.
[5] C. Tarhan, C. Aydın, Why should municipalities use management information systems in their decision-making processes? Int. J. Inf. Technol. Comput. Sci. 11 (No.4) (2019) 1–8, https://doi.org/10.5815/ijitcs.2019.04.01.
[6] M. Hossain, R. Hassan, M. Amjad, M. Rahman, Web performance analysis: an empirical analysis of e-commerce sites in Bangladesh, Int. J. Inf. Eng. Electron. Bus. 13 (4) (2021) 47–54, https://doi.org/10.5815/ijieeb.2021.04.04.
[7] N. Kankanamge, T. Yigitcanlar, A. Goonetilleke, How engaging are disaster management related social media channels? The case of Australian state emergency organisations, Int. J. Disaster Risk Reduc. 48 (2020), 101571.
[8] C.M. Pulido, L. Ruiz-Eugenio, G. Redondo-Sama, B. Villarejo-Carballido, A new application of social impact in social media for overcoming fake news in health, Int. J. Environ. Res. Publ. Health 17 (7) (2020) 2430.
[9] I. Korobiichuk, P. Snitsarenko, V. Katsalap, R. Hryshchuk, Determination and evaluation of negative informational and psychological influence on the military personnel based on the quantitative measure, Int. Workshop Control Optim. Anal. Process. Soc. Network. 2392 (2019) 66–78. http://ceur-ws.org/Vol-2392/paper6.pdf.
[10] R. Hryshchuk, K. Molodetska, Y. Syerov, Method of improving the information security of virtual communities in social networking services, in: Proc. CEUR Workshop 2392, 2020, pp. 23–41. Retrieved from, http://ceur-ws.org/Vol-2392/paper3.pdf.
[11] R. Hryshchuk, K. Molodetska, Synergetic control of social networking services actors' interactions, Recent Adv. Syst. Control Inf. Technol. (2016) 34–42, https://doi.org/10.1007/978-3-319-48923-0_5.
[12] N.A. Hadiwijaya, H. Hamdani, A. Syafrianto, Z. Tanjung, The decision model for selection of tourism site using analytic network process method, Int. J. Intell. Syst. Appl. 10 (No.9) (2018) 23–31, https://doi.org/10.5815/ijisa.2018.09.03.
[13] A. Klein, V.M. Sharma, Consumer decision-making styles, involvement, and the intention to participate in online group buying, J. Retailing Consum. Serv. 64 (2022), 102808.
[14] H. Hamdani, R. Wardoyo, K. Mustofa, A method of weight update in group decision-making to accommodate the interests of all the decision makers, Int. J. Intell. Syst. Appl. 9 (No.8) (2017) 1–10, https://doi.org/10.5815/ijisa.2017.08.01.
[15] N. Giocoli, Savage vs. Wald: Was Bayesian Decision Theory the Only Available Alternative for Postwar Economics? June, 2004, https://doi.org/10.2139/ssrn.910916. https://ssrn.com/abstract=910916.
[16] L. Labsker, The property of synthesizing by the wald-savage criterion and economic application, Ekon. i Mat. Metody 55 (4) (2019) 89–103.
[17] E. Tsenina, T. Danko, K. Ekimova, V. Sekerin, A. Gorohova, Indication of competitiveness of the potential of the region through Hurwitz and Wald criteria, Global J. Pure Appl. Math. 12 (1) (2016) 325–335.
[18] M. Brill, Interactive democracy: new challenges for social choice theory, in: The Future of Economic Design, The Continuing Development of a Field as Envisioned by Its Researchers, 2019, pp. 59–66.
[19] D.R. Agrawal, W.H. Hoyt, J.D. Wilson, Local policy choice: theory and empirics, J. Econ. Lit. 60 (4) (2022) 1378–1455.
[20] S. Fedushko, M. Davidekova, Analytical service for processing behavioural, psychological and communicative features in the online communication, Proc. ComputInt. J. Ethics Syst. Sci 160 (2019) 509–514, https://doi.org/10.1016/j.procs.2019.11.056.
[21] K. Gao, L. Sun, Y. Yang, F. Meng, X. Qu, Cumulative prospect theory coupled with multi-attribute decision making for modeling travel behavior, Transport. Res. Pol. Pract. 148 (2021) 1–21.

[22] P.K. Jain, G. Srivastava, J.C.-W. Lin, R. Pamula, Unscrambling customer recommendations: a novel lstm ensemble approach in airline recommendation prediction using online reviews, IEEE Trans. Comput. Soc. Syst. 9 (6) (2022) 1777–1784, Dec, https://doi.org/10.1109/TCSS.2022.3200890.
[23] S.P. Wan, W. Zou, J.Y. Dong, Prospect theory based method for heterogeneous group decision making with hybrid truth degrees of alternative comparisons, Comput. Ind. Eng. 141 (2020), 106285.
[24] M. Ahmad, S. Shah, Y. Abbass, The role of heuristic-driven biases in entrepreneurial strategic decision-making: evidence from an emerging economy, Manag. Decis. 59 (3) (2021) 669–691.
[25] M. Darshan, Tank, Enable better and timelier decision-making using real-time business intelligence system, Int. J. Inf. Eng. Electron. Bus. 7 (1) (2015) 43–48, https://doi.org/10.5815/ijieeb.2015.01.06.
[26] A. Ceschi, A. Costantini, R. Sartori, J. Weller, A. Di Fabio, Dimensions of decision-making: an evidence-based classification of heuristics and biases, Pers. Indiv. Differ. 146 (2019) 188–200.
[27] S. Zybin, Y. Bielozorova, Risk-based decision-making system for information processing system, Int. J. Inf. Technol. Comput. Sci. 13 (No.5) (2021) 1–18, https://doi.org/10.5815/ijitcs.2021.05.01.
[28] A.A. Selçuk, A guide for systematic reviews: PRISMA, Turk. Arch. Otolaryngol. 57 (1) (2019) 57.
[29] O. Svenson, Process descriptions of decision making, Organ. Behav. Hum. Perform. 23 (1) (1979) 86–112.
[30] L.K. Trevino, Ethical decision making in organizations: a person-situation interactionist model, Acad. Manag. Rev. 11 (3) (1986) 601–617.
[31] R.M. Dawes, B. Corrigan, Linear models in decision making, Psychol. Bull. 81 (2) (1974) 95–106, https://doi.org/10.1037/h0037613.
[32] M. Jelokhani-Niaraki, J. Malczewski, Decision Complexity and Consensus in Web-Based Spatial Decision Making: A Case Study of Site Selection Problem Using GIS and Multicriteria Analysis, 2015, pp. 60–70, https://doi.org/10.1016/j.cities.2015.03.007.
[33] C. Rinner, C. Keßler, S. Andrulis, The use of Web 2.0 concepts to support deliberation in spatial decision-making, Comput. Environ. Urban Syst. 32 (5) (2008) 386–395.
[34] J. Gao, C. Zhang, K. Wang, S. Ba, Understanding online purchase decision making: the effects of unconscious thought, information quality, and information quantity, Decis. Support Syst. 53 (4) (2012) 772–781.
[35] X. Mi, M. Tang, H. Liao, W. Shen, B. Lev, The state-of-the-art survey on integrations and applications of the best worst method in decision making: why, what, what for and what's next? Omega 87 (2019) 205–225.
[36] K. Pažek, Č. Rozman, Decision making under conditions of uncertainty in agriculture: a case study of oil crops, Poljoprivreda 15 (1) (2009) 45–50.
[37] M.K. Starr, A discussion of some normative criteria for decision-making under uncertainty, IMR; Industrial Management ReviewInd. Manag. Rev. IMR (pre-1986) (pre-1986) 8 (1) (1966) 71.
[38] J.G. Pereira Jr., P.Y. Ekel, R.M. Palhares, R.O. Parreiras, On multicriteria decision making under conditions of uncertainty, Inf. Sci. 324 (2015) 44–59.
[39] D. Bugas, Modelling the expert's preferences in decision-making under complete uncertainty, E. Eur. J. Enterprise Technol. 5 (4) (2016) 12–17.
[40] N. Thao, Evaluating water reuse applications under uncertainty: a novel picture fuzzy multi criteria decision making medthod, Int. J. Inf. Eng. Electron. Bus. 10 (No.6) (2018) 32–39, https://doi.org/10.5815/ijieeb.2018.06.04.
[41] D.A. Kobus, S. Proctor, S. Holste, Effects of experience and uncertainty during dynamic decision making, Int. J. Ind. Ergon. 28 (5) (2001) 275–290.
[42] W. Bossert, P.K. Pattanaik, Y. Xu, Choice under Complete Uncertainty: Axiomatic Characterizations of Some Decision Rules, Economic Theory, 2000, pp. 295–312.
[43] V.V. Malyshev, B.S. Piyavsky, S.A. Piyavsky, A decision making method under conditions of diversity of means of reducing uncertainty, J. Comput. Syst. Sci. Int. 49 (2010) 44–58.
[44] J.R. Busemeyer, Decision making under uncertainty: a comparison of simple scalability, fixed-sample, and sequential-sampling models, J. Exp. Psychol. Learn. Mem. Cognit. 11 (3) (1985) 538.
[45] J. Ma, J.D. Harstvedt, R. Jaradat, B. Smith, Sustainability driven multi-criteria project portfolio selection under uncertain decision-making environment, Comput. Ind. Eng. 140 (2020), 106236.
[46] A.V. Vyatkin, L.V. Fomina, Z.N. Shmeleva, Empathy, emotional intelligence and decision-making among managers of agro-industrial complex, Roles Toler. Uncertain. Decision-Making IOP Conf. Ser.: Earth Environ. Sci. 315 (2) (2019), 022081. IOP Publishing.
[47] V.A. Marchau, W.E. Walker, P.J. Bloemen, S.W. Popper, Decision Making under Deep Uncertainty: from Theory to Practice, Springer Nature., 2019, p. 405, https://doi.org/10.1007/978-3-030-05252-2.
[48] A.V. Vyatkin, L.V. Fomina, Z.N. Shmeleva, Empathy, tolerance for uncertainty and emotional intelligence among the agro-industrial complex managers to predict the decision-making efficiency in the antagonistic game, IOP Conf. Ser. Earth Environ. Sci. 421 (No. 3) (2020), 032037. IOP Publishing.
[49] A. Weerasuriya, X. Zhang, J. Wang, B. Lu, K. Tse, C. Liu, Performance evaluation of population-based metaheuristic algorithms and decision-making for multi-objective optimization of building design, Build. Environ. 198 (2021), 107855.
[50] A. Adem, E. Çakıt, M. Dağdeviren, A fuzzy decision-making approach to analyze the design principles for green ergonomics, Neural Comput. Appl. (2022) 1–12.
[51] I. Chakir, M. El Khaili, M. Mestari, Logistics flow optimization for advanced management of the crisis situation, Proc. Comput. Sci. 175 (2020) 419–426.
[52] A. Belhadi, S.S. Kamble, V. Mani, V.G. Venkatesh, Y. Shi, Behaviour al mechanisms influencing sustainable supply chain governance decision-making from a dyadic buyer-supplier perspective, Int. J. Prod. Econ. 236 (2021), 108136.
[53] S. Iqbal, M. Sholihin, The role of cognitive moral development in tax compliance decision making: an analysis of the synergistic and antagonistic tax climates, International Journal of Ethics and Systems 35 (2) (2019) 227–241, https://doi.org/10.1108/IJOES-10-2018-0152.
[54] C. Schneeweiss, Distributed decision making – a unified approach, Eur. J. Oper. Res. 150 (2) (2003) 237–252.
[55] M.R. Bailey, E.H. Simpson, P.D. Balsam, Neural substrates underlying effort, time, and risk-based decision making in motivated behaviour, Neurobiol. Learn. Mem. 133 (2016) 233–256.
[56] A. Bechara, Risky business: emotion, decision-making, and addiction, J. Gambl. Stud. 19 (2003) 23–51.
[57] C. Jansen, G. Schollmeyer, T. Augustin, Concepts for decision making under severe uncertainty with partial ordinal and partial cardinal preferences, in: Proceedings of the Tenth International Symposium on Imprecise Probability: Theories and Applications, PMLR., 2017, pp. 181–192.
[58] R. Pelissari, M.C. Oliveira, A.J. Abackerli, Ben-Amor S, M. Assumpção, Techniques to model uncertain input data of multi-criteria decision-making problems: a literature review, Int. Trans. Oper. Res. 28 (2) (2021) 523–559.
[59] Y.P. Xu, Y.K. Tung, Decision-making in water management under uncertainty, Water Resour. Manag. 22 (2008) 535–550.
[60] M.C. Troffaes, Decision making under uncertainty using imprecise probabilities, Int. J. Approx. Reason. 45 (1) (2007) 17–29.
[61] B.S. Ahn, R.R. Yager, The use of ordered weighted averaging method for decision making under uncertainty, Int. Trans. Oper. Res. 21 (2) (2014) 247–262.
[62] S. Seuken, S. Zilberstein, Formal models and algorithms for decentralized decision making under uncertainty, Aut. Agents Multi-Agent Syst. 17 (2008) 190–250.
[63] K. Madani, L. Read, L. Shalikarian, Voting under uncertainty: a stochastic framework for analyzing group decision making problems, Water Resour. Manag. 28 (2014) 1839–1856.
[64] J. Xu, Z. Wu, Y. Zhang, A consensus based method for multi-criteria group decision making under uncertain linguistic setting, Group Decis. Negot. 23 (2014) 127–148.
[65] T. Augustin, Optimal decisions under complex uncertainty–basic notions and a general algorithm for data-based decision making with partial prior knowledge described by interval probability, ZAMM-J. Appl. Math. Mech./Z. Angew. Math. Mech.: Appl. Math. Mech. 84 (10-11) (2004) 678–687.
[66] Z. Wang, F. Xiao, Z. Cao, Uncertainty measurements for Pythagorean fuzzy set and their applications in multiple-criteria decision making, Soft Comput. 26 (19) (2022) 9937–9952.
[67] K.Y. Mashunin, Y.K. Mashunin, Simulating engineering systems under uncertainty and optimal decision making, J. Comput. Syst. Sci. Int. 52 (2013) 519–534.
[68] S. Chen, J. Liu, H. Wang, J.C. Augusto, A group decision making model for partially ordered preference under uncertainty, Inf. Fusion 25 (2015) 32–41.
[69] A.V. Bochkov, N.N. Zhigirev, Development of computation algorithm and ranking methods for decision-making under uncertainty, in: Advanced Mathematical Techniques in Science and Engineering, River Publishers, 2022, pp. 121–154.
[70] A.J. Keith, D.K. Ahner, A survey of decision making and optimization under uncertainty, Ann. Oper. Res. 300 (2) (2021) 319–353.

[71] V. Kreinovich, Decision making under interval uncertainty (and beyond), in: Human-centric Decision-Making Models for Social Sciences, 2014, pp. 163–193.
[72] S. Kaplan, N.N. Barish, Decision-making allowing for uncertainty of future investment opportunities, Manag. Sci. 13 (10) (1967) B–569.
[73] M. Stuermer, G. Abu-Tayeh, T. Myrach, Digital sustainability: basic conditions for sustainable digital artifacts and their ecosystems, Sustain. Sci. 12 (2017) 247–262.
[74] W. Krings, R. Palmer, A. Inversini, Industrial marketing management digital media optimization for B2B marketing, Ind. Market. Manag. 93 (2021) 174–186.
[75] K. Bradley, Defining digital sustainability, Libr. Trends 56 (1) (2007) 148–163.
[76] C.W. Ho, Y.B. Wang, Does social media marketing and brand community play the role in building a sustainable digital business strategy? Sustainability 12 (16) (2020) 6417.
[77] F. Corradini, F. Fornari, A. Polini, B. Re, F. Tiezzi, A. Vandin, A formal approach for the analysis of BPMN collaboration models, J. Syst. Software 180 (2021), 111007.
[78] J.J. Shuster, D.W. Theriaque, B.M. Ilfeld, Applying Hodges-Lehmann scale parameter estimates to hospital discharge times, Clin. Trials 5 (6) (2008) 631–634.
[79] Facebook page of Lviv Polytechnic National University. https://www.facebook.com/groups/206197692740294 (access at 23 April 2023).
[80] T. Raz, A.J. Shenhar, D. Dvir, Risk management, project success, and technological uncertainty, R D Manag. 32 (2) (2002) 101–109.